THESIS

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

By

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Graduate Program
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ABSTRACT

Various forms of coastal landuse covering the study area has been observed to have undergone changes as evidently detected between the satellite images sensed in 1994 and 2001 at Banten Bay. It is important to identify what these changes are. Therefore, an appropriate change detection must be selected. In this study, three main objectives were set: 1) To determine the image preprocessing and image processing techniques that is needed for digital coastal landuse change detection, 2) To perform digital coastal landuse supervised classification, and 3) To study the coastal landuse change of Banten bay in two dates.

The image preprocessing step involved removing errors from the raster data. This was done performing basic processes, such as, radiometric correction, geometric correction and image calibration. The image processing step comprised of supervised classification and change detection techniques. Supervised classification was employed in this study to transform multispectral image data into user defined thematic information classes and to serve as a reference for the quantitative results of the change detection techniques. On the other hand, change detection techniques tested on this study to show the best results included Red Green Method, Image Differencing Method, Image Ratioing Method and Principal Component Analysis Method (PCA).

Red Green Method gave the best result for detecting the coastal landuse change because the number of changed area closely resembled the total number of changed area reference. Through careful comparison it was observed that Red Green Method is suitable for detecting areas changes in the paddyfields increase and settlement increase; Image Differencing Method is better to detect areas changes in agriculture increase, fishponds decrease and natural area decrease; Image Ratioing Method gave the best result for monitoring areas change in fishponds increase, paddyfields decrease and agriculture decrease because the number of each changed area (per hectare) nearly coincides more with the size of changed area (per hectare) of each increase and decrease reference.

Every coastal landuse category increased in utility area except for the natural area. The observed reduction in the area size of the natural area is due to the growth rate of the population and increased activities along this area. Based from field checking, some parts of agriculture and paddyfields became fishponds in LONTAR zone.

Key words: Coastal Landuse, Remote Sensing, Landsat, Supervised Classification and Change Detection.
DECLARATION LETTER

I, Mr. Puvadol Doydee, hereby declare that the thesis title:

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

contains correct results from my own work, and that it have not been published ever before. All data sources and information used factual and clear methods in this project, and has been examined for its factualness.

Bogor, August 2002

Puvadol Doydee
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THESIS

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

By

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A Thesis Submitted to
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AUTOBIOGRAPHY

Mr. Puvadol Doydee was born on December 20, 1975 at Phetchaburi Province, Thailand. He grew up in a modest family together with 2 younger sisters. High school days not only involved enjoying the company of friends at Phrommanusorn Phetchaburi Province high school, but also making careful decisions after graduation. It was a time of making big decisions for a very expansive future that lay ahead. Decisions and circumstances lead him in becoming a fisheries biologist. This choice was made because of his interest in knowing more about fisheries science, its nature and the field study involved. Up till now, he never regretted making this decision.

Mr. Puvadol was deeply enthusiastic with Fisheries, learning as much as he could in this field. This lead him in earning a Bachelor’s Degree from the Department of Fishery Management, Faculty of Fisheries, at Kasetsart University, Bangkok, Thailand in 1998. As soon as he graduated he started working as a fisheries biologist at the Department of Fishery Management, Faculty of Fisheries, at Kasetsart University. Currently, he is still working with this institution as a faculty and fisheries biologist.

Among Mr. Puvadol’s other interests are coastal zone management, coastal area planning and also small-scale fisheries management. In 2000, he was selected by SEAMEO-SEARCA (SEAMEO Regional Center for Graduate Study and Research in Agriculture) for its scholarship for the Master of Science in Information Technology for Natural Resources Management program. This program is hosted by the Bogor Agricultural University (IPB) and is based at the SEAMEO-BIOTROP campus. His decision to enroll and attend this graduate program significantly changed his life. GIS (Geographic Information System) and Remote Sensing became his life since then. He is really keen on recent developments in GIS and remote sensing in order to apply these technologies in coastal zone management.
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Firstly, I would like to express my sincere thanks and faithful appreciation to the SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEAMEO-SEARCA), Philippines for awarding me the scholarship for this Master of Science program. I would like to express my heartfelt thanks to the chairman of the study program Dr. Ir. Handoko for accepting me in this study program. I would also like to thank my supervisor Dr. Ir. Vincentius P. Siregar and my co-supervisor Dr.-Ing Fahmi Amhar for their guidance, technical comments and encouragement throughout the period of my study.

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1 INTRODUCTION

1.1 Background

Remote sensing technique plays an important role for monitoring coastal landuse change. Some researchers have performed change detection but almost most of them are interested in climate change and change of vegetation. However, in a specific area, such as, coastal zone, this application is also essential for monitoring change. This study emphasizes on the capability of remote sensing technique to detect the change in coastal landuse by using four methods of change detection techniques, and then compares the result of those with each other.

This study can benefit coastal landuse management, which is necessary as a part of sustainable development in line with coastal area planning. One of the image datasets used in this study was recently captured last 2001. Nowadays, Banten Bay is a famous study area for researchers and fisheries biologists because the region is convenient. There are more activities, such as, paddyfields, fish and shrimp farming, harbor, and power plant have had established along this area and, no doubt, those activities will influence the coastal zone and fisheries resources. Thus, the phenomena that have changed might have influence this area and also in the case of small-scale fisheries community.

The coastal zone is that space in which terrestrial environment is influenced by marine environments (Carter, 1988). As boundaries between land and water, coasts are characterized primarily by geologic nature of the land where the loose sedimentary coast is relatively unstable and often fragile. The coastal zone is an extremely dynamic system. It is composed of coastal zone as an overall part, coastal strip and coastline. Variations in the characteristics of its major constituents occur rapidly over space and time. Sand and other materials are moved onto and off beaches by current and waves (Williams et al., 1997). Consequently, it may induce the living
environment or cause physical damages. Coastal landuse changes are the most important part of coastal dynamics.

Theory suggests that global warming will result in a rise in global mean sea level hence coastal areas will be affected by potential changes not only with the climate system but also the sea level. The potential impacts of environmental changes on humanity maybe greater in this compartment of the geosphere and biosphere system more than many other area of the surface of the globe since the range of geometric driven of change includes not only climate change in the broadest sense of changes in temperature, rainfall and wind regimes but also includes changes in ocean climate, storminess, flooding and inundation (LOICZ, 1994).

Coastal ecosystem and organisms that have important biogeomorphological function include coral reefs, calcareous algae, and a range of shell-producing animals that contribute to the formation of calcareous sediments; coastal wetland forest, sand ridge, mangrove, sea grass, salt marsh and macro algae communities that tend to trap land or ocean derived particulate material; benthos invertebrates that can stabilize or destabilize near shore sediments; and various organisms (micro algae, bacteria) that promote sediment cohesiveness through the production of extra cellular metabolites.

Coastal zone pollution is a variety of waters that originate from both land and marine-based activities and eventually enters into the marine environment. Sources of land-based pollution include coastal and upstream agriculture that discharges pesticide, fertilizer and sediment runoff. For urban and industrial development that discharges untreated waste and effluent. Source of marine-based pollution include oil and gas related activities resulting in discharges of drilling wastes, chronic spills and potentially major oil spills (tanker accidents, blowouts); and marine traffic accidents resulting in release of waste and toxic material, as well as the heavy accumulation of waste in coastal and marine waters, especially in area with high population density and industrial activities (Rais et al., 1997).
Change detection has been one of the major applications of remote sensing since 1960s. There are many approaches to change detection. Despite of their differences in change identification algorithms, accurate spatial registration of the various dates of imagery is a requirement for all these methods. There are essentially two different categories of image rectification approaches, the deterministic and the statistical approaches. The deterministic approach relies on data of the flight parameters and the terrain information, and is effective when types of distortion are well characterized (Richards, 1995). The statistical approach, by means of ground-control-points (GCP) dataset, establishes mathematical relationship between image coordinates and their corresponding map coordinates using standard statistical procedures. Remote sensing can be used as a management tool to map coastal landuse and monitor the coastal landuse change.

There are several existing and former coral islands of patch and fringing forms and submerged reefs in Banten Bay, two of which are conserved as bird sanctuary, sea grass beds and mangroves. The existence of corals form the base and cause stability of the coral island and supply new sediment on the coast. Coral reefs, sea grasses, and mangroves are the main tropical coastal ecosystems their composition, distribution and function are affected by impacts of sedimentation, erosion forces, sand and rubble mining, eutrophication, and over fishing. Coral reefs stability is very much dependent on the living benthos life. The living benthos life, the more stable or expanding the reefs as function of time. Sea grass plays an important role to fisheries, and its prosperity is affected by changes in sediment runoff. At present, this system is diminishing due to very active reclamation activities, some of which are converted into fishponds. The area reduction and disappearance of mangroves, coral reefs and sea grass will reduce coastline stability or accelerate the erosion rate of coastal area (Saptarini, 2000).

Referring to the regional development plan, northwest coast of Banten province has been allocated for industrial development area, such as, steel casting industry, petro-
chemical, dock, and power plant. On the other hand, the northeastern coast is for coastal fishery cultivation, conservation area, coastal green belt, and settlement area. Coastal and marine fisheries support some seventy thousand people who live around Banten Bay. In line with the increase of population number with its activities and needs, and lack of proper development control, there are prominent coastal landuse shifts and changes from that previously planned and subsequently various conflicts of interests occur.

An international seaport for containers and jetties are now being constructed with pronounced reclamation activities (Saptarini, 2000) due to rapid growth of industries, which it needs transportation and seaport. Thus, this region have change influent current direction and velocity, and consequently may stimulate sedimentation in the near up drift and coastal erosion at the far up drift and near down drift parts. On the other hand, constructions of seaport, industries and residential areas, agriculture and aquaculture modify sedimentation process and its distribution in the Banten Bay.

Therefore, coastal landuse change is an essential matter 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 that was used to accomplish in this study is remote sensing that offers a faster and better synoptic view of large areas compared with traditional way, such as, terrestrial mapping and aerial photo, as well as it is easier and cheaper of coastal management for sustainable development.
1.2 Objectives

The objectives of this study involved mapping coastal landuse and monitoring coastal landuse change from Landsat image data, which were compared between the years of 1994 and 2001. The study area is in Banten Bay, West Java Island, Indonesia. The detailed objectives are below:

1. To determine the image preprocessing and image processing techniques that is needed for digital coastal landuse change detection,
2. To perform digital coastal landuse supervised classification,
3. To study the coastal landuse change of Banten Bay in two dates.
2 LITERATURE REVIEW

The essential and important issue of coastal zone management for sustainable development have had concerned about coastal landuse, coastal ecosystem and environment, carrying capacity and land suitability, which in this study handled with information technology that emphasize in application of remote sensing for coastal landuse change detection. The key words are Coastal Landuse, Remote Sensing (RS), Landsat, Supervised Classification and Change Detection. So, its needed to determine a definition of keys words and some portion relationship in order to effective and efficient for performing and accomplishment in this study.

2.1 Coastal Zone

In the United States of America, the term coastal zone (legal definition for coastal zone management) means the coastal waters (including the lands therein and thereunder) and the adjacent shorelands (including the waters therein and thereunder), strongly influenced by each and in proximity to the shorelines of the several coastal states, and includes islands, transitional and inter-tidal areas, salt marshes, wetlands, and beaches (NOAA, 1998).

For mapping purposes in Indonesia, coastal zone is defined as an area between land and sea that affects each other, having a specific geosphere characteristics, to the direction of land that is limited by the effect of marine socio-economic and physical characteristics, while to the direction of sea it is limited by the natural process and caused by human activities against the land environment.

Sometimes coastal zone definition depends on the project purposes, such as that defined for the Land-Ocean Interactions in the Coastal Zone (LOICZ) project. The coastal zone is considered to extend from the coastal plains to the outer edges of the continental shelf, approximately matching the region that has been alternately flooded
and exposed during the sea level fluctuations of the late-Quaternary period. Definitions of coastal zone may extend to the landward and seaward limits of marine and terrestrial influence respectively. At the other extreme, the coastal zone can be restricted to the coastline and adjacent geomorphological features determined by the action of the sea on the land margin. Coastal zone boundary is presented in Figure 1.

![Coastal Zone Diagram](image)

Figure 1. Coastal zone boundary (Holligan and de Boois, 1993).

### 2.2 Shoreline (Coastline)

Shoreline is intersection of the land with the water surface. The shoreline represents the line of contact between the land and a selected water elevation. In areas affected by tidal fluctuations, this line of contact is the mean high water line. In confined coastal waters of diminished tidal influence, the mean water level line may be used (NOAA, 2001). Furthermore, coastlines vary in time, and coastline detected by Remote Sensing may be influenced by this variation, so that a correction might be necessary. Several different shoreline definitions are in use by various state, and local authorities. The use of inconsistent shoreline definitions between maps, charts, Geographic Information Systems (GIS), and other products can lead to confusion by users and can contribute to misinformed decision-making.

Shoreline defined as the line of ordinary low water along that portion of the coast that is in direct contact with the open sea and the line marking the seaward limit of inland
waters. In coast survey usage, shoreline is considered synonymous with coastline and defined as the line of contact/crossing line between the land and a body of water. On coastal and geodetic survey nautical charts and surveys, the shoreline approximately uses the mean high water line (Saptarini, 1998).

Another definition of shoreline is the line where the average high tide, known as mean high water (MHW), interacts the coast. Basically, planning map uses high water line or mean sea level as shoreline reference as they are easier to be determined and frequently exposed. This is different from the depth reference in bathymetric map that usually uses low water line for safe navigation as applied in most ports of Indonesia. However, use mean sea level (MSL) as reference level for comparative morphological studies or sea level changes.

2.3 Remote Sensing Technique for Coastal Management

Remote sensing is the technique of collecting information from a distance. By convention, “from a distance:” is generally considered to be large relative to what a person can reach out and touch, hundreds of feet, hundreds of miles, or more. Remote sensing techniques are used intensively to gather measurements, Satellite-based systems can now measure phenomena that change continuously over time and cover large, often inaccessible areas (Aronoff, 1991).

There are various journal concerns the application of remote sensing for coastal management, such as, fisheries detection using NOAA satellite, why can fishing grounds be monitored by remote sensing, monitoring the water sediment dynamics, satellite ocean color use for oceanic resources, general inventory of shrimp aquaculture potential, suitable land selection for shrimp farm development, bathymetry mapping, and coral reef mapping in order to manage coastal resource into sustainable development carry on. However, Landsat imagery is useful for image interpretation for a much wider range of application than other satellite images. This
is caused of the Landsat TM and ETM⁺ has both an increase in the number of spectral bands and an improvement in spatial resolution.

2.4 Landuse and Coastal Landuse

Landuse is defined in terms of a specific combination of land activity and landcover. Land "activity" is regarded as the active use man makes of the land. It is not to be confused with other variables, such as, tenure, ownership, economic activity or land value. Landcover is regarded as the vegetative, natural or artificial construction covering the land surface (Yusuf, 2001).

Definitions of landuse raise the following issues:
- The difference between present and proposed uses needs to be clarified
- Both landcover and land activities need to be included
- Landcover complicates the inventory and its unnecessary

Coastal landuse is defined in terms of a specific combination of land activity and landcover on the coastal zone. Land "activity" is regarded as the active use man makes of the land occurred on the coastal zone. Coastal landcover is regarded as the vegetative, natural or artificial construction covering the coastal land surface. Coastal landuse, such as, natural area and agriculture might be either change into paddyfields, fishponds or settlement. Moreover, those may be change by natural hazard, such as, storm, floodwater, landslide and earthquake. However, the faster one that has effected with coastal landuse is human activities. Coastal landuse changed very important phenomena because its have influent with biogeomorphological function. For example, coral reefs zone, calcareous algae, and a range of shell-producing animals that contribute to the formation of calcareous sediments, sea grass, salt marsh and macro algae communities that tend to trap land or ocean derived particulate material, benthos invertebrates that can stabilize or destabilize near shore sediments; and
various organisms (micro algae, bacteria) that promote sediment cohesiveness through the production of extra cellular metabolites.

2.4.1 Coastal Landuse Change

Coastal landuse change is one of the most critical dynamic elements of coastal zone. This pattern is a product of the interaction between ecological and socioeconomic processes. Understanding the function and structure of coastal landuse, primarily in terms of human impacts, requires integration of biological and socioeconomic knowledge. Natural resource managers, in particular, need this integration to effectively evaluate the social and environmental cost of alternative management scenarios.

The basic concept of landuse changes is related to the biogeochemical cycle, energy cycle, global climate change, and the aspect of human dimension. Energy flows through an ecosystem in a cyclic manner and do materials that necessary for a life, such as, carbon, oxygen, nitrogen, potassium, water, and many others. The path these substances take a place in the environment are called biogeochemical cycles. Some biogeochemical cycles are keeping up by large storages in the atmosphere and other are dominated by terrestrial storages, usually in rocks and sediment. Energy in an ecosystem (and also humansystem) is eventually derived from the sun, called solar energy. The energy passes through a series of storages by way of many paths, before lastly being return to the space as radiant energy. Ecosystems consist of all living organisms in a defined geographic area together with all the physical entities (soil, water, dead organic matter, and so on), with which they interact. Since one type of organism in an ecosystem consume another, a pattern of energy flow through the ecosystem is set up, called food chain.

There is a general recognition about the significance of coastal landuse changes to the variety of global environmental issues, among others, the role of coastal landuse and
coastal landcover in effecting the biochemical flows, and the states of the biosphere geosphere. Also coastal landuse in its own right as it interacts with human activities that drive and take action to the environmental change. Changes in coastal landuse may result in deforestation and soil degradation, such as, desertification and salinization, loss of wetlands, changes in hydrology function, and changes in the distribution of chemical and biological properties of aquatic and terrestrial ecosystem (Yusuf, 2001).

There are four aspects of large-scale environmental perturbations that are considered as the term of “global change”: 1). Change in landuse and landcover, 2). Worldwide decline in biodiversity, 3). Change in atmospheric composition, especially the increase in CO₂ concentration and 4). Change in climate. The most rapid changes of coastal zone are in coastal landuse, mainly in terms of coastal landuse conversion, such as, forest conversion for agricultural purpose, fishery cultivation purpose, human settlements, industrial areas, and other intensive uses.

2.4.2 Coastal Landuse Change Monitoring

Determination of coastal landuse change monitoring can be conducted using various methods, among others, mapping using GPS (Global Positioning System). In recent decades, remote sensing technique has been use for monitoring landuse changes. Remote sensing techniques consist of some methods, such as, map-used, aerial photograph, and data imagery. Beginning with the early use of aerial photography, remote sensing has been recognized as a precious tool for viewing, analyzing, characterizing, and making decision about environment problems. Remote sensing technology though a larger instantaneous field of view therefore it is acquired in larger scope of areas, fast and cost-effective. Satellite remote sensing has become more and more important as a technique for regional studies, especially for less accessible large areas where previously information was very limited. Some scientists have been used Remote Sensing technique to detect and monitor environmental
changes; especially, landuse and landcover changes and for this study have used for detecting the change in coastal landuse.

2.5 Landsat Imagery

2.5.1 Landsat-5 TM (Thematic Mapper)

Landsat-5 TM was lunch in 1984. Thematic Mapper (TM) is instrument that upgrades included improved ground resolution (30 meters) and 3 new channels or bands. The TM is a highly advanced sensor incorporating a number of spectral radiometric and geometric design improvements relative to the MSS. Spectral improvements include the acquisition of data in seven bands instead of four, with new bands in the visible (blue), mid-infrared, and thermal portions of the spectrum. Also, based on experience with MSS data and extensive field radiometer research result, the wavelength range and location of the TM bands have been choose to improve the spectral differentiability of major earth surface feature.

Radiometrically, the TM performs its onboard analog-to-digital signal conversion over a quantization range of 256 digital numbers (8 bits). This corresponds to a fourfold increase in the gray scale range relative to the 64 digital numbers (6 bits) used by the MSS. This finer radiometric precision permits observation of smaller changers in radiometric magnitudes in a given band and provides grater sensitive to changes in relationships between bands. Thus, difference in radiometric values that are lost in one digital number in MSS data may now be distinguished.

Geometrically, TM data are collected using a 30-m ground resolution cell (for all but the thermal band, which has 120 m resolution). This represents a decrease in the lineal dimensions of the ground control cell of approximately 2.6 times, or a reduction in the area of the ground resolution cell of approximately 7 times. At the same time, several design changes have been incorporated within the TM to improve the accuracy of the geodetic positioning of the data. Most geometrically corrected TM
data are supplied using 28.5 X28.5-m pixels registered to the Space Oblique Mercator (SOM) cartographic projection. The data may also be fit to the Universal Transverse Mercator (UTM) or Polar Stereographic projection (Lillesand and Kiefer, 1994). The TM bands and TM Technical Specifications are presented in Table 1.

Table 1. TM Bands and TM Technical Specifications (NASA, 2002).

<table>
<thead>
<tr>
<th>TM Bands</th>
<th>TM Technical Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band</td>
<td>Micrometers</td>
</tr>
<tr>
<td>1</td>
<td>0.45 - 0.55</td>
</tr>
<tr>
<td>2</td>
<td>0.52 - 0.60</td>
</tr>
<tr>
<td>3</td>
<td>0.63 - 0.69</td>
</tr>
<tr>
<td>4</td>
<td>0.76 - 0.90</td>
</tr>
<tr>
<td>5</td>
<td>1.55 - 1.75</td>
</tr>
<tr>
<td>6</td>
<td>10.40 - 12.50</td>
</tr>
<tr>
<td>7</td>
<td>2.08 - 2.35</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.5.2 Landsat-7 ETM⁺ (Enhanced Thematic Mapper Plus)

The Land Remote Sensing Act of 1992 once again transferred the management responsibility for the Landsat program with the design and operation of Landsat-7 and its successors. Under this legislation NASA and the Department of Defense (DOD) jointly managed the program. According to the design of Landsat-7 has been developed in an attempt to meet the needs of both the defense community and civilian users. At the time of this writing (1993), many aspect of the design and operation of Landsat-7 were still under discussion (particularly in light of launch failure of Landsat-6). The following describes the plans for the system as of that date. The design of the ETM⁺ (Enhanced Thematic Mapper Plus) stresses the provision of data
continuity with Landsat-4 and Landsat-5. Similar orbits and repeat patterns are used, as is the 185-km swath width for images. As with the ETM planned for Landsat-6, the system is designed to collect 15-m-resolution “panchromatic” data and six bands of data in the visible, near-IR, and Mid-IR spectral regions at a resolution of 30 m. A seventh, thermal band is to be incorporated with a resolution of 60 m. As with the ETM, high and low gain setting for the individual channels may be controlled from the ground.

Several other design features characterize the ETM+. First, the system will include a “dual mode solar calibrator, “in addition to an internal lamp calibrator. This will greatly improve the radiometric calibration of the ETM+ data. Also, data can be transmitted to ground in three possible ways: directly, via the tracking. Finally, because the spacecraft includes a GCP receiver, subsequent geometric processing of the data will be facilities (Lillesand and Kiefer, 1994). The ETM+ bands and ETM+ Technical Specifications are presented in Table 2.

Table 2. ETM+ Bands and ETM+ Technical Specifications (NASA, 2002).

<table>
<thead>
<tr>
<th>ETM+ Bands</th>
<th></th>
<th>ETM+ Technical Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Band</strong></td>
<td><strong>Micrometers</strong></td>
<td><strong>Resolution</strong></td>
</tr>
<tr>
<td>1</td>
<td>.45 to .515</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>.525 to .605</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>.63 to .690</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>.75 to .90</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>1.55 to 1.75</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>10.40 to 12.5</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>2.09 to 2.35</td>
<td>30</td>
</tr>
<tr>
<td>Pan</td>
<td>.52 to .90</td>
<td>15</td>
</tr>
</tbody>
</table>
2.6 Classification

2.6.1 Supervised Classification

Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers. Sokal (1974) defined it as "the ordering or arrangement of objects into groups or sets on the basis of their relationships." A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relation between classes. Classification thus necessarily involves definition of class boundaries that should be clear, precise, possibly quantitative, and based on objective criteria (Jensen, 1986).

Supervised classification is the method used to transform multispectral image data into thematic information classes. This procedure typically assumes that imagery of a specific geographic is gathered in multiple regions of the electromagnetic spectrum. The basic steps in supervised classification are presented in Figure 2.

![Diagram showing the process of supervised classification](image)

Figure 2. Basic steps in supervised classification (Lillesand and Kiefer, 1994).
Supervised classification, the identifying and location of feature classes or cover types (urban, forest, water, etc) are known beforehand through fieldwork, analysis of aerial photographs, or other means. Typically, identify specific areas on the multispectral imagery that represent the desired known feature types, and use the spectral characteristics of these known areas to train the classification program to assign each pixel in the image to one of these classes. Multivariate statistical parameters, such as, means, standard deviation, and correlation matrices are calculated for each training region, and each pixel is evaluated and assigned to the class to which it has the most likelihood of being a member (according to rules of the classification method chosen).

One of the simple classification strategies that may be used is Maximum Likelihood Classifier. The Maximum Likelihood Classifier quantitatively evaluates both the variance and covariance of the category spectral response patterns when classifying an unknown pixel. In essence, the maximum likelihood classifier delineates ellipsoidal “equiprobability contours” in the scatter diagram. These decision regions are showed in Figure 3. The shape of the equiprobability contours expresses the sensitivity of the likelihood classifier to covariance.

![Figure 3. Equiprobability contours defined by a maximum likelihood classifier (Lillesand and Kiefer, 1994).](image)
An extension of the maximum likelihood approach is the Bayesian classifier. This technique applies two weighting factors to the probability estimate. First, the analyst determines the “a priori probability”, or the anticipated likelihood of occurrence for each class in the given scene. Second, a weight associated with the “cost” of misclassification is applied to each class. Together, these factors act to minimize the “cost” of misclassifications, resulting in a theoretically optimum classification. In practice, most maximum likelihood classification is performed assuming equal probability of occurrence and cost of misclassification for all classes. If suitable data exist for these factors, the Bayesian implementation of the classifier is preferable (Jensen, 1986). Image classification is an automatically categorize all pixels in an image into coastal landuse classes or themes. These categorized data may then be used to produce thematic maps of the coastal landuse present in an image and produce summary statistic on the areas covered by each land cover type.

2.6.2 Knowledgebase Classification

The human visual interpretation that is mainly an object-based has to be considered as a natural and logical alternative, since the traditional computer-assisted algorithms have produced less information than is desirable when they are applied to higher resolution remotely sensed data. To integrate geographical information system (GIS) and remote sensing (RS) system it is important that both systems are object oriented. A data structure with a higher information level can be obtained by using the concept of terrain objects. In GIS terrain objects are represented by three components: an identifier, a thematic data, and a geometric data. In RS the information derived from classification is feature based. Of late there has been lots of research going on how to link GIS and RS. The integration between GIS and RS is vital since in GIS the data can become obsolete quickly, so it is essential to update periodically with new spatial and thematic data. Remote sensing is often the most cost effective source for these updates (Yusuf, 2001).
Remote sensing data is used by a variety of users from ecologist, geologist, landuse planner and meteorologist to oceanographer. For many of these surveying applications the images are classified into classes that are relevant to the users. The classification is based on spectral characteristics. The spectral characteristics are difficult to classify because we require knowledge about the class in terms of texture, pattern, and shape of the objects. Additional information in form of ancillary data can be used to enhance the classification; the latter category is called “knowledgebased classification” (Middelkoop et al., 1991).

The knowledge base in our case takes the form of a production rule base. The knowledgebased system has three types of rules: the initialization rules, landcover to landuse rules and local consistency rules. These rules have been adapted in classifying our landcover maps to landuse. The initialization rules use a priori knowledge to give a score to each landcover. For coastal landuse classification it is not possible to retain all characteristic features of an object. The criteria of classification have to be selected (this implies that some features will be emphasize) and some other neglected. The most common systems of classification are: physiognomic, ecological, geographical, dynamic or evolutionary and functional system.

The level of detail may also determine the criteria of classification. For example, when inventories have to be made over extensive areas using remote sensing techniques, physiognomic criteria will acquire more importance. Physiognomic systems are more related to the landcover than to the actual use to which the land is put. Landuse is inferred from analysis and interpretation of landcover features. The success of such interpretation relies on the analyst's ability to identify relevant physical characteristics of land attributes and relate those observable parameters to the use made of local resources. Assessment of the actual landuse is also dependent on the availability of an appropriate classification. A logical succession of operations is presented in Figure 4. Human knowledge with respect to texture, shape, size,
neighborhoods, proximity and association, as well as pattern (quality analysis) due to the requirement of landuse classification for satellite images.

Figure 4. Landuse inventory – a logical succession of operations.

2.7 Change Detection

Coastal landuse change detection is needful for updating coastal landuse maps and the coastal resources management. The change is usually by comparison between two dates images, or sometimes between an old map and update remote sensing image. Change detection is a method to identify the changes in imagery of the same geographic area obtained at different times. Aerial photo and data imagery are two of data source that often used in change detection. Digital change detection is a method that involving data imagery as source of data. A fundamental assumption of digital change detection is that there exists a difference in the spectral response of a pixel on two dates if the landcover or landuse changes from one type to another. A change detection method should be based on a sensor system that:

- Has a systematic period between over flights,
- Records imagery of the same geographic area,
- Reduces relief displacement as much as possible, and
- Records reflected radiant flux (Jensen, 1986).
The change detection processing using satellite imagery is an ideal way to determine changes in coastal landuse in order to enable organizations to maintain the integrity of the data that they manage. The periodic availability of remotely sensed data makes it well suited to change detection applications. Multidate imagery can be processed to highlight changes in pixel spectral response between image dates. Such information can be used in the decision making process, or used to monitor changes over time as an aid to updating information database.

2.8 Validation Method

2.8.1 Error Matrix

One of the most common means of expressing classification accuracy is the preparation of a classification error matrices (sometimes called a confusion matrix or a contingency table) Error metrics compare, on a category-by-category basis, the relationship between known reference data (ground truth) and the corresponding results of an automated classification. Such matrices are square, with the number of rows and columns equal to the number of categories whose classification accuracy is being assessed (Lillesand and Kiefer, 1994). The matrix is a square array of numbers set out in rows and columns that express the labels of samples assigned to a particular category in one classification relative to the labels of samples assigned to a particular category in another classification. Example error matrix is presented in Figure 5.

2.8.2 Ground Truth

A commonly used term for observations made on the surface of the earth with respect to remotely sensed data is ground truth. Other terms of a similar meaning are in situ data, or collateral data, but all refer to sample data gathered in order to establish a relationship between the sensor response and particular surface conditions. It is
commonly used to determine the accuracy of categorized data obtained through classification (ER Mapper, 1997).

<table>
<thead>
<tr>
<th></th>
<th>Reference Data</th>
<th>Coastal Landuse Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>F</td>
<td>65</td>
<td>4</td>
</tr>
<tr>
<td>P</td>
<td>6</td>
<td>81</td>
</tr>
<tr>
<td>AG</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>S</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td>75</td>
<td>103</td>
</tr>
</tbody>
</table>

**Coastal Landuse Categories**
- **F** = fishponds
- **P** = paddyfields
- **AG** = agriculture
- **S** = settlement

**OVERALL ACCURACY**
\[
\text{Accuracy} = \frac{65 + 81 + 85 + 90}{434} = \frac{321}{434} = 74\%
\]

**PRODUCER'S ACCURACY**
- **F** = 65/75 = 87%
- **P** = 81/103 = 79%
- **AG** = 85/115 = 74%
- **S** = 90/141 = 64%

**USER'S ACCURACY**
- **F** = 65/115 = 57%
- **P** = 81/100 = 81%
- **AG** = 85/115 = 74%
- **S** = 90/104 = 87%

Figure 5. Example error matrix (Modified from Green, K. and Congalton, R.G., 1999).
3 METHODOLOGY

3.1 Time and Location

This study was conducted from March to August 2002 and the location covered Banten Bay, West Java Island, Indonesia. The study area is presented in Figure 6. The area is 46,785.69 hectare (ha) wide, and located in an equatorial area between from 106°5’ to 106°17’ East longitude and from 05°53’ to 06°5’ South latitude. Data analysis was carried out at the MIT (Master of Science in Information Technology Program). Bogor Agricultural University (IPB), SEAMEO-BIOTROP campus.

Figure 6. The Study Area (Banten Bay, West Java Island, Indonesia).
3.2 Data Sources

There are three kinds of data were used in this study as enumerated below:

3.2.1 Remote Sensing Data

The remote sensing datas that were used in this study are the images Landsat-5 TM, with the path/row 123/064 and acquisition date of April 6, 1994, and Landsat-7 ETM+ with path/row 123/064 and acquisition date of August 7, 2001. These were acquired from Bakosurtanal.

3.2.2 Topographic Maps

The topographic maps that were used in this study included 6 sheets: 1109-643 Pontang, 1109-634 Serang, 1109-633 Cilegon, 1110-311 Bojonegoro, sheet 1110-312 Pasir Putih, sheet 1110-321 Lontar. All sheets in scale had a scale of 1: 25000 published by Bakosurtanal in 1999.

3.2.3 Geomorphological Map

The geomorphological map covering the coastal area of Banten Bay, West Java Island, which was modified on February 2000 by Mr. I Nyoman Sukmantalya from Bakosurtanal, had a scale of 1:50000.

3.3 Required Tools

In this study, we used some supporting tools, in terms of software and hardware as the followings:

3.3.1 Software

- ER Mapper 5.5 is a powerful, easy-to-use geographical data viewer and processor that operating system can be run on PC Windows 95, Windows 98 and PC Windows NT
- Banten Bay Information System 3.0 is powerful, easy-to-use ecosystem data, Banten bay database and geographic information for planning and developing. Moreover, to take care for the provision of environmental information
- ArcView GIS version 3.1 is powerful, easy-to-use tool that brings geographic information, gives the power to visualize, explore, query and analyze data spatially
- Microsoft Excel 2002 and Arc/Info version 3.5 might be use as supporting tools

Processor need for software above as following:

- 16 MB Main Memory (expandable to 64 MB)
- Internal 207-Mbyte and External 424-Mbyte [40U] S I Disks (total of 631-Mbyte)
- 3.5-inch 1.44 Mbyte Internal floppy Disk Drive
- CD-ROM drive, SCSI Peripheral Interface
- 2 Serial RS-4 ports
- 8 bit, 256 Color Display

3.3.2 Hardware

- PC Windows 98 Pentium(r) III Processor, 64 MB RAM
- Computer Server Pentium II 266 MHz 64 MB RAM
- Global Positioning System (GPS) Type: Navigation GPS, hand-held, Trade mark: Garmin, III plus
- Laser Printer Type: Hewlett Packard, Laserjet 6L GOLD

3.4 Methodology

The methods were used for this study has three main tasks as described below; and the methodology flowchart is presented in Figure 7.
Figure 7. Methodology flowchart.
3.4.1 Image Preprocessing

Image preprocessing is the first step prior to analysis of the remotely sensed data that is to remove errors. The flow chart of image preprocessing is presented in Figure 8. Radiometric and geometric error are the most common types of error encountered in remotely sensed imagery and image calibration is needed to perform in order to a good quality of results of change detection techniques.

![Image Preprocessing Flowchart]

Figure 8. Image preprocessing flowchart.

- **Radiometric Correction**

The effect of atmospheric scattering that was caused by particles is a problem in imagery that should be removed or minimized to avoid bias in each spectral band. Histogram adjustment is one of the ways to minimize the bias. The radiometric correction algorithm is defined as below:

\[
\text{output } BV_{i,j,k} = \text{input } BV_{i,j,k} - \text{bias}
\]

Where:

- input \( BV_{i,j,k} \) = input pixel value at line \( i \) and column \( j \) of band \( k \)
- output \( BV_{i,j,k} \) = corrected pixel value at the same location
- Geometric Correction

Geometric correction that is commonly used to make digital remote sensor data truly useful is geometric rectification. Geometric rectification is the process of using Ground Control Points (GCPs), which are selected to transform the geometry of the images so that each pixel corresponds to a position in a real world coordinate system. Rectification is the process by which the geometry of an image area is made planar metric (Jensen, 1986).

The basic operations in geometric rectification:

- Collect GCP

Ideally \( x' \) would equal to \( x_{\text{orig}} \) and \( y' \) would equal to \( y_{\text{orig}} \) but some distortion usually happened in GCPs collection. A simple way to measure such distortion is by computing the RMS error for each control point using the equation as below:

\[
\text{RMS}_{\text{error}} = \sqrt{(x' - x_{\text{orig}})^2 + (y' - y_{\text{orig}})^2}
\]

Where:

- \( x_{\text{orig}} \) and \( y_{\text{orig}} \) = the original row and column coordinates of the GCP in the image
- \( x' \) and \( y' \) = the computed or estimated coordinate in the original image

**RMS threshold is 0.5 pixel or RMS_{error} < 0.5, and less then 0.5 pixels is expected.**

- Transformation

Use equation solution to transform the entire image. Polynomial (Control Point) is used as type of rectification. Coordinate transformation equations can be used to interrelate the geometrically correct (map) coordinates and the distorted image coordinates.
- Resampling

Resampling is used to determine the pixel values to fill into the output matrix from the original matrix (Lillesand Kiefer, 1994). Resampling technique chosen is nearest neighbor. The value for a pixel in the output image could be assigned simply on the basis of the value of closest pixel in the transformed image.

- Image Calibration

Image calibration is needed to enhance two images by checking the mean DN values for the dark and bright features at the same location and then define polygon by drawing training regions. The second image was performed statistics and transformation the second image linearly shown as below:

\[ Y_1 = aX_1 + b, \quad Y_2 = aX_2 + b \]

Where:

- \( Y_1 \): Bright Value of image 1994
- \( Y_2 \): Dark Value of image 1994
- \( X_1 \): Bright Value of image 2001
- \( X_2 \): Dark Value of image 2001

From the means summary report (Derived from View/Statistics) and formula above. After computing and getting the value for \( a \) and \( b \), each band (6 bands) was then substituted in the formula editor dialog box of the algorithm window dealing with image 2001.

3.4.2 Image Processing

- Area of Interest (AOI)

Area of interest was prepared by cropping the images of study area. When possible areas that were covered with cloud were avoided. This is important for saving disk space and the image processing will be faster compared with the huge original data.
• **Define Training Area**

Before performing supervised classification, there is a need to select training regions, where annotation tools were used to draw polygons defining training regions in the image (areas of known feature types of cover and then calculate region statistics). Calculate statistics for pixels in each training region. Evaluate the class signatures, view and evaluate the statistics for training regions in tabular format or graphical format using histogram or scattergrams. Concerning regions: regions are vector polygons that define an area of interest in an image. Regions can be used to process or display parts of an image separately from others, masking out parts of an image for mosaicing. The definition of each region is stored in the header file for the raster dataset (ER Mapper, 1997).

• **Supervised Classification**

The objective of these operations is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene. This involves the analysis of multispectral image data and the application of statistically based decision rules for determining the coastal landuse identity of each pixel on an image. These procedures fall into the domain of spatial pattern recognition. The intent of the classification process is to categorize all pixels in a digital image into one of several coastal landuse classes. The general guide steps taken in this study are presented below:

- Classification scheme
- Initial image display
- Image interpretation
- Training site selection
- Statistic extraction
- Supervised classification
- Accuracy assessment

The overall accuracy of classified image is computed by dividing the total number of correctly classified pixels by the total number of reference pixels. The accuracies of individual categories calculated by dividing the number of correctly classified pixels in each category by the total number of pixels.

- Change Detection Techniques

In this study change detection techniques were composed of four methods, which included with Red Green Method, Image Differencing Method, Image Ratiosing Method and Principal Component Analysis Method. Red Green Method is a widely used technique, and is particularly useful for interactive viewing of change area. This technique involves displaying simultaneously one dataset in green and one dataset in red. The output combined images containing mainly shades of yellow (indicating the same response between dates), but areas that have changed, appear as green or red. Red areas tend to have more contrast than green areas, therefore, it is suggested that the most current image be used so that the red layer is increased in pixel brightness and vice versa. A viewing scale 1: 20000 or larger is ideal for panning across the image to delineate areas of interest. This technique is most effective where the magnitude of the areas to be found is anticipate being quite large, such as, cleared fields or changes in crop growth.

Image Differencing Method is perhaps the most simple of all change detection techniques. It is based upon the principle that by subtracting the pixel responses in one image from the corresponding pixel responses in another image, any negative value in the output image represents an increase or decrease in pixel response depending on the order of subtracting. For example, if the spectral response value from the latest image were subtracted from the spectral response value from the older
image then all negative values in the output image would indicate an increase in pixel brightness. Image Differencing Method has the formula as below:

\[
\text{Input1} - \text{Input2}
\]
Where: \( \text{Input1} = \text{Image	extunderscore 1994} \)
\( \text{Input2} = \text{Image	extunderscore 2001} \)

Image Ratioing Method involves dividing the spectral response value of a pixel in one image with the spectral value of the corresponding pixel in another image. This is done in order to suppress similarities between bands. The nature of band rationing is that every pixel that has the same spectral response between input bands will have a value of 1 in the output image; deviations from 1 indicate progressively different initial spectral values. Areas of greatest change are found in tails of the resultant histogram. Production of a change image involves thresholding the image histogram to suppress those areas where little or no change has occurred. Image Ratioing Method has the following formula as below:

\[
\text{Input1} / \text{Input2}
\]
Where: \( \text{Input1} = \text{Image	extunderscore 1994} \)
\( \text{Input2} = \text{Image	extunderscore 2001} \)

Principal Component Analysis Method (PCA) is a technique employed in image processing to reduce the correlation between bands of data and enhance features that are unique to each band. A characteristic of PCA is that information common to all input bands (high correlation between bands) is mapped to the first principal component (PC) while subsequent PCs account for progressively less of the total scene variance. The advantage of PCA principle is that it obtains all common information of the six bands applied in the PCA, especially in principle component 1. After accumulating all information common to the six bands in PCs for both the multitemporal imagery, which in ER mapper has already been provided the formula, the editor formula open the principal components then select PC1 generic or Landsat
TM PC1. Create it into 2 inputs. The areas of greatest change are found in the tails of curve in image histogram. Though information common to the bands applied in the PCA of the multitemporal imagery is used and the precautions should be taken in applying principal component analysis method. Principal Component Analysis Method (PCA) for PC#2 has the following formula as below:

\[
\text{SIGMA}(I_1..I_2 \mid I? * \text{PC_COV}(I_1..I_2 \mid , R1, I?, 2))
\]

Where:
- \( I_1 = \text{Image}_{1994} \)
- \( I_2 = \text{Image}_{2001} \)

### 3.4.3 Image Analysis

The aim of image analysis in this study is to determine an area of coastal landuse change in Banten Bay in two dates. And then, defined the coastal landuse changes by overlaying two images between Landsat-5 TM in 1994 and Landsat-7 ETM+ in 2001 and using four methods of change detection techniques as described above. Then, determine which method that suitable for this study and how many area hectare of coastal landuse has changed base on supervised classification as the reference.
4 RESULTS AND DISCUSSION

4.1 Radiometric Correction

In this study, radiometric correction was performed only image 1994, because image 2001 has already been corrected. Histogram adjustment was used to remove the atmospheric bias that may occur in the imagery in each band. The comparison of transform line is presented in Figure 9. Image 1994: before and after corrected is presented in Figure 10.

Figure 9. Transform line: Band 1 of image 1994: before corrected (left) and after corrected (right).

Figure 10. Image 1994: before corrected (left) and after corrected (right).
The result of histogram adjustment for radiometric correction is presented in Table 3. DN value of original data has increased the minimum brightness all bands. Generally, after performed histogram adjustment the minimum brightness value will be zero.

Table 3. Comparing the DN value before and after performed histogram adjustment of image 1994.

<table>
<thead>
<tr>
<th>Number of band</th>
<th>DN value Original data</th>
<th>Histogram adjustment value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>76 – 255</td>
<td>0 – 179</td>
</tr>
<tr>
<td>2</td>
<td>28 – 136</td>
<td>0 – 108</td>
</tr>
<tr>
<td>3</td>
<td>23 – 182</td>
<td>0 – 159</td>
</tr>
<tr>
<td>4</td>
<td>12 – 165</td>
<td>0 – 153</td>
</tr>
<tr>
<td>5</td>
<td>6 – 230</td>
<td>0 – 224</td>
</tr>
<tr>
<td>7</td>
<td>3 – 171</td>
<td>0 – 168</td>
</tr>
</tbody>
</table>

4.2 Geometric Correction

The geometric correction process is normally implemented as a two-step procedure. First, those distortions that are systematic, or predictable, are considered. Second, those distortions that are essentially random, or unpredictable, are considered (Lillesand and Kiefer, 1994).

The image 1994 needed to perform geometric correction in order to create a new dataset into the same geodetic datum (WGS84) and map projection (SUTM48) similar to image 2001. The number and distribution of ground control points will influence the accuracy of the geometric correction and also root mean square error (RMS) should be less than 1.00. This process is very important for overlaying simultaneously both images. The Ground Control Point (GCPs) is presented in Figure 11. (RMS errors provided in appendix part).
Figure 11. Ground Control Points (GCPs) in geometric correction processed from Landsat 1994 into Landsat 2001.

After performing rectified the image 1994, which have the geodetic datum as RAW and Map projection as RAW the dataset information changed into geodetic datum as WGS84 and also map projection as SUTM48, which is the same as the image 2001. This is very important process for overlaying both of images together. Otherwise, it's unable to achieve the image calibration process and change detection techniques. The dataset information of image 1994 is presented in Figure 12.

Figure 12. Dataset information of image 1994 before corrected (left) and after corrected (right).
4.3 Image Calibration

Image calibration was performed by checking the mean DN values from the most dark and bright features at the same location in both images (1994 and 2001). The statistic was calculated and the mean summary report was opened in view statistics, which it showed the number of each band (6 bands: 1,2,3,4,5 and 7). The linear transform was used to find out the value of a and b in order to calibrate image 2001. The result is presented in Figure 13. (Linear transform provided in appendix part).

![Image 2001: before calibrated (left) and after calibrated (right).](image)

4.4 Coastal Landuse in 1994 and 2001

The feature classes of coastal landuse in 1994 and 2001 composed of 5 classes, such as, paddyfields, fishponds, settlement, agriculture and natural area. The result of coastal landuse in 1994 is presented in Figure 14. The result of coastal landuse in 2001 is presented in Figure 15. Supervised classification was used in this study to transform multispectral image data into user-defined thematic information classes. The advantage of supervised classification for mapping coastal landuse is that it is easier for the user to define the type of coastal landuse.
Figure 14. Coastal landuse in 1994.

Figure 15. Coastal landuse in 2001.

The maps of coastal landuse in this study composed of Banten Bay Coastal Landuse 1994 and Banten Bay Coastal Landuse 2001, which completed with the north arrow, scale, legend, data information that related with each map. Those maps derived from the supervised classification that was used the band combination as 542 for nominal spectral as red, green and blue, respectively. Both Banten Bay Coastal Landuse maps were played as the reference for coastal landuse category and helpful to the user to define the category of coastal landuse and also aid to find out that how much hectare of changed area in two dates. Banten Bay Coastal Landuse 1994 is presented in Figure 16. Banten Bay Coastal Landuse 2001 is presented in Figure 17.
Figure 16. Banten Bay Coastal Landuse 1994.

Figure 17. Banten Bay Coastal Landuse 2001.
4.5 Change Detection Techniques

4.5.1 Red Green Method

Red Green Method is a widely used technique and this particularly useful for interactive viewing of changed area. This method involves displaying simultaneously one dataset in green and one dataset in red. In this study image 1994 was displayed as red (Banten_Red_1994.ers) and image 2001 was displayed as green (Banten_Green_2001.ers). The comparison of red image and green image is presented in Figure 18.

![Figure 18](image1.png)  ![Figure 18](image2.png)

Figure 18. Comparing the image 1994 as red (left) with image 2001 as green (right).

Basically, the coastal landuse changed can directly be interpreted from both images above and rechecked with the geomorphological map for more details. However, it is quite easy and faster than that just overlaying image 1994 with image 2001.

The red color means that this area only existed in image 1994 and the green color means that this area only existed in image 2001. For example, in 1994 the LONTAR zone portion of paddyfields became fishponds base on the Banten Bay Coastal Landuse Maps in 1994 and 2001. Therefore, the red color in the result is represented as a paddyfields in 1994, but its have changed into fishponds in 2001. This can be rechecked from the geomorphological map and also the thematic coastal landuse
mapping that have already done in part of supervised classification. The result of red green method is presented in Figure 19.

![Image of results](image)

Figure 19. Result of red green method: in entire area (left) and zoom in area (right).

4.5.2 Image Differencing Method

The formula editor was used in this study to subtract the spectral response of DN value on the images. The DN value of image 2001 was subtracted from the spectral response DN value of image 1994. The basic concept of this method is that, in the raster data, there are DN values for each band. Therefore, if its was subtracted in the same DN value of each pixel in both images, the output is equal 0. And also the output might be minus or plus in the case that those pixels do not have the same DN value, which these value can be applied into change detection techniques. After have performed the image differencing method and then display the output as pseudocolor, which noticed that the red brightness appear covering the study area, the result is presented in the Figure 20 (left). The raster data should be converted from raster cells into vector polygon and then overlay that vector (change portion) with the original image so that it can be distinguished the raster (original image) and vector polygon, the result is presented in Figure 20 (right).
Figure 20. The result of image differencing method: the entire area (left) and vector polygon overlay with original image (right).

4.5.3 Image Ratioing Method

Actually, in this process is almost the same as the image differencing method just change the formula from subtraction to division. So, areas that have the same DN value output is equal 1, which means those areas do not change. Again, the result that received after performed by using this method is the raster data. Therefore, the raster cell should be converted into the vector polygon. The image ratioing method result is presented in Figure 21. Figure in the left hand side was displayed in the entire area and in the right hand side displayed as zoom in. The formula editor was used in this study for dividing the spectral response DN value of images. The spectral response DN value of image 1994 divided with the DN value of image 2001, which this concept also can be applied in change detection techniques.

4.5.4 Principal Component Analysis Method

The PC#2 was used in this study and assigned the inputs only two bands, which used input1 from image 1994 and the input2 from image 2001 due to dealing with two
images. The ER Mapper software has already provided the formula (Formula available in appendix). Noted that the blue brightness appear covering the study area, the result is presented in Figure 22 (left). However, the areas of greatest change are found in the tails of the image histogram. Moreover, the output should be converting from raster cells into vector polygon in order to distinguish and easy to interpret, the result is presented in Figure 22 (right).

Figure 21. The result of image ratioing method: All dataset (left) and zoom in (right).

Figure 22. The result of principal component analysis method: Pseudocolor (left) and vector polygon overlay with the original image (right).
4.6 Coastal Landuse Change Analysis

In this study, the entire study area was 46,785.69 hectare (ha), which consisted of the land (coastal landuse category, such as, paddyfields, fishponds, settlement, agriculture and natural area) 23,437.26 ha, and the sea (deep water and shallow water) 23,348.43 ha. The area of coastal landuse between two dates is presented in Table 4.

Table 4. Area of coastal landuse between two dates.

<table>
<thead>
<tr>
<th>Coastal Landuse</th>
<th>1994 (ha)</th>
<th>1994 (%)</th>
<th>2001 (ha)</th>
<th>2001 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddyfields</td>
<td>3,814.20</td>
<td>16.27</td>
<td>5,827.77</td>
<td>24.87</td>
</tr>
<tr>
<td>Fishponds</td>
<td>3,454.02</td>
<td>14.74</td>
<td>5,755.14</td>
<td>24.56</td>
</tr>
<tr>
<td>Settlement</td>
<td>385.56</td>
<td>1.65</td>
<td>1,101.24</td>
<td>4.70</td>
</tr>
<tr>
<td>Agriculture</td>
<td>4,194.81</td>
<td>17.90</td>
<td>6,871.23</td>
<td>29.32</td>
</tr>
<tr>
<td>Natural area</td>
<td>11,588.67</td>
<td>49.45</td>
<td>3,881.88</td>
<td>16.56</td>
</tr>
<tr>
<td>Total</td>
<td>23,437.26</td>
<td>100.00</td>
<td>23,437.26</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Regarding to table 4, noticed that every coastal landuse category increased in utility area except for the natural area that was reduced. This is due to the growth rate of the population, In 1994 about 840 people per km.² and in 2001 about 950 people per km.², (Source from Banten Bay Information System 3.0) and also more activities along this area. From the field check, some part of agriculture and paddyfields became fishponds in LONTAR zone this is because in year of 1995 and 1996 the shrimp farming was very popular, where there are some stakeholders that took over areas and developed it into the shrimp farming in order to gain more money from this business. Moreover, some villager and rice farmers changed their own area from agriculture and paddyfields into fishponds. However, since 1997 there are problem about aquatic disease due to the water quality that was very poor, because of the intensive system farming, more use of drugs and chemicals and did not have a proper
way to treat the water before and after farming activities. Therefore, at this time the fishponds are still there but don’t have the stakeholder for taking care of them because of the problem as stated above. According to verbal communications made with some of the villagers along, the big problem comes from fish and shrimp kidnapping, especially, when they have reached marketable sizes. These unidentified thieves scout for the sizes for fishes and shrimps and later steal them causing profit loss to pond owner.

The total area of coastal landuse changed was 7,706.79 hectare (ha). Paddyfields in 1994 changed into fishponds 812.46 ha, settlement 70.16 ha, and agriculture 712.66 ha in 2001, respectively. Fishponds in 1994 changed into settlement 8.15 ha in 2001 while settlement in 1994 have no changed. Agriculture in 1994 changed into paddyfields 1,015.06 ha, fishponds 761.39 ha and settlement 317.18 ha in 2001, respectively. Natural area in 1994 changed into paddyfields 998.51 ha, fishponds 727.27 ha, settlement 320.19 ha and agriculture 1,963.76 ha in 2001, respectively. The coastal landuse area of hectare change between 1994 and 2001 is presented in Table 5.

Table 5. Coastal landuse change between 1994 and 2001.

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>Paddyfields</th>
<th>Fishponds</th>
<th>Settlement</th>
<th>Agriculture</th>
<th>Natural area</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paddyfields</td>
<td>812.46</td>
<td>70.16</td>
<td>712.66</td>
<td></td>
<td></td>
<td>1,595.28</td>
<td></td>
</tr>
<tr>
<td>Fishponds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.15</td>
</tr>
<tr>
<td>Settlement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>1,015.06</td>
<td>761.39</td>
<td>317.18</td>
<td></td>
<td></td>
<td>2,093.63</td>
<td></td>
</tr>
<tr>
<td>Natural area</td>
<td>998.51</td>
<td>727.27</td>
<td>320.19</td>
<td>1,963.76</td>
<td></td>
<td>4,009.73</td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>2,013.57</td>
<td>2,301.12</td>
<td>715.68</td>
<td>2,676.42</td>
<td></td>
<td>7,706.79</td>
<td></td>
</tr>
</tbody>
</table>
According to table 5, observed that there are two ways of change, the first way is area increase and the second way is area decrease. Among the change detection techniques that were used in this study which method is suitable. The total area change (ha) from the table 5 was used as total reference and it helpful for selecting the best method. The area change deference (ha) is presented in Table 6.

Table 6. Comparison of change detection techniques in total reference.

<table>
<thead>
<tr>
<th>Change Detection Techniques</th>
<th>Area Change (ha)</th>
<th>Area Change Difference (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Green Method</td>
<td>7,094.97</td>
<td>611.82</td>
</tr>
<tr>
<td>Image Differencing Method</td>
<td>6,185.25</td>
<td>1,521.54</td>
</tr>
<tr>
<td>Image Ratioing Method</td>
<td>8,490.96</td>
<td>784.17</td>
</tr>
<tr>
<td>PCA Method (PC#2)</td>
<td>5,920.47</td>
<td>1,786.32</td>
</tr>
<tr>
<td>Total Reference</td>
<td>7,706.79</td>
<td></td>
</tr>
</tbody>
</table>

From table 6, the total reference data shows 7,706.79 ha of change area, in this case total reference was applied for area change increase and area change decrease because based on the entire area changed of coastal landuse (area increase equal area decrease). Red Green Method shows 7,094.97 ha, Image Differencing Method shows 6,185.25 ha, Image Ratioing Method shows 8,490.96 ha and Principal Component Analysis (PC#2) shows 5,920.47 ha, respectively. Therefore, in this study the assessment would conclude that Red Green Method is better for detecting the coastal landuse change, because the total number of change area hectare for Red Green Method more closely agrees with the number of hectare of change area on total reference. (7,706.79 hectare - 7,094.97 hectare = 611.82 hectare difference for Red Green Method while Image Differencing Method differs by 1,521.54 hectare, Image
Ratioing Method differs by 784.17 hectare and PC#2 differs by 1,786.32 hectare, respectively).

However, the result and discussion above used the total area change as reference. So, if assign the reference in each coastal landuse category which method is suitable for this case. Comparison of change detection techniques with area change increase in each coastal landuse category is presented in Table 7. Comparison of area change increase difference in each coastal landuse category is presented in Table 8.

Table 7. Comparison of change detection techniques with area change increase in each coastal landuse category.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Red Green</th>
<th>Image Differencing</th>
<th>Image Ratioing</th>
<th>PC#2</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddyfields</td>
<td>1,969.86</td>
<td>1,680.39</td>
<td>2,088.15</td>
<td>1,802.88</td>
<td>2,013.57</td>
</tr>
<tr>
<td>Fishponds</td>
<td>2,161.82</td>
<td>1,806.74</td>
<td>2,394.97</td>
<td>1,988.55</td>
<td>2,301.12</td>
</tr>
<tr>
<td>Settlement</td>
<td>804.84</td>
<td>439.41</td>
<td>827.13</td>
<td>493.20</td>
<td>715.68</td>
</tr>
<tr>
<td>Agriculture</td>
<td>2,158.44</td>
<td>2,258.72</td>
<td>3,180.70</td>
<td>1,635.85</td>
<td>2,676.42</td>
</tr>
<tr>
<td>Total</td>
<td>7,094.97</td>
<td>6,185.25</td>
<td>8,490.96</td>
<td>5,920.47</td>
<td>7,706.79</td>
</tr>
</tbody>
</table>

Table 8. Comparison of area change increase difference in each coastal landuse category.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Red Green</th>
<th>Image Differencing</th>
<th>Image Ratioing</th>
<th>PC#2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddyfields</td>
<td>43.71</td>
<td>333.18</td>
<td>74.58</td>
<td>210.69</td>
</tr>
<tr>
<td>Fishponds</td>
<td>139.30</td>
<td>494.38</td>
<td>93.85</td>
<td>312.57</td>
</tr>
<tr>
<td>Settlement</td>
<td>89.16</td>
<td>276.27</td>
<td>111.45</td>
<td>222.48</td>
</tr>
<tr>
<td>Agriculture</td>
<td>517.98</td>
<td>417.70</td>
<td>504.28</td>
<td>1,040.57</td>
</tr>
<tr>
<td>Mean</td>
<td>158.03</td>
<td>304.31</td>
<td>156.83</td>
<td>367.26</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>207.79</td>
<td>189.22</td>
<td>198.81</td>
<td>398.81</td>
</tr>
</tbody>
</table>
According to table 8, the assessment would conclude that Red Green Method is suitable for detecting changes in paddyfields increase and settlement increase, because the number of change area hectare for Red Green Method more nearly agrees with the number of hectare of change area of paddyfields and settlement in increase references (2,013.57 ha - 1,969.86 ha = 43.71 ha difference for paddyfields and 804.84 ha - 715.68 = 89.16 ha difference for settlement) However, the Image Differencing Method is better to detect changes in agriculture increase due to the number of change area hectare is more closely agrees with the number of hectare of change area of agriculture in increase reference. The assessment of the Image Ratioing Method would conclude that this method is better for monitoring changes in fishponds increase. This is because of the number of change area hectare for this method more closely agrees with the number of hectare of change area of the fishponds in increase reference.

As table 7 and table 8 have already supported for coastal landuse change in line of area change increase. Thus, it is also necessary to find out which method is suitable in case of coastal landuse change in line of area change decrease. Comparison of change detection techniques with area change decrease in each coastal landuse category is presented in Table 9.

Table 9. Comparison of change detection techniques with area change decrease in each coastal landuse category.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Red Green</th>
<th>Image Differencing</th>
<th>Image Ratioing</th>
<th>PC#2</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddyfields</td>
<td>294.84</td>
<td>270.82</td>
<td>387.45</td>
<td>278.92</td>
<td>1,595.28</td>
</tr>
<tr>
<td>Fishponds</td>
<td>486.80</td>
<td>397.17</td>
<td>694.27</td>
<td>464.59</td>
<td>8.15</td>
</tr>
<tr>
<td>Agriculture</td>
<td>483.42</td>
<td>849.15</td>
<td>1,480.00</td>
<td>111.89</td>
<td>2,093.63</td>
</tr>
<tr>
<td>Natural area</td>
<td>5,829.93</td>
<td>4,668.11</td>
<td>5,929.25</td>
<td>5,065.07</td>
<td>4,009.73</td>
</tr>
<tr>
<td>Total</td>
<td>7,094.97</td>
<td>6,185.25</td>
<td>8,490.96</td>
<td>5,920.47</td>
<td>7,706.79</td>
</tr>
</tbody>
</table>
Comparison of area change decrease difference in each coastal landuse category is presented in Table 10.

Table 10. Comparison of area change decrease difference in each coastal landuse category.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Red Green</th>
<th>Image Differencing</th>
<th>Image Ratioing</th>
<th>PC#2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddyfields</td>
<td>1,300.45</td>
<td>1,324.46</td>
<td><strong>1,207.83</strong></td>
<td>1,316.36</td>
</tr>
<tr>
<td>Fishponds</td>
<td>478.65</td>
<td><strong>389.02</strong></td>
<td>686.12</td>
<td>456.44</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1,610.22</td>
<td>1,244.48</td>
<td><strong>613.63</strong></td>
<td>1,981.74</td>
</tr>
<tr>
<td>Natural area</td>
<td>1,820.20</td>
<td><strong>658.38</strong></td>
<td>1,919.52</td>
<td>1,055.34</td>
</tr>
<tr>
<td>Mean</td>
<td>1,302.38</td>
<td>904.09</td>
<td>1,106.78</td>
<td>1,202.47</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>589.19</td>
<td>453.96</td>
<td>603.02</td>
<td>632.04</td>
</tr>
</tbody>
</table>

According to table 10, the assessment would conclude that Image Differencing Method is better for detecting changes in fishponds decrease and natural area decrease compared with other methods. The assessment of Image Ratioing Method would conclude that this method is better for monitoring changes in paddyfields decrease and agriculture decrease. This is because of the number of change area hectare for both methods more closely agrees with the number of hectare of change area of the in decrease reference.

Further discussion; in this study assume that both images have the same tidal information. Thus, the tide effect is not considered because of the tidal information would be useful for coastline change detection, but in this study dealing with coastal landuse change detection. The tidal information for applying in the image processing is Actual Apparent Coastline (AAC) this is the range between Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT), which it is not steadfast like the Mean Sea Level (MSL), in purpose of topographic map; the LAT, in purpose of navigation; and the HAT, in purpose of island definition. AAC could be corrected by
Digital Elevation Model (DEM) data and Tidal data. Unfortunately, such accurate data \(^1\) for this purpose are not available. Usually, the entire coastal landuse category especially, that made by human should be above the HAT in order to easy and convenient in term of coastal area planning.

As already have known that the remotely sensed data that were used in this study consisted of image 1994 and image 2001 this periodic is quite long time so that, the aspect of change area would be more change and easier to detect than the date of image that short time difference. For example, if perform the change between image 1994 with image 1998 some area that have changed, but those area changed not more than 30 meters (m.) it will be unable to find out, this is because the constrain of the resolution of landsat imagery (30 m. X 30 m.). Moreover, assume that coastal landuse between year of 1994 and 1998 there are total area of fishponds changed 20,000 hectare. Thus, it would say that the fishponds changed 5,000 ha per year (20,000 hectare/4 years = 5,000 ha per year), but if in fact result shown that 1994 and 2001 the fishponds changed 40,000 ha, which in this case the total area of fishponds will be changed 5,714.28 ha per year by average. From above example gave the idea that the periodic of time has influence of the final result in coastal landuse change detection using remote sensing technique.

\(^1\) The DEM data should have accuracy about 25-50 cm in vertical to eliminate the tidal effect.
5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

- The image preprocessing consisted of the radiometric correction, geometric correction and image calibration. A radiometric correction is the process of eliminating particles effects. A geometric correction is the process in image preprocessing, which is very important in order to perform an adjustment on both images have the same geodetic datum and map projection. An image calibration is necessary for the quality of change detection techniques. These are the standard of image preprocessing for everyone who would perform the digital coastal landsue change detection.

- The image processing consisted of supervised classification and change detection techniques. The advantage of supervised classification for mapping coastal landuse is that it is easier for users to define the classes of coastal landuse. In this study there are five classes, which consisted of paddyfields, fishponds, settlement, agriculture and natural area. Change detection techniques that were used in this study included with Red Green Method, Image Ratiriong Method, Image Differencing Method and Principal Component Analysis Method.

- In this study supervised classification was use to performed the banten bay coastal landuse 1994 and 2001. The total of area changed was 7,706.79 hectare (ha), which this supported as the total reference. The Red Green Method gave the best result for detecting the coastal landuse change, because the number of change area more closely with the total number of change area on the reference.
- However, through careful comparison it was observed that Red Green Method is suitable for detecting areas changes in the paddyfields increase and settlement increase; Image Differencing Method is better to detect areas changes in agriculture increase, fishponds decrease and natural area decrease; Image Ratioing Method gave the best result for monitoring areas change in fishponds increase, paddyfields decrease and agriculture decrease because the number of each changed area (per hectare) nearly coincides more with the size of changed area (per hectare) of each increase and decrease reference.

- Every coastal landuse category increased in utility area except the natural area that was reduced. This is due to the growth rate of the population, In 1994 about 840 people per km.$^2$ and In 2001 about 950 people per km.$^2$, (Source from Banten Bay Information System 3.0) and also more activities along this area. From the field check, some part of agriculture and paddyfields became fishponds in LONTAR zone. And information from verbal communication made with some villager along that area said in year of 1995 and 1996 the shrimp farming was very popular. Therefore, there are some stakeholders that took over those areas and developed it into shrimp farming. Some villagers and rice farmers also changed their own area from agriculture and paddyfields into fishponds for the purpose of having more money.
5.2 Recommendation

- In this study has used the simple techniques to extract the coastal landsue changed. Other methods, such as, Intensity Hue Saturation (HIS), PC#1 as image differencing method and image ratioing method might be able to apply in coastal landuse change detection. Dataset from LANDSAT imagery only that were used in this study. Thus, other satellites, such as, SPOT, IKONOS and SAR imagery might be necessary for the best final result.

- It is excellent to integrate the remote sensing (RS) with the geographic information system (GIS), such as, the digital base map in order to emphasis the boundary of coastal landuse category and it is great if possible to create the spatial database in each coastal landuse category, which can be run in GIS directly.

- The bathymetric mapping and the tidal information will be helpful to analyst coastline change. In the theme of coastal zone management and environmental impact assessment (EIA) will be very important issue to foretell the trend of coastal landuse change in the future.
REFERENCES


APPENDIX

I. Metadata

1. West java (path/row: 123/64) – Landsat-5 TM 1994
   
   Version = "5.5"
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   LastUpdated = Thu Apr 25 15:23:21 GMT 2002
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   band 3 (0.63–0.69 μm)
   band 4 (0.76–0.90 μm)
   band 5 (1.55–1.75 μm)
   band 7 (2.08–2.35 μm)

2. West java (path/row: 123/64) – Landsat-7 ETM+ 2001

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II. Geometric Correction

GCPs for dataset : D:\Banten\BN_1994.ers

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Average RMS error : 0.272
Total RMS error : 11.964

End of GCP details

III. Image Calibration

Linear transformation technique

Means Summary Report for Banten_1994.ers

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Means Summary Report for Banten_2001.ers

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From \( Y_1 = aX_1 + b \), \( Y_2 = aX_2 + b \)

Where:

\( Y_1 \) : Brightness value of Banten_1994.ers
\( Y_2 \) : Darkness value of Banten_1994.ers
\( X_1 \) : Brightness value of Banten_2001.ers
\( X_2 \) : Darkness value of Banten_2001.ers
Answer  Band1  Band2  Band3  Band4  Band5  Band7  
a    1.546514  0.642  0.772  0.9729  0.9135  0.7144  
b   -35.0647  -1.925  1.471  -4.384  1.9947  0.388  

Opening Banten_2001.ers dataset and then display in pseudo layer. Using formula editor in the Algorithm window, create formula as $II^*a + b$, which its need to perform the entire bands (Ex. Band1 using a1, b1, Band2 using a2, b2 and etc.) After have successful finished all bands save as new dataset.

IV. Formula for supervised classification and change detection

The formula for displaying a region is:

if inregion (region1) then input1 else null
The formula for Image Differencing Method is: $\text{Input}_1 - \text{Input}_2$

The formula for Image Ratioing Method is: $\text{Input}_1 / \text{Input}_2$

The formula for Principal Component Analysis Method (PC#2) is:

$$\text{SIGMA}(\text{I}_1..\text{I}_2 | \text{I}_? \ast \text{PC_COV}(\text{I}_1..\text{I}_2 | , \text{R}_1, \text{I}_?, 2))$$