ความสัมพันธ์ระหว่างการใช้ที่ดินบริเวณชายฝั่งกับการเปลี่ยนแปลงของชายฝั่งทะเล จังหวัดเพชรบุรีและจังหวัดประจวบคีรีขันธ์ จากการศึกษาด้วยเทคนิครีโมทเซนซิ่ง

นางสาวกฤติกา บุญยชาติพิสุทธิ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาวิทยาศาสตร์สภาวะแวดล้อม สหสาขาวิชาวิทยาศาสตร์สภาวะแวดล้อม
บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2542

ISBN 974-334-722-4

RELATIONSHIP BETWEEN LAND USE AND COASTLINE CHANGE IN PHETCHABURI AND PRACHUAP KHIRI KHAN PROVINCES AS INVESTIGATED BY REMOTE SENSING TECHNIQUE

Miss Krittika Bunyachatphisuth

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Environmental Science

Inter-Department of Environmental Science
Graduate School
Chulalongkorn University
Academic Year 1999
ISBN 974-334-722-4

Thesis Title	RELATIONSHIP BETWEEN LAND USE AND COASTLINE CHANGE IN PHETCHABURI AND PRACHUAP KHIRI KHAN PROVINCES AS INVESTIGATED BY REMOTE SENSING TECHNIQUE
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กฤติกา บุญยชาติพิสุทธิ์ : ความสัมพันธ์ระหว่างการใช้ที่ดินบริเวณชายฝั่งกับการเปลี่ยนแปลงของชายฝั่งทะเลจังหวัดเพชรบุรีและจังหวัดประจวบคีรีขันธ์ จากการศึกษาด้วยเทคนิครีโมทเซนซิ่ง (RELATIONSHIP BETWEEN LAND USE AND COASTLINE CHANGE IN PHETCHABURI AND PRACHUAP KHIRI KHAN PROVINCES AS INVESTIGATED BY REMOTE SENSING TECHNIQUE) อาจารย์ที่ปรึกษา : ดร. ศุภิชัย ตั้งใจตรง, 72 หน้า. ISBN 974-334-722-4

ความสัมพันธ์ระหว่างการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินบริเวณชายฝั่ง กับการเปลี่ยนแปลงของชายฝั่งทะเล สามารถคำนวณได้จากข้อมูลการเปลี่ยนแปลงของชายฝั่งทะเลและการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินบริเวณชายฝั่งที่ได้จากการศึกษาด้วยเทคนิครีโมทเซนซิ่ง โดยใช้ข้อมูลรูปถ่ายทางอากาศและข้อมูลดาวเทียมแลนด์แซททีเอ็ม ระหว่างปี 2497 ถึง 2537 การศึกษานี้ใช้วิธีการวิเคราะห์ถดถอยโลจิสติกในการหาความสัมพันธ์ระหว่างการเปลี่ยนแปลงของชายฝั่งกับการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดิน 10 ประเภท คือ 1) พื้นที่ชุมชนหนาแน่น 2) พื้นที่ชุมชน 3) พื้นที่ชายหาด 4) พื้นที่ว่างเปล่า 5) พื้นที่ป่าชายเลน 6) พื้นที่ที่ปกคลุมด้วยต้นไม้หนาแน่น 7) พื้นที่ที่ปกคลุมด้วยต้นไม้เบาบาง 8) นาข้าว 9) ที่ราบน้ำท่วมถึง และ 10) แหล่งน้ำ

จากการศึกษาพบว่า การเปลี่ยนแปลงชายฝั่ง ณ จุดใดๆ มีความสัมพันธ์กับการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินบริเวณชายฝั่ง ณ จุดนั้นที่ระดับนัยสำคัญน้อยกว่า 0.2063 โดยพื้นที่ชุมชนหนาแน่นเป็นบริเวณที่มีค่าความน่าจะเป็นในการเกิดการกัดเซาะชายฝั่งสูงในทุกกรณีที่ศึกษา ในขณะที่พื้นที่ว่างเปล่าเป็นบริเวณที่มีความน่าจะเป็นในการเกิดการกัดเซาะชายฝั่งต่ำ สำหรับการวิเคราะห์ความสัมพันธ์ระหว่างการเปลี่ยนแปลงชายฝั่ง ณ จุดใดๆ กับการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดิน ณ จุดนั้นและบริเวณถัดไปทางต้นน้ำพบว่า ความสัมพันธ์ระหว่างการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินกับการเปลี่ยนแปลงชายฝั่งไม่สามารถสรุปได้ โมเดลถดถอยโลจิสติกไม่สามารถแสดงความสัมพันธ์ใดๆ ของการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินแต่ละชนิดกับการเปลี่ยนแปลงชายฝั่งที่ระดับนัยสำคัญมากกว่า 0.1581 นอกจากนี้ยังพบว่า เมื่อโมเดลมีตัวแปรการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินมากขึ้น โดยการเพิ่มข้อมูลการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินในบริเวณต้นน้ำ ความสัมพันธ์ระหว่างการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินกับการเปลี่ยนแปลงชายฝั่งมีนัยสำคัญเพิ่มขึ้น ($P < 0.005$)

สหสาขา วิชาวิทยาศาสตร์สภาวะแวดล้อม ลายมือชื่อนิสิต..........................
สาขาวิชา วิทยาศาสตร์สภาวะแวดล้อม ลายมือชื่ออาจารย์ที่ปรึกษา..........................
ปีการศึกษา 2542 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม..........................

3970031623 : MAJOR ENVIRONMENTAL SCIENCE
KEY WORD : COASTLINE CHANGE / LAND USE / REMOTE SENSING / LOGISTIC REGRESSION

KRITTIKA BUNYACHATPHISUTH : RELATIONSHIP BETWEEN LAND USE AND COASTLINE CHANGE IN PHETCHABURI AND PRACHUAP KHIRI KHAN PROVINCES AS INVESTIGATED BY REMOTE SENSING TECHNIQUE. THESIS ADVISOR : SUPICHAI TANGJAITRONG, Ph.D. 72 pp. ISBN 974-334-722-4.

Relationship between land use/land cover and coastline change in Phetchaburi and Prachuap Khiri Khan provinces was investigated by using remote sensing technique. Aerial photographs and Landsat-5 TM image from 1954 to 1994 were used for detection of coastline change and classification of land use/land cover. This study used logistic regression to evaluate the relationship between coastline change and 10 categories of land use/land cover, i.e. 1) high density built-up area, 2) built-up area, 3) beach area, 4) bare soil, 5) mangrove area, 6) vegetation: well develop, 7) vegetation: sparseness, 8) paddy field, 9) flood plain, and 10) inland water.

The results showed that coastline change at any shoreline segment has significant relation with land use/land cover at that segment at significant value less than 0.2063. The high density built-up area always has high probability of erosion, while bare soil always has low probability of erosion. In analysis of relationship between coastline change at any shoreline segment with land use/land cover at that segment as well as the adjacent updrift segment, it was found that the relation between land use/land cover with coastline changes could not be concluded. The logistic model did not exhibit any statistical relationship between individual of land use/land cover with the coastline change at significant value greater than 0.1581. When the model contained more land use/land cover variables by adding updrift land use/land cover information, the significance increased ($P < 0.005$).

สหสาขา วิชาวิทยาศาสตร์สภาวะแวดล้อม ลายมือชื่อนิสิต...........................
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ACKNOWLEDGEMENT

The author wishes to express the sincere appreciation to the following persons and organizations for their help, support, and encouragement.

Dr. Supichai Tangjaitrong, thesis advisor, for his encouragement and valuable suggestions.

Assistant Professor Dr. Pipat Patanaponpaiboon, Associate Professor Absornsuda Siripong, and Dr. Darasri Dowreang, who served as thesis chairman and thesis committees respectively.

The National Science and Technology Development Agency granted the scholarship for supporting the study.

The National Research Council of Thailand provided satellite data and valuable information used in this study.

The Office of Environmental Policy and Planning favored the GIS information and document related to the study.

The Computer Center of Science faculty and their staffs for offering computer facilities, suggestion, and help.

Department of Marine Science, Faculty of Science, Chulalongkorn University, for room permission and facilities support.

Mr. Sarojpan Kanlampu prepared Turbo Pascal and Visual Basic program for data management.

Miss Kanokwan Komonveeraket, Mr. Narumitr Sawangphol, Miss Nawarat Kieomat, and Miss Somrudee Meprasert supported information and techniques.

Finally, the author's parents and Mr. Chadon Suwanarit and his family always encouraged and helped in every situations and everytime.

CONTENTS

CONTENTS (Cont.)

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

1.1 Background Information

Naturally, shorelines experience the dynamic processes of erosion and deposition. Physical processes are the most important process affecting erosion and deposition in all coastal zones. These natural processes caused no problem until human activities began to develop along shorelines.

Many human activities bring about changes which result in some degree of artificiality to many environments. Coast is a typical environment in which human impacts have led to a whole range of changes. The coast is typically a high populated area. In addition, many people also see the coast as a place to spend their free time, and taking advantage of beach and attractive scenery. As a result, coastal zone experiences extreme pressure and demands from the community. The coast ceases to be natural, and the natural processes which operate in that coast are affected by unnatural conditions (French, 1997).

The rapid urbanization along most of the length of the beach has caused the total destruction of the dune field in most of the area. This loss leads to a more vulnerable shoreline since wind protection has been completely removed so that the transportation of beach sand by wind action out of the littoral has increased significantly.

Remote sensing is an efficient technology for management of coastal zone because it yields a large space scales and spends short time scales. In particular, the remote sensing has shown it usefulness for providing novel information on physical and biological processes of the coastal area. Remote sensing of the coastal zone finds applications in studies of land use/land cover, sediment transport, coastal runoff and circulation, and dynamical processes.

Despite all these facts, the relationship between land use/land cover and coastline change has never been investigated. Therefore, this study was conducted.

1.2 Objectives

1.2.1 To apply remote sensing technique for determining the changes of land use/land cover in coastal area and shoreline in Phetchaburi and Prachuap Khiri Khan provinces.

1.2.2 To determine the dependent of land use/land cover on coastline change which can be used for coastline change prediction in the future.

1.3 Scope of the Study

1.3.1 The study area covered the coastal area from Chaosamran beach, Phetchaburi province to the north of Khao Takiap, Prachuap Khiri Khan province as shown in Figure 1.1.

1.3.2 Shorelines were delineated from aerial photographs. Land use/land cover were derived from Landsat-5 Thematic Mapper images except land use/land cover in 1954, were classified from the aerial photographs.

1.3.3 Logistic regression was used to determine the dependent of land use/land cover on coastline change.

1.4 Anticipated Benefits

1.4.1 The land use/land cover and coastline change can be investigated by remote sensing technique and their relationship can be evaluated.

1.4.2 Findings of the study can be used to support coastal planning and management in the future.

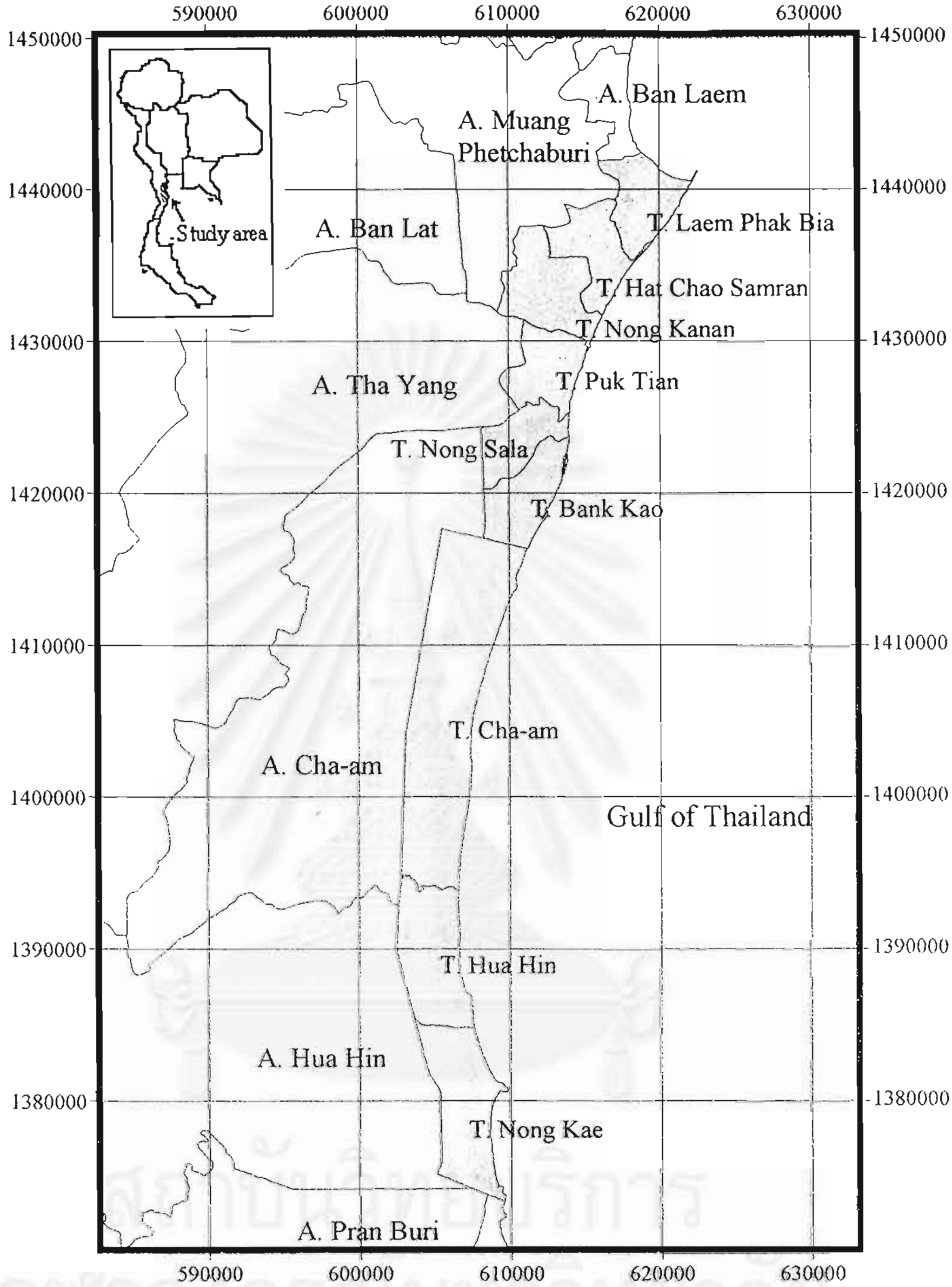

Figure 1.1: Study area

Source: The Specification of Environmental Conservation and Protected Area in Phetchaburi and Prachuap Khiri Khan Provinces Project. (OEPP, 1999)

4 0 4 Kilometers

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CHAPTER 2

LITERATURE REVIEW

2.1 Coastal Erosion

Coastal zones are the most dynamic and changing areas. Their shorelines experience the dynamic processes of erosion and deposition. Wave activity is the most important process affect erosion and deposition in all coastal zones. Current generated by rising and falling tides are also important agents along oceanic shoreline. These natural geologic processes posed no problem until people began their activities along shorelines (Coch and Ludman, 1992).

Beaches continually deposit and erode depending on the balance among sediment deposition, longshore drift, and sand removal by storm waves. Erosion and deposition occur simultaneously along all shorelines. However, the one that dominates in forming shoreline features differents from coast to coast. Wherever wave removes more material than deposited, net erosion occurs, and the beach is eroded. Wherever more sediment is being deposited than eroded, net deposition occurs, and the beach builds seaward.

The various factors which affect to coastal change are mainly divided into three groups: terrestrial factors, marine factors, and biological factors (Hansom, 1990).

1) Terrestrial factors

Structural base

Geological structure can be considered simply as a container within which all coastal features develop. However, the degree to which structure influences landforms also depends on the supply of sediment to the coast. The continuum of landforms also depends on the supply of sediment to the coast. The continuum of coastal types from hard to soft also reflects a transition from structurally dominated coasts to sediment-dominated coasts.

Bedrock characteristics are less important on soft coasts because the rock basins are masked to varying degrees by superficial sediments. These sediments are highly mobile. They accumulate where wave action is low or moderate or where the supply of sediment far exceeds its removal.

Subaerial processes

The present climate affects the rate of weathering on coastal cliffs or the build-up of coastal sand dunes. Its principal effect on coastal development lies in the nature and rate of terrestrial sediment transport to the coast. Climate is an important control on the rainfall, vegetation type, and fluvial discharge which affect denudation of the coastal hinterland. Consequently, rivers deliver the large amounts of sediment to coasts.

2) Marine factors

Tides

Tides, the regular and predictable rises and falls of sea-level are important because they increase the vertical range which current and wave activity can take place. Tides are also responsible for currents which transport sediments. Where tidal range is limited, wave produce forms are more common. Where tidal range is great, the influence of tide on morphology is enhanced. Large tidal ranges also produce strong currents capable of moving substantial amounts of sediment perpendicular to the shoreline.

Waves

The principle source of energy input into the coastal zone comes from wind-generated waves. Sea surface is composed of waves of several sizes travelling in various directions. In deep water, water particles in a wave have only a local orbital motion. The orbital motion ceases entirely at depth equal to about one-half of the wavelength of the waves at the surface. This depth is the bottom limit of orbital water movement and is known as the wave base. Above the wave base is a zone of agitated water, while the water below it is not influenced by wave motion. Where waves approach shallow water, the wave base intersects the seafloor. They begin to feel the bottom and waves in this zone are called of shoaling (shallowing) waves (Coch and Ludman, 1992).

From this point landward, the waves grow taller and less symmetrical. The zone in which these changes occur is called the breaker zone. Finally, these oversteepened waves topple within the surf zone. Here, actual forward movement of the water itself occurs within the wave. It is in the surf zone that the energy stores in the wave causes erosion, transport, and deposition of sediment along the shoreline.

Waves approach the coastline at an oblique angle depending on the bottom topography and the direction of the wave sources. The part of a wave front that passes over a shallow area begins to slow. Parts of the wave that are in the deeper water continue to move landward without slowing. This bend the wave fronts as the waves advance toward shore, a phenomenon called wave refraction. The result of continued wave refraction is that waves erode headlands and smooth out the shoreline. Eroded sediment is deposited offshore, on beaches, or in the bays.

Wave-induced currents

There are two types of wave-induced current: shore-normal currents and shore-parallel or longshore currents. These currents are responsible for the transportation of most coastal sediment and for changes in coastal morphology (Hansom, 1990).

As water depths decrease to the depths of surf base or less, the orbital motions of water particles in waves produce shore-normal current. The circular orbits of the water particles become increasingly elliptical until they eventually move back and forth along a line. However, the onshore and offshore velocities of these reversing currents are not equal. These currents are responsible for the movement of sediment on and offshore.

Longshore current is generated by differences in wave height along the beach or by an oblique wave approach. This longshore current acts parallel to the coastline and is responsible for the movement of large amount of beach material.

Coastal Storms

A coastal storm has low pressure at its center, surrounded by winds that move counterclockwise. As such a storm approaches a coast, the central low pressure causes the sea surface below it to rise. In addition, its winds act similar to a bulldozer, pushing water ahead of the storm and raising the ocean surface further. The elevated water surface that results from all these factors is called a storm surge (Coch and Ludman, 1992).

High waves from storms erode large quantities of sediment from beach and dune areas. Some is shifted along the shore by accelerated longshore currents and some moved offshore.

After the storm, sand stripped from a beach is returned eventually through formation of an offshore ridge of sand and its migration landward. During its landward migration, the ridge is separated from the beach by a water-filled trough, called a runnel (together, they are called a ridge and runnel). The migration ridge can be welded itself to the damaged beach, restoring its width in little more than a week. Ridge and runnel formation is an important beach-restoration process that is visible on many beaches after a storm, although the width of the beach may have been restored, the front of the beach now may be located further inland than before. Thus, net erosion occurs along many coasts.

3) Biological factors

Vegetation

The plants which initially colonize beaches and sand dunes do so in areas that are infrequently disturbed by inundation at the rear of the beach. These plants produce horizontal and vertical shoots or rhizomes which extend from the parent plant. As a result of this colonization, the deposition of sediment increases (Hansom, 1990).

Animals

Several species of marine animals exploit coastal rocks for food and shelter. Some browse on the algae that inhabit rock surfaces and remove rock in the process. Some bore into coastal rock both weakening it and making it more susceptible to erosion. The coral reefs represent the most potent forms of organic deposition on the coast and their offshore substantially reduces the wave and current processes operating on the shore.

2.2 Remote Sensing Theory

2.2.1 Remote Sensing Definition and Concept

Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 2000). Remote sensing uses electromagnetic waves as the means to investigate objects. An object reflects electromagnetic wave (e.g. sunlight) or emits

its own internal energy, which serves as a signature for its identification (Rajan, 1991).

Electromagnetic wave can be categorized by their wavelength location within the electromagnetic spectrum, consist of cosmic rays, gamma rays, x-rays, ultraviolet, visible light, infrared, microwave and radio waves (Lillesand and Kiefer, 2000).

Remote sensing system can be classified into 2 types:

1) Active remote sensing systems, such as radar, supply their own source of energy to illuminate interested features and detect the signal that reflects backward.

2) Passive remote sensing systems, such as multispectral scanner and thermal scanner, sense naturally available energy.

The basic interactions of electromagnetic energy on any earth surface feature are reflection, absorption, and/or transmission. The proportions of energy reflected, absorbed, and transmitted will vary for different earth features, depending on their material type and condition. However, within a given feature type, the proportion will vary at different wavelength.

An object reflects only particular wavelengths of the sunlight and absorbs all other wavelengths (Rajan, 1991). The spectral reflectance is the percentage of the reflectance characteristics of earth surface features which are measured as a function of wavelength. A graph between spectral reflectance and wavelength is called spectral reflectance curve as shown in Figure 2.1 (Lillesand and Kiefer, 2000). All spectral reflectance data are unique to the sample and the environment in which they are measured (Schowengerdt, 1997). Thus, many earth surface features of interest can be identified, mapped, and studied on the basis of their spectral characteristics.

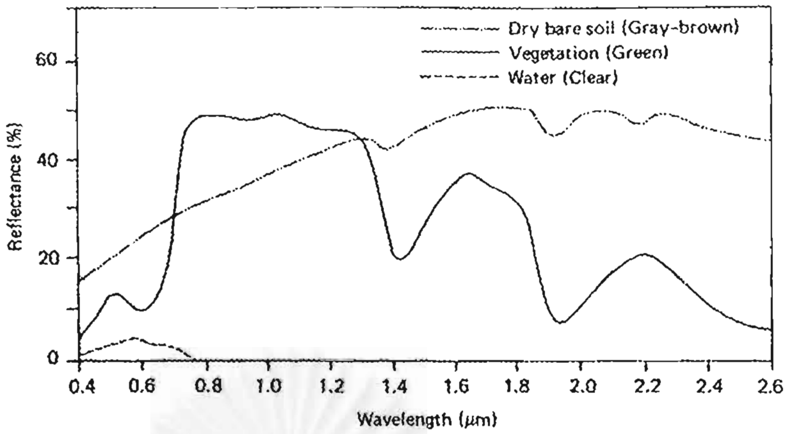


Figure 2.1: Typical spectral reflectance curves for vegetation, soil, and water (Lillesand and Kiefer, 2000)

2.2.2 Data Analysis

The detection of electromagnetic energy can be performed either photographically or electronically. Therefore, the data interpretation can involve analysis of pictorial (image) and/or digital data. Visual interpretation techniques use the excellent ability of the human mind to qualitatively evaluate spatial patterns in an image. The spectral characteristics are not always fully evaluated in visual interpretation efforts. Thus, in applications where spectral patterns are highly informative, it is therefore preferable to analyze digital image data rather than pictorial image data. The use of computer-assisted techniques permits more fully examine of the spectral patterns in remote sensing data.

Digital Image Processing

Digital image processing is the use of computer-assisted techniques to manipulate and interpret the digital images (Lillesand and Kiefer, 2000). Basically, there are three stages of digital image processing procedure involved: image pre-processing, image enhancement, and image analysis and classification.

1) Image pre-processing (or image rectification and restoration)

The intent of image rectification and restoration is to correct image data for distortions or degradations from the image acquisition process. The procedures vary considerably with such factors as the digital image acquisition type, platform, and total field of view. This step involves the geometric correction, radiometric correction and noise removal.

2) Image enhancement

Image enhancement involves techniques for increasing the visual distinctions between features in a scene, in order to more effectively display or record the data for subsequent visual interpretation. There are several techniques such as contrast stretching, spatial filtering, principal component analysis, band combination, etc (Rajan, 1991).

3) Image classification

These operations are the quantitative techniques for identification of feature in a scene and for categorization of all pixel into one of several land cover classes or themes, base on statistically decision rules. The decision rules are based solely on spectral, spatial, and temporal characteristics (Lillesand and Kiefer, 2000). The spectral pattern present within each pixel is used as the numerical basis for categorization.

Two types of methods use in image classification are supervised classification and unsupervised classification. In supervised classification, a representative sample (called training area) is selected and its spectral signatures are analyzed. Then, each pixel in the image data set is categorized into land cover class it most closely resembles. The different supervised classification schemes are minimum distance to means classifier, parallelepiped classifier, and maximum likelihood classifier (Rajan, 1991; Lillesand and Kiefer, 2000).

Unsupervised classification does not utilize training data as supervised classification. These classifier involved algorithms that examine the unknown pixels in an image and aggregate them into a number of classes based on the natural groupings or clusters present in the image values. The analysts must compare the classified data with some form of reference data, such as, larger scale imaqery, maps or field data, to determine the identity and informational value of the spectral classes (Lillesand and Kiefer, 2000).

2.2.3 Landsat Data

Landsat satellites have provided repetitive, synoptic, global coverage of high-resolution mutispectral imagery. Landsat thematic mapper (TM) data are available in seven narrow bands. The wavebands recorded by the TM and their application are show in Table 2.1. Data from each of the seven band of TM can be viewed separately as black and white image. The color composite image can be obtained by combining single- band (assigning one color per band) in computer. The commonly used band combination and their applications are described by EOSAT as shown in Table 2.2.

Landsat TM data are composed of line formed by adjacent pixels, each pixel cover a ground surface of 30 x 30 meter, 120 x 120 meter in thermal infrared band. A complete scene consists of 5,760 lines with a maximum of 6,920 pixels on a line and covers an area of 185 x 170 kilometer (Rajan, 1991).

Table 2.1: Thematic Mapper spectral bands

Band	Wavelength (μm)	Nominal Spectral Location	Principal Applications
1	0.45-0.525	Blue	Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest type mapping, and cultural feature identification.
2	0.52-0.60	Green	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63-0.69	Red	Designed to sense in a chlorophyll absorption region aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76-0.90	Near infrared	Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55-1.75	Mid-infrared	Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from clouds.
6	10.4-12.5	Thermal infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7	2.08-2.35	Mid-infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

Band 6 and 7 are out of wavelength sequence because band 7 was added to the TM late in the original system design process (Lillesand and Kiefer, 2000).

Table 2.2: Examples of Landsat TM band combinations

Band Combinations (R,G,B)	Typical Applications
3, 2, 1	Penetrates shallow water and shows submerged shelf, water turbidity
4, 5, 3	Shows land/water boundaries and highlights subtle details not readily apparent in the visible bands alone. Vegetation type and condition are shown as variations in hues (green, browns, and oranges) as well as in tone. Shows moisture differences. The wetter the soil, the darker it appears.
4, 3, 2	Senses peak chlorophyll reflection as red. The resulting red hues are easily discriminated by the human eye. Generally, deep red hues indicate broad leaf and healthy vegetation. Lighter reds indicate grasslands. Densely populated urban areas are shown in light blue. Water boundaries are defined clearer in the 3, 2, 1 combination.
7, 4, 2	Retains the benefits of the infrared bands and yet presents vegetation in familiar green tones. Moisture content in both vegetation and oils is discriminated.

Source: EOSAT.cite in Rajan (1991)

2.3 Remote Sensing for Coastal Erosion Study

Remote sensing has played an important role in coastal studies because it helps to speed up the research process.

Mapping of historical aerial photography coastline is a difficult task as a result of two typical problems. The first concerns data quality which varies greatly due to acquisition apparatus, methods, and storage conditions, such as object displacement, geometrical distortions, and low contrast. The second problem concerns coastal zone complexity and dynamics, due firstly to its wide range of components and their mixtures, and secondly to the fast rate of changes in their spatial distribution.

Coastline changing has been studied by comparison of aerial photographs taken from the same section at different dates.

Dolan, Hayden, and Heywood (1978) used historical aerial photographs as the data base for developing a common-scale mapping method in order to systematically measure shoreline erosion and storm surge penetration along extensive reaches of the United State Atlantic coast. Aerial photographs covering four decades were used to provide long-term baseline information on shoreline dynamics. The standard 1:5,000 scale base maps of the study region were prepared to interpret the aerial photographs. The aerial photographs were then enlarged to the exact scale of the base map by projection onto the base map. After that, the shoreline and active sand zone line (storm penetration line) were traced from the projection. This study was concluded that of the available types of historical data only aerial photographs provide a record with sufficient spatial and temporal detail for a national mapping program.

Hashim (1989) integrated the photogrammetric analysis of the 1966,1975, and 1980 aerial photographs with remotely sensed, Landsat Thematic Mapper and SPOT-1 multispectral, images to provide pertinent information on the trend of shoreline changes along the eastern coast of Peninsular Malaysia. For the aerial photographs, the normal high tide mark, viewed as the land/water interface, was located as the shoreline. Direct comparison with the shoreline determined from hydrographic records show that the shoreline obtained by the remote sensing/photogrammetric method show the same trend and magnitude of shoreline movement as the aerial photographs.

Shoshany *et al.* (1996) studied the utilization of digital image processing techniques for detecting long-term coastal changes indicative of sand transport direction, littoral drift, along the coastline of Israel by using the historical aerial photography for the years between 1951 and 1990. The image processing technique such as the enhancement of the shoreline appearance in scanned aerial photography, allowed an increased accuracy of the detection of coastal changes. The contributory result has been shown that the effect of coastal structures on the position of the shoreline is not limited to a few hundred meter from the structure, as was believed in the past, but to a distance of about 1.5 km.

Ly (1993) examined the applicability of remote sensing data for monitoring and predicting shoreline change in Rayong province, Thailand, without any sort of protective barrier. The study used TM data. Linear feature overlay method was used for quantitative data analysis. The temporal images comparison was used for qualitative data analysis. The result shown accretion and erosion area and accretion rate. The changes were mainly due to long time wave action, predominately by southwest waves from May to September, and construction of structures, such as jetties, breakwater etc. The study proved that remote sensing is a good potentials as tools for monitoring and predicting coastline changes and concluded that shoreline changes was mainly affected by new construction on the boundary of shoreline and wave action.

In order to achieve the accuracy necessary for determining long-term coastal changes, there are three key elements as follow:

1) Selection of the time of year which is most suitable for monitoring the shoreline, i.e. during the time that the sea is at its lowest wave energy regime.

2) Selection of the type of shoreline which is most suitable for monitoring the shoreline from aerial photography acquisition. High water line provides the most suitable shoreline due to its relatively clear and sharp representation in the low rate of momentary change.

3) A large number of previous works utilized aerial photography for detecting historical shoreline changes base mainly on human interpretation which lead to some level of subjectivity and inconsistency in the detection process. Application of digital image processing methods should reduce such problems.

2.4 Relations between Human Activities and Coastline Change

As noted by Coch and Ludman (1992), any shoreline experiences the dynamic processes of erosion and deposition. These natural geologic processes posed no problem until people began to live along shorelines.

Accelerating beach erosion has always led to engineering structures to prevent erosion. Although these structures do control erosion in one place, they frequently increase it in another. This is because structures built within the coastal zone disturb the longshore drift. This building alters the dynamic equilibrium along the coast by cutting off the sand supply needed to nourish beaches.

Dune elimination

Dunes are being destroyed by human activities, as people walk across vegetated dunes toward the beach, they kill the grass. The grass roots hold the sand in place and protect it from wind erosion, or deflation. Without the grass, wind eventually erodes shallow depressions called blowouts in the dunes. These depressions lower dune height and make it easier for a storm surge to breach the dunes and overwash the area behind them. Once a storm-surge channel is established, the dunes erode much faster because they now erode laterally from storm surges as well as vertically from the wind. Eventually, these dunes become reduced to a low sandy area.

Seawalls

The seawalls constructed parallel to the shore can prevent damage to coastal structures. These massive can protect a coastal segment for several years. However, a seawall eventually accelerates beach erosion. This occurs because incoming wave energy is reflected off the seawall rather than being dissipated across a wide area of beach. This reflected energy is directed downward in part, causing beach erosion in front of the seawall.

Groins

Walls of rock, concrete, or wood, called groins, commonly are built at right angles to the shoreline to trap sand and replenish a beach. The updrift beaches do indeed grow by net deposition. However, beaches downdrift of the groin are eroded, because the groin traps the longshore-drift sand that would have replenished them.

Jetties

Sediment transport along a coast is also disturbed by the construction of long walls called jetties on either side of tidal inlets. These structures prevent sand from filling the inlet. Such inlets are stabilized inlets. However, inlet stabilization by jetty construction cause beach erosion downdrift. The updrift jetty traps most of the sediment being carried along the beach. Sediment that can pass around the updrift jetty usually does not make it across the inlet to nourish the beaches on the downdrift side. Instead, most of the sediment is swept into the inlet by tidal currents and is deposited on tidal deltas in the bay.

The factors influencing the erosion regime in Phetchaburi and Prachuap Khiri Khan provinces include the geomorphology of the area, the degree of coastal erosion along the beaches, the area's climate and sediment supply, sea level, and human intervention. Human intervention is rapidly becoming the most significant factor influencing coastal erosion, as urbanization and its associated infrastructure have disrupted coastal processes and the sediment budget.

2.5 Logistic Regression

2.5.1 The Logistic Regression Model

Logistic regression is a technique for determining the relationship among one or more independent (predictor or covariate) variables, which can be continuous or noncontinuous, and the dichotomous dependent variable. That is, the dependent (predicted) variable has only two values, such as erosion or non-erosion. However, this technique can be extended to situations involving outcome variables with three or more categories (polytomous, or multinomial, dependent variables). The relationship between the predictors and the predicted values is assumed to be nonlinear. The logistic regression curve is generally S shaped, or sigmoidal. In logistic regression analysis for dichotomous dependent variable, one attempt to predict the probability that an observation belongs to each of two groups (Wright, 1995).

The assumptions of logistic regression are

First, the random variable of interest is a dichotomous variable taking the value 1 with probability P_1 and the value 0 with probability $P_0 = 1 - P_1$

Second, the outcomes must be statistically independent, a single case can be represented in the data set only once.

Third, the model must be correctly specified (Aldrich & Nelson, 1984 cited in Wright, 1995). The specificity assumption requires that the model contain all relevant predictors and no irrelevant predictors.

Fourth, the categories under analysis must be mutually exclusive and collectively exhaustive. In other words, a case cannot be in more than one of outcome category at a time, and every case must be a member of one of the categories under analysis.

Finally, to test hypotheses involving the logistic regression coefficients, large samples are required. For most application, a minimum of 50 cases per predictor variable is sufficient (Ibid.).

A logistic model yields a constant term (β_0) and a regression coefficient for the predictor variable (β_k). The predicted probability of any case of membership in the target group can be computed by using these coefficients and scores. Follow these steps.

1) Add the constant to the product of the regression coefficient and the predictor to obtain the quantity $\hat{y}$:

$$\hat{y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k$$

where β_0 is constant term

β_1 to β_k are partial regression coefficient

X_1 to X_k are the values of k different predictors

2) Insert $\hat{y}$ into the following equation:

$$e^{\hat{y}} / (1 + e^{\hat{y}})$$

The predicted probabilities from the logistic model can be used to compute predicted group memberships for each case. If the predicted probability for a case of cutoff value, generally be 0.50, the case is classified as a member of the target group. And if the predicted probability is less than the cutoff value, the case is classified as a member of the other group (Wright, 1995).

2.5.2 Inference for Logistic Regression Model

The methods of statistical inference for logistic regression model included the log-likelihood statistic and Wald statistic. The statistics based on the log-likelihood provides the most powerful test (Agresti and Finlay, 1997; Hosmer and Lemeshow, 1989; Hutcheson and Sofroniou, 1999).

The log-likelihood statistic provides a measure of the difference between the observed values and those predicted from the model, that is a measure of deviance for a model. This statistic is generally quoted as - two times the log-likelihood, -2LL.

The significance of the change in -2LL can be calculated using the chi-square distribution with degrees of freedom equal to the difference in the number of terms between two models.

A measure of the effect that all predictors in the model have on the dependent variable can be obtained by comparing the -2LL for a model with and without the predictor in the model. The smaller significant value (*p*-value) indicates the convincing evidence that the predictor is a significant variable in predicting the dependent variable or the better the model fit. This statistic is sometimes referred to as the model chi-square which is in common use in many statistical packages, such as SPSS.

The Wald statistic, a chi-square statistic with degrees of freedom equal to 1, tests for the hypothesis that the regression coefficient for the predictor is zero (H_0: $\beta = 0$). That is the predictor has no effect on the dependent variable. The Wald statistic is the square of z statistic, obtained by comparing of regression coefficient to an estimate of its standard error. A significant Wald statistic (i.e., small significant value) suggests that the predictor has an effect on the dependent variable.

2.5.3 Comparing Logistic Regression Models

The effect that individual or groups of variables have on the model fit can be determined by comparing -2LL for a model with a set of predictors to with -2LL for a simpler model having fewer predictors. That is an approximate chi-square statistic with degrees of freedom given by the difference in the number of terms between two models. The smaller significant value indicates the better fit for the complex model.

2.6 Study Area

Phetchaburi province is located between latitude 12° 32' to 13° 21' N and longitude 99° 6' to 100° 7' E in the southern part of the lower central region of

Thailand. This province covers the area of 6,225.138 square kilometer with about 82 kilometer of coastline.

Prachaub Kirikhan province is situated at latitude 12° 31' N and between longitude 99° 9' to 100° 1' E, the southernmost province of the lower central region. It has long range shape lie from the north to the south cover a total area of 6,357.62 square kilometer, with 17 islands and 224.8 kilometer of coastline.

Both provinces are bounded by hill on the west and the Gulf of Thailand on the east. The agricultural land uses are evenly splitted between rice paddy, field crops, and tree crops. The eastern area of Phetchaburi, where connecting to the sea, is manly used for shrimp culture and salt production.

The study area is located along the coastline of Phetchaburi and Prachuap Khiri Khan from Chaosamran beach to the north of Khao Takiap. There are a number of beautiful beaches and archaeological places that are appropriate for tourist activities, such as Cha-am beach, Hua Hin beach, and Marukkhathaiwan Palace. In addition, Prachuap Khiri Khan is a biggest center of tourist accommodations and services. Due to high potential for tourism of the study area, the tourist activities and facilities has been expanded higher than other areas.

Since, in the past, Phetchaburi had no land use planning, the land use was in a state of disorder especially in the coastal area. Examples for disordering are mangrove and public area invasion, and sea reclamation for resorts construction (Office of Environmental Policy and Planning (OEPP), 1998a).

Prapawadee Powtongchin (1995) studied the impact of tourism on land use in Phetchaburi province and found that tourism in Phetchaburi has given rise to land use expansion for tourist accommodations and real estate, such as condominium, housing and golf course, rapidly. The most impacted areas are the shorelines where expansion are concentrated.

Larger investment in real estate and tourism industries in Prachuap Khiri Khan has been increased since 1989 and lead to the coastal land use problem. Accordingly, land use patterns in the coastal area were degraded and changed by the construction of condominiums, resorts, bungalows, and other infrastructures invading beach areas (OEPP, 1998b).

CHAPTER 3

METHODOLOGY

3.1 Data Collection

The existing data related to the study were collected as follows:

1) Topographic maps at scale 1: 50,000 in L7017 series. The required sheet included map number 4934I, 4934II, 5034IV and 5035III prepared and published by the Royal Thai Survey Department.

2) Aerial photographs which were taken in 1954, 1991 and 1994 at scale 1:42,000, 1:40,000 and 1:50,000 respectively. The photos were taken by the Royal Thai Survey Department.

3) Radiometrically and system corrected Landsat-5 Thematic Mapper (TM) image in path 129 row 051 was acquired on 2 November 1991. The data was provided by the National Research Council of Thailand (NRCT) (Figure 3.1).

4) Data and summary statistics information of wave, current, and wind acquired from Phetchaburi and Hua Hin observatory buoys: The buoys are operated under the Sea Watch project of the National Research Council of Thailand (NRCT).

5) GIS information of the Specification of Environmental Conservation and Protected Area in Phetchaburi and Prachuap Khiri Khan Provinces Project. The data set was provided by the Office of Environmental Policy and Planning.

3.2 Software Use

PCI program version 6.1 was used for processing and analysis of aerial photographs and satellite data (PCI, 1997).

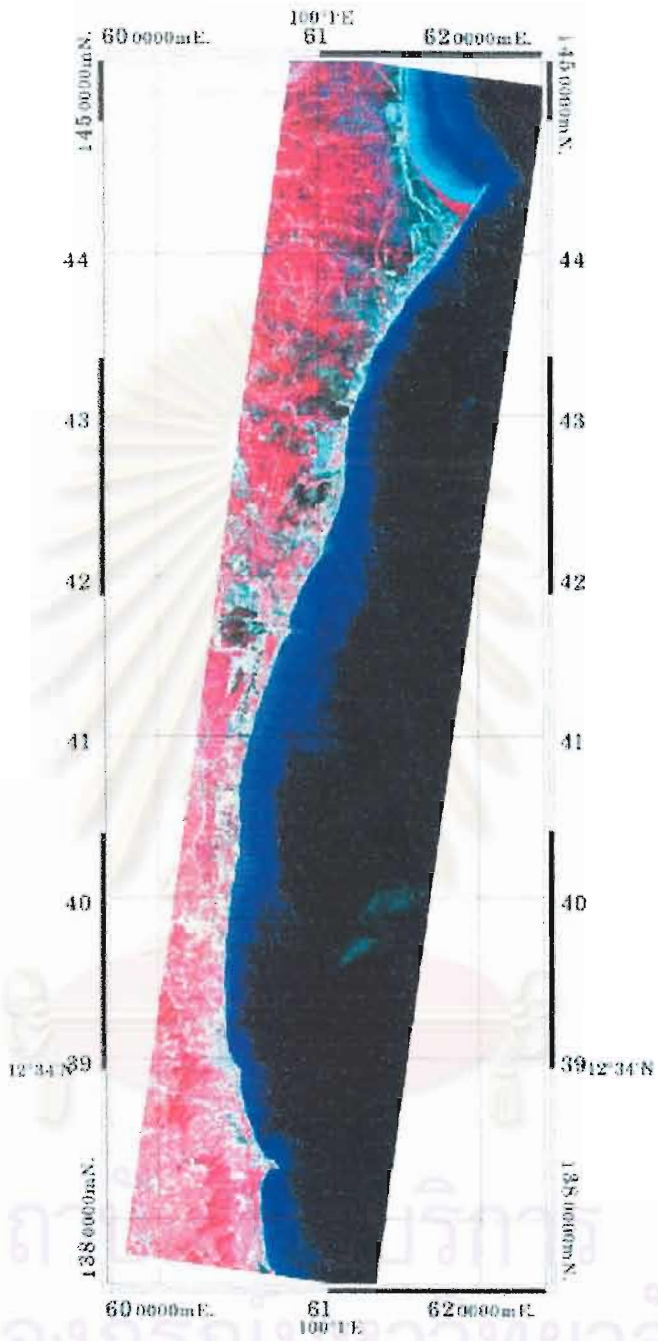
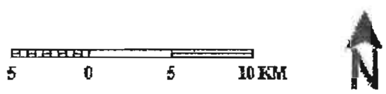


Figure 3.1: False color composite of Landsat-5 TM image showing the study area in 1991

Note: Landsat-5 TM image (4, 3, 2 : R, G, B) was acquired on 2 November 1991



ArcView GIS program version 3.1 was used for utilization of GIS data (Environmental System Research Institute (ESRI), 1996).

SPSS for Windows release 7.5.2 was used for logistic regression analysis (SPSS, 1996).

Adobe Photoshop was used for images presentation (Adobe System, 1998).

3.3 Methodology

This study used three sets of aerial photographs for the detection of shoreline changes and used Landsat-5 TM images in the classification of land use/land cover except for the year 1954, where the satellite data was not available and aerial photos have to be used. The results from this step were used to evaluate the relation between land use/land cover type and coastline change by using the logistic regression model. Work flow diagram of this study was showed in Figure 3.2.

3.3.1 Pre-processing

Image Rectification

Geometric Correction

Geometric correction process can be defined as the process of projecting data onto a plane and making it conform to a map projection system. For multitemporal images, it is necessary to adjust the image coordinates to be in accordance to the map in order to get accurate spatial references.

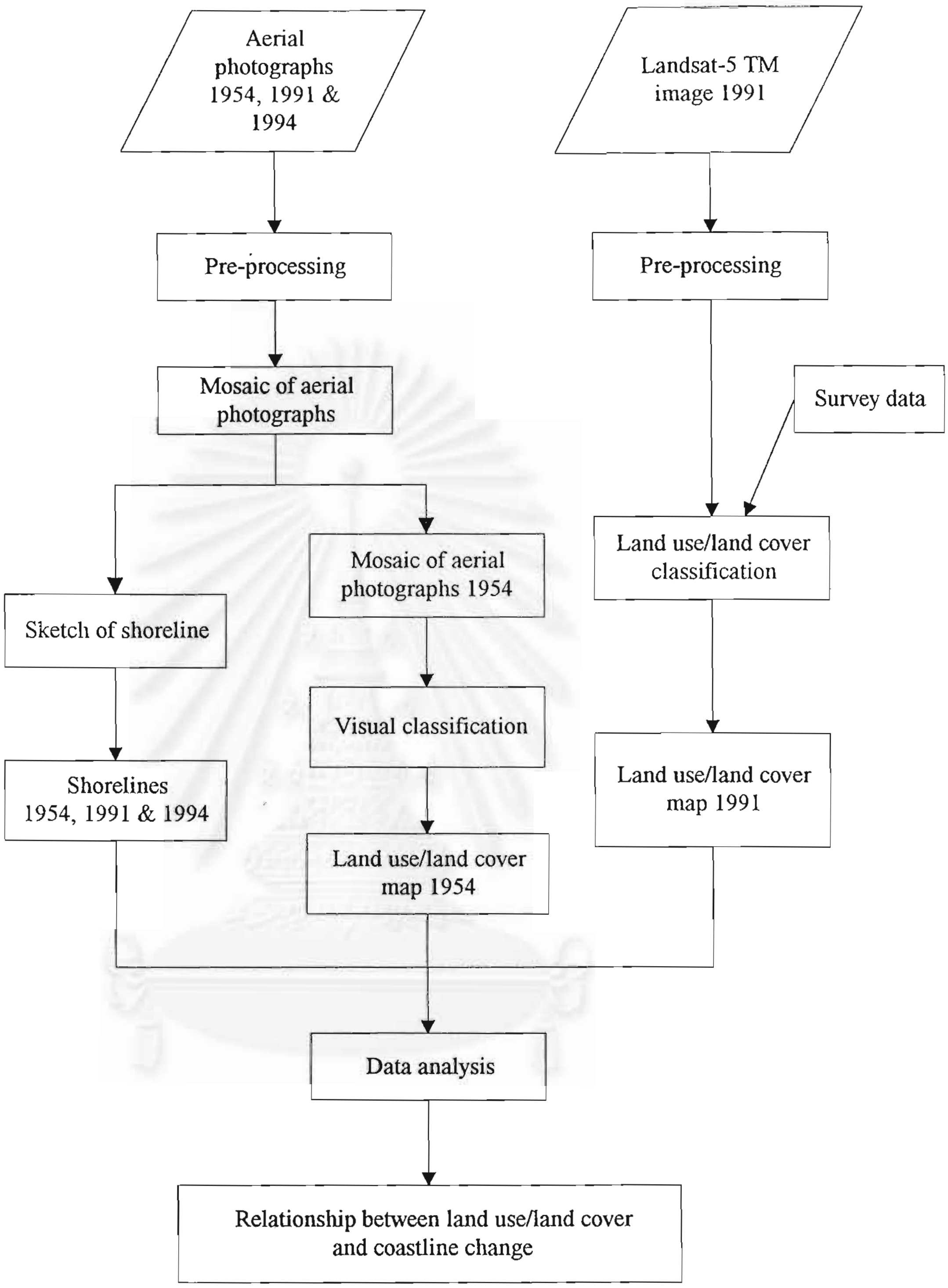


Figure 3.2: Work flow diagram for determining the relationship between land use/land cover and coastline change

Satellite image coordinates were corrected with the use of transformation matrix determined by using a set of ground control points (GCPs). A set of GCPs was collected from satellite image in pixel and line coordinate, then specified in the Universal Transverse Mercator (UTM) coordinate obtained from topographic map, at a scale of 1:50,000. The best GCPs are the points which are easy to be recognized and located on both the image and the topographic map and distribute evenly over the whole image. This study selected a number of GCPs from road intersections, road and railway intersections, and irrigation canals.

This study used the Nearest Neighbor technique, i.e., uses the value of the closest pixel as the resampling procedure to interpolate gray levels from pixel locations in the original distorted image and their relocation to the appropriate matrix coordinate location in the rectified image. The pixel size for every image was arranged to be 50 x 50 meter.

For aerial photographs, the geometric correction was done for a set of aerial photographs taken in 1994 based on topographic map. Then, image to image registration was done in order to register the aerial photographs in 1991 and 1954 with geocoded 1994 image. Since the best GCPs could not be located on the aerial photographs which were taken in 1954. In this case, less reliable GCPs were used at the expense of accuracy (e.g. a corner of paddy field which remained stable over the time span of the study). After correction of geometric distortion, aerial photographs were mosaicked to form a complete image cover the study area for each year. The mosaic of aerial photographs in years 1954, 1991, and 1994 were showed in Figures 3.3 to 3.5.

Image enhancement

Linear stretch technique was performed to improve the visible contrast of an image. Image pixels with close gray level values may now be displayed in sufficiently different gray levels.

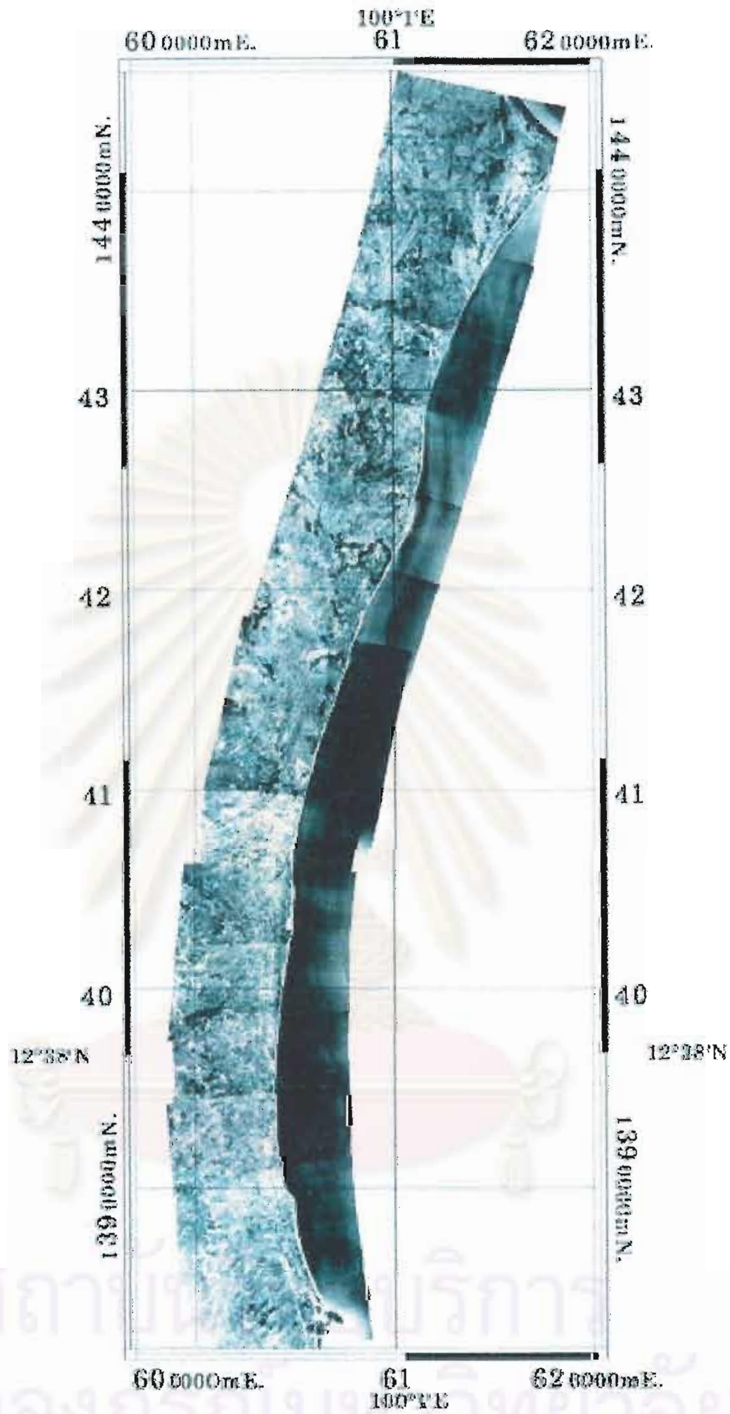
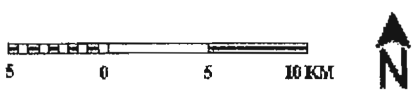


Figure 3.3: Mosaic of aerial photographs of the study area in 1954

Note: Aerial photographs were taken on 23 December 1954



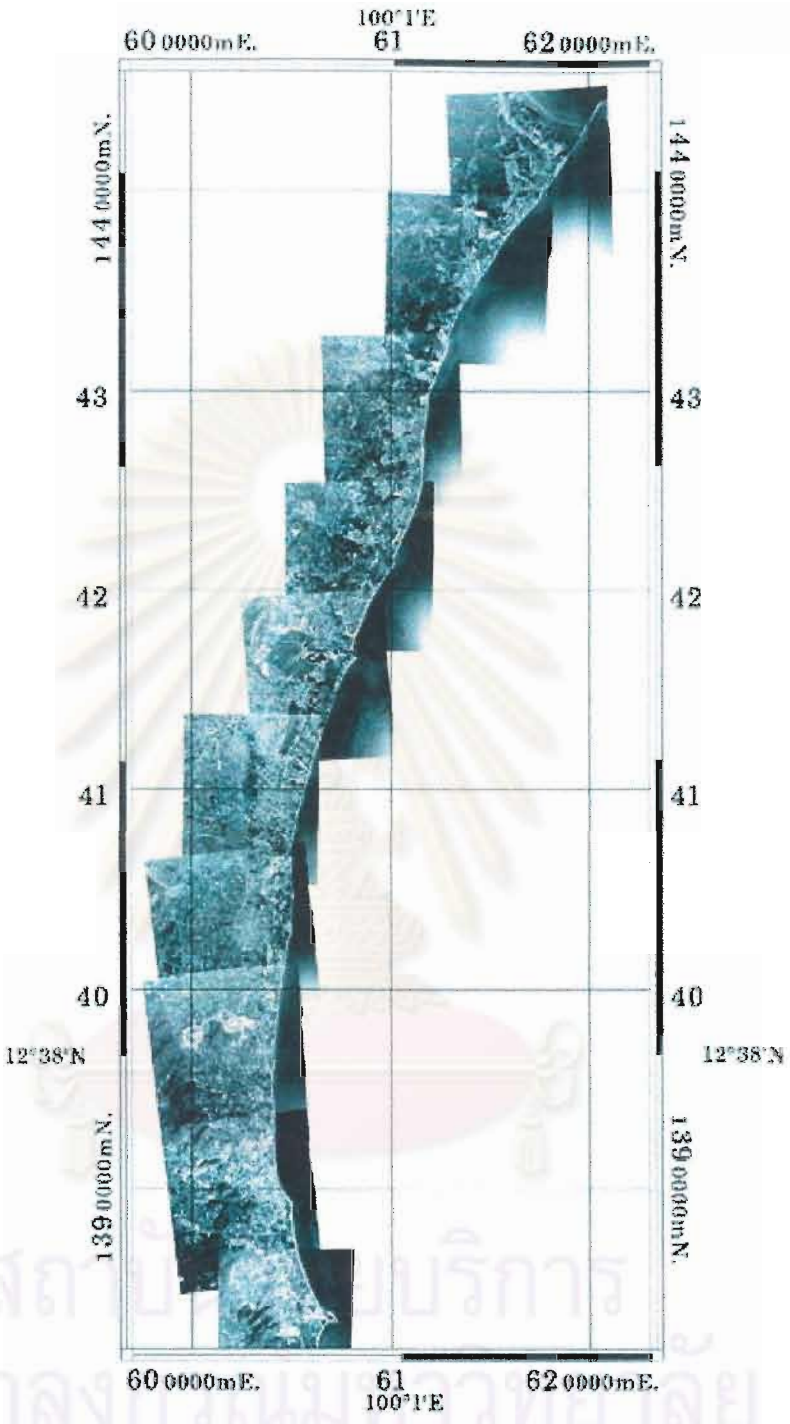
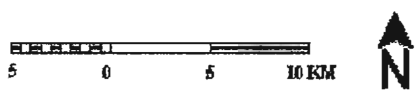


Figure 3.4: Mosaic of aerial photographs of the study area in 1991

Note: Aerial photographs were taken on 29-30 November 1991



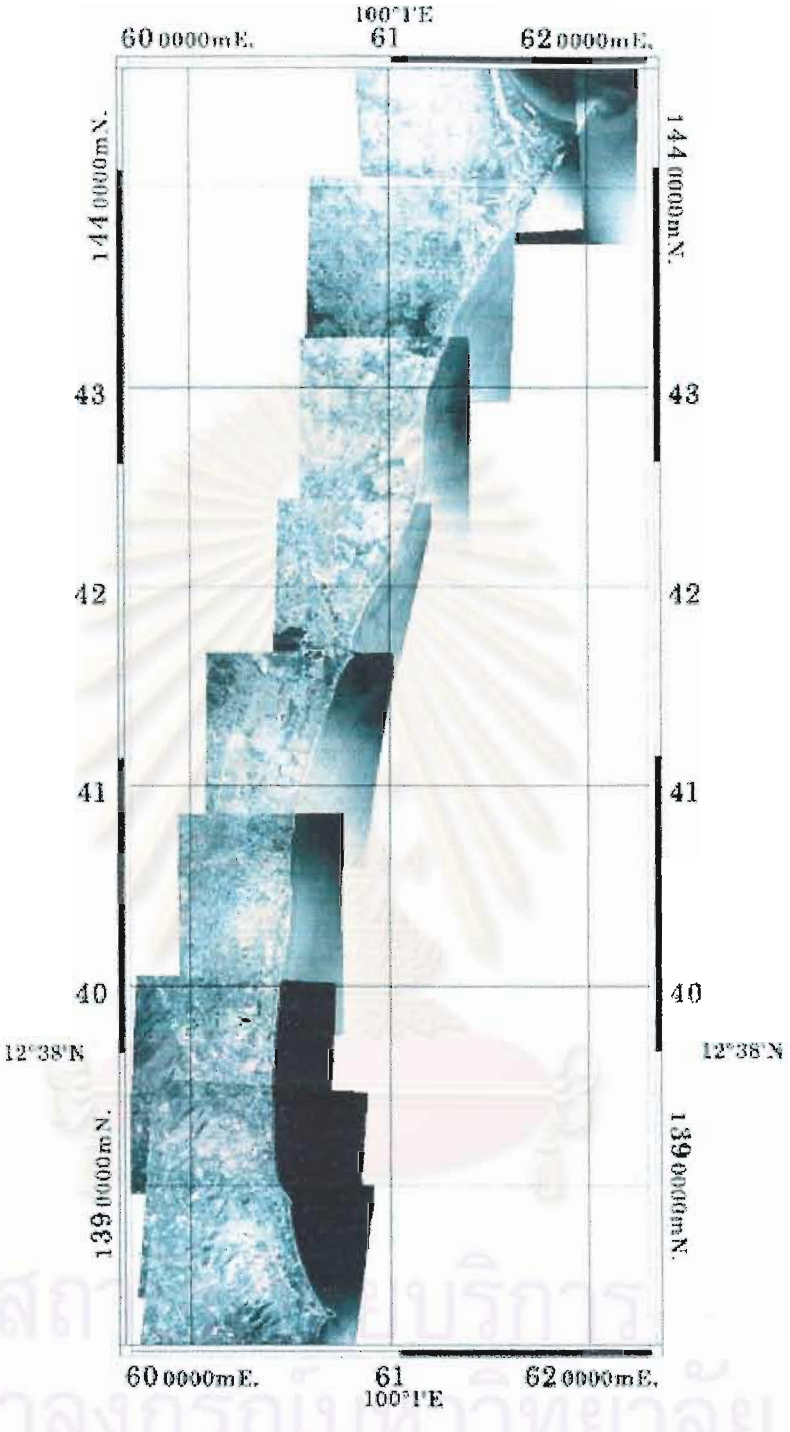


Figure 3.5: Mosaic of aerial photographs of the study area in 1994

Note: Aerial photographs were taken in December 1994

5 0 5 10 KM

N

3.3.2 Data Processing

3.3.2.1 Coastline Change Detection

PCI software was used to delineate shoreline position. All the shorelines from different years were digitized and stored in digital vector format. The land/water interface was identified as the shoreline. Shore profile was showed in Figure 3.6. The aerial photographs in years 1954 and 1994 were taken between 10:59 to 11:10 am and 9:28 to 11:52 am, respectively. The 1991 photos were taken in the morning but exact time can not be specified because the camera clock was out of order. Tide data at Ko Lak, Hua Hin, and Maha Chai station showed that all photos were taken during high tide. It should be noted that this identification might not represent the actual shoreline but the shoreline at the time of data acquisition. Tide at Ko Lak, Prachuap Khiri Khan province, is a mixed predominantly diurnal type. The mean tidal range, as calculated from data between 1940-1984, is 0.952 meter (Absornsuda Siripong, 1985). Since the area has low tidal range and all photos were taken during high tide, it was considered that changes of shoreline position according to the tidal effect are negligible.

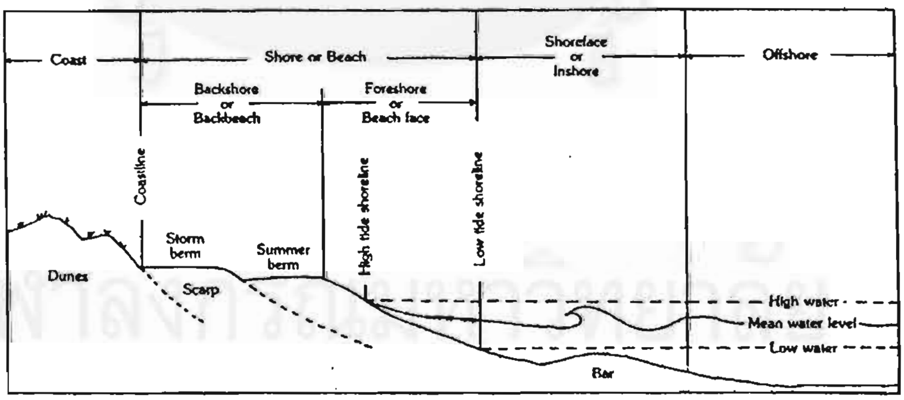


Figure 3.6: Shore profile (Snead and Rodman, 1982)

Each shoreline vector was then exported to a text file. Since each vector consist of list of vertices (x, y coordinates) which define line representing shoreline, thus the output file contained UTM coordinates. Then, each set of shoreline coordinates must be interpolated in order to fix the same y coordinate with 50 meter of interval by using Turbo Pascal program. At this step, the coastline changes can be detected by the comparison between each interpolated shoreline information, i.e. 1954 and 1991, 1954 and 1994, and 1991 and 1994.

3.2.2.2 Land Use/Land Cover Classification

For satellite image, the supervised classification procedure was used to categorize all pixels on image into land use/land cover classes. The classification divided into two stages.

1) Training stage

Satellite image, false color composite, was displayed for classes identification assistance. The most alike color pixels were grouped to be the representative training areas. After that, the training areas were used to train the computer to recognize the spectral signature of each image pixel as belonging to one of a number of learned signatures.

2) Classification stage

Each pixel in the satellite image data set was compared to each training area signature. This comparison was done numerically using any one of a number of different strategies to decide which training area signature the image data set pixel most closely resembles. Maximum likelihood classifier was used as mathematical decision rules to categorize each pixel on the image.

The visual interpretation was used for aerial photograph classifying. Image characteristic such as tone, texture, and pattern were translated into land use/land cover attributes. Polygons were drawn around features (e.g. vegetation, built-up area, beach area, etc) and a label was assigned to each polygon. Then, a layer of polygons was converted to be a raster image.

Land use/land cover classification can be categorized into 14 primary classes as shown in Table 3.1. Typical areas for land use/land cover categories were showed in Figure 3.7.

Table 3.1: Land use/land cover classification result.

Class	Symbol	Definition
Mangrove	MG	Mangrove area
Built-up area	BU	Residential, commercial, industrial, and transportation facilities
Beach	BE	Beach, sandy area other than beach
Inland water	IW	Stream, canal, aquaculture pond, and salt farming
Paddy Field	PF	Cultivation area
Vegetation: well develop	VW	Well developed plants i.e. natural vegetation or orchard
Flood plain	FP	Non-forested wetland
Vegetation : sparseness	VS	Predominantly shrubs and crop land
Bare soil	BS	Range land, transition areas, bare expose rock
High density built-up area	HB	High density built-up area with structures adjacent to or trespass into the sea
Mud flat	MF	Mud flat area
Sea	SE	Sea
Cloud and its shade *	CL	Area covered by cloud and it's shade
Hill	HI	Hill

** Remark: This class was not appeared in 1954 image.*

Each classified image was exported to text file. After that, these text files were imported into Visual Basic program where the five pixels landward from the sea were selected. Each pixel was representing one land use/land cover type within the area of 50x50 square meter. These selected pixels were used as the independent variables for the next step of the study.

Paddy field (Cha-am)

Sparseness vegetation (Cha-am)

Inland water (salt farming in Laem Pak Bia)

High density built-up area
(north of Khao Takiap)

Mangrove area (Laem Luang)

Bare soil (Puk Tian)

Figure 3.7: Typical areas for land use/land cover categories (November 1999)

3.3.2.3 Relationship between Land Use/Land Cover and Coastline Change

Because this study focused on the land use/land cover types which are potentially affecting the coastline change, there were ten land use/land cover types used to evaluate their relation with the coastline change. Sea, mud flat, hill, and cloud were excluded.

The relationship between land use/land cover and coastline change was identified by using of logistic regression to estimate the probability of erosion for each type of land use/land cover. The predictor variable (called covariate) was land use/land cover type. It was treated as categorical covariate. The indicator contrast method, which indicates the presence or absence of category membership and reference category is represented in the contrast matrix as a row of zero (SPSS, 1996), was used. That is, the presence and absence of each land use/land cover type has code 1 and 0 respectively. The categorical covariate is also called dummy code variable. The dependent variable was coastline change which has only two values, erode (code 1) or non-erode (code 0). It was a qualitative dichotomous variable.

There are two major approaches for determining the relationships between land use/land cover and coastline change. The first one, which from now will call hypothesis I, states that coastline change at any shore segment is depend on the type of land use/land cover at that shore segment. Another, called hypothesis II hereafter, states that coastline change at any coastal segment is depend on the adjacent land use/land cover as well as the updrift segments. The arrangement of shoreline segment for hypothesis II was illustrated in Figure 3.8. For this study, each hypothesis composed of three cases, that is, there were six cases as described in Table 3.2.

In general, the classification cutoff value (threshold) is 0.5. This value allows the user to determine the cut point for classifying cases. Cases with predicted values that exceed the classification cutoff are classified as positive, while those with predicted values smaller than the cutoff value are classified as negative. This value can be entered between 0.01 and 0.99 (SPSS, 1996). This study selected the classification cutoff value at 0.4 because it gave the highest overall accuracy for almost cases. Figure 3.9 showed graph of overall accuracy of each case when varied the classification cutoff value.

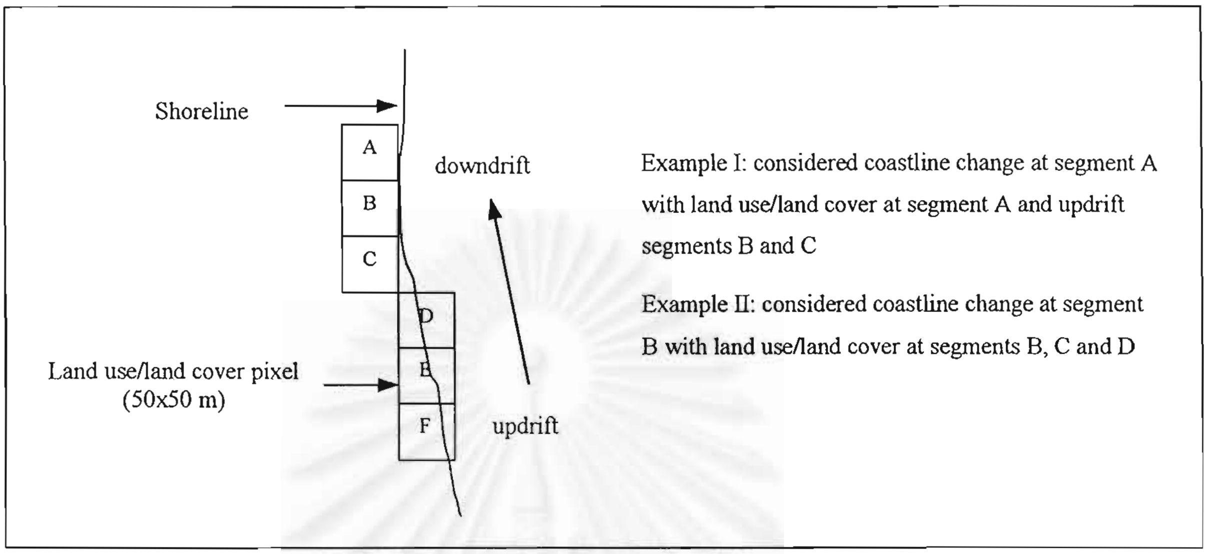


Figure 3.8: Segment arrangement for the study of relationship between land use/land cover and coastline change for hypothesis II

Table 3.2: Description of case study for determining the relationship between land use/land cover and coastline change

Hypothesis	Case	Year of land use/land cover classification	Year of coastline change detection
I (one to one pixel at the same coastal segment)	1A	1954	1954 – 1991
	1B	1954	1954 – 1994
	1C	1991	1991 - 1994
II (one to three pixels at the same and updrift coastal segments)	2A	1954	1954 – 1991
	2B	1954	1954 – 1994
	2C	1991	1991 - 1994

The log-likelihood statistic has been tested for significance of the model. The contribution made by all as well as individual and groups of predictor can be determined. There are two comparisons of the model including 1) between the model with and without the predictor, and 2) between the complex model (hypothesis II) and the simpler model (hypothesis I).

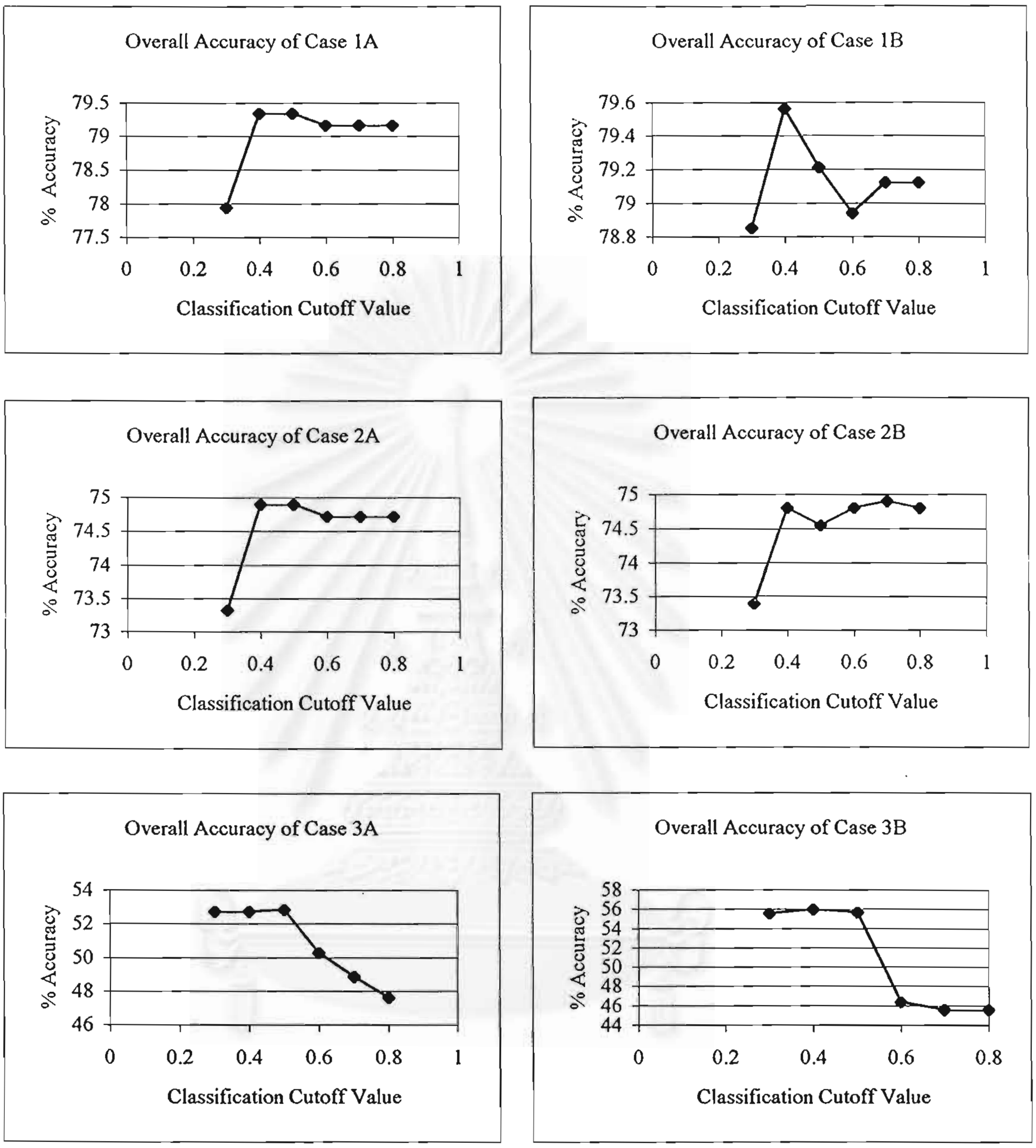


Figure 3.9: Overall accuracy of each case study varied by cutoff value

CHAPTER 4

RESULTS AND DISCUSSIONS

This study was distinct the results into three aspects according to the procedures of the study including coastline change detection, land use/land cover classification, and relationship between land use/land cover and coastline change. Results of the study will be elaborated and discussed in this chapter.

4.1 Coastline Change Detection

The original study had planned to use the temporal shoreline differences to detect changes of the coast. However, coastline changes were difficult to assess accurately because of three main reasons.

Firstly, it was difficult to located control points distributing over the whole 1954 image. Thus, the processed image still has some distortion. It can be noticed by the incompletely overlay of the road vectors in images from different year.

Secondly, due to the scale of aerial photographs, resolution of scanned photos, and tidal conditions when the photos were taken, the boundary line between land and sea cannot be certainly identified.

Finally, the effective areas were not delineated because these areas were too small to locate control points. Thus, the images may still have the effect of topographic displacement.

Therefore, for each mosaic of image, road vectors of Phetch Kasem highway were detected and set as offset for each pixel having the same *y* coordinate. And then the offsets were used to calibrate shoreline positions.

The coastline changes detected from three dated aerial photographs were illustrated in Figure 4.1. As mentioned in section 3.3.2, the coastline changes were detected from aerial photographs between years 1954 and 1991, 1954 and 1994, and 1991 and 1994. Therefore, there are three charts showing in this figure including (a) coastline change between 1954 and 1991, (b) coastline change between 1954 and 1994, and (c) coastline change between 1991 and 1994.

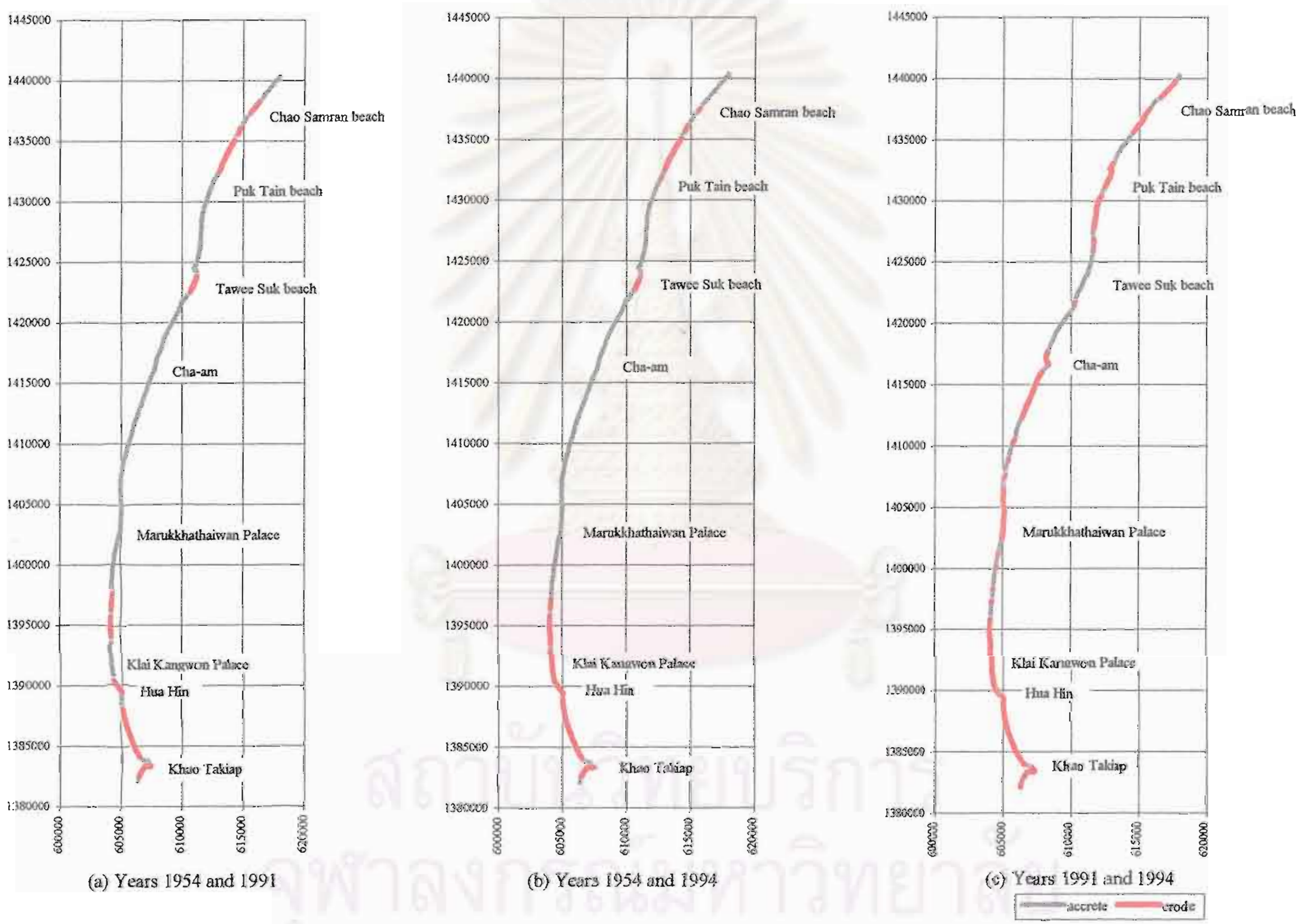
From chart (a), almost the whole coastline was accreted. The eroded coastlines were located between Chao Samran beach and Puk Tian beach, Tawee Suk beach, and north and south of Hua Hin airport and Khao Takiap. The severest erosion occurred at Ban Hat Chao Samran, south of Chao Samran beach.

In chart (b), the eroded coastlines were similar to chart (a). In addition, the eroded beaches in front of Klai Kangwon Palace and Hua Hin were included. Ban Hat Chao Samran was the area with the most erosion.

There were many areas of erosion presented in chart (c), such as north and south of Chao Samran beach, Puk Tian beach, Cha-am beach, beaches in front of Marukkhathaiwan and Klai Kangwon Palace, and beaches from Hua Hin to north of Khao Takiap. The severest erosive coastline was located at south of Puk Tian canal.

When considered the coastline change between years 1954 to 1991 and years 1954 to 1994, almost the whole coastline along the study area was accreting. Whereas the most of coastline change from 1991 to 1994 was eroding. The different pattern of these changes suggested that the coastline change in long-term (accretion) was stronger than the change which occurred in short-term (erosion).

The most of patterns of coastline change detected from 1954 to 1991 is inconsistent with the report of Vongvisessomjai *et al.* (1989), which detected the change from 1954 to 1988. The most likely reason for the difference is the errors in the shoreline positions as discussed in the previous page.



(a) Years 1954 and 1991 (b) Years 1954 and 1994 (c) Years 1991 and 1994

Figure 4.1: Coastline changes as detected from aerial photographs

However, the coastline change between years 1991 and 1994 was consistent with the earlier report investigated by Vongvisessomjai *et al.* (1997).

4.2 Land Use/Land Cover Classification

Classified images showing land use/land cover classes of the study in 1954 and 1991 were illustrated in Figures 4.2 and 4.3 respectively.

In 1954, major land use/land cover types were sparse vegetation, paddy field and flood plain. There were small patches of other land use/land cover scattering over the study area.

The 1991 image showed that built-up area (both high and normal density) were located along the road and coastline such as at Cha-am and Hua Hin beaches. In the landward areas next to the coastal zone, there are various types of land use/land cover, including paddy field, flood plain, vegetation, and bare soil.

4.2.1 Classification Accuracy Assessment

The classified images were compared with aerial photographs, which were taken in the same year as the image, to evaluate the accuracy of the classification. Field survey for ground truthing was not carried out due to the fact that the satellite images were too outdated. The 300 ground control points were randomly selected all over the study area.

Overall accuracy is the accuracy of total number of correctly classified pixels, defined as:

$$\text{Overall accuracy} = \sum_{i=1}^{k} x_{ii} / N$$

Producer's accuracy is measure of omission error and indicates the probability that a location on the ground is correctly categorized on the map. It defined as:

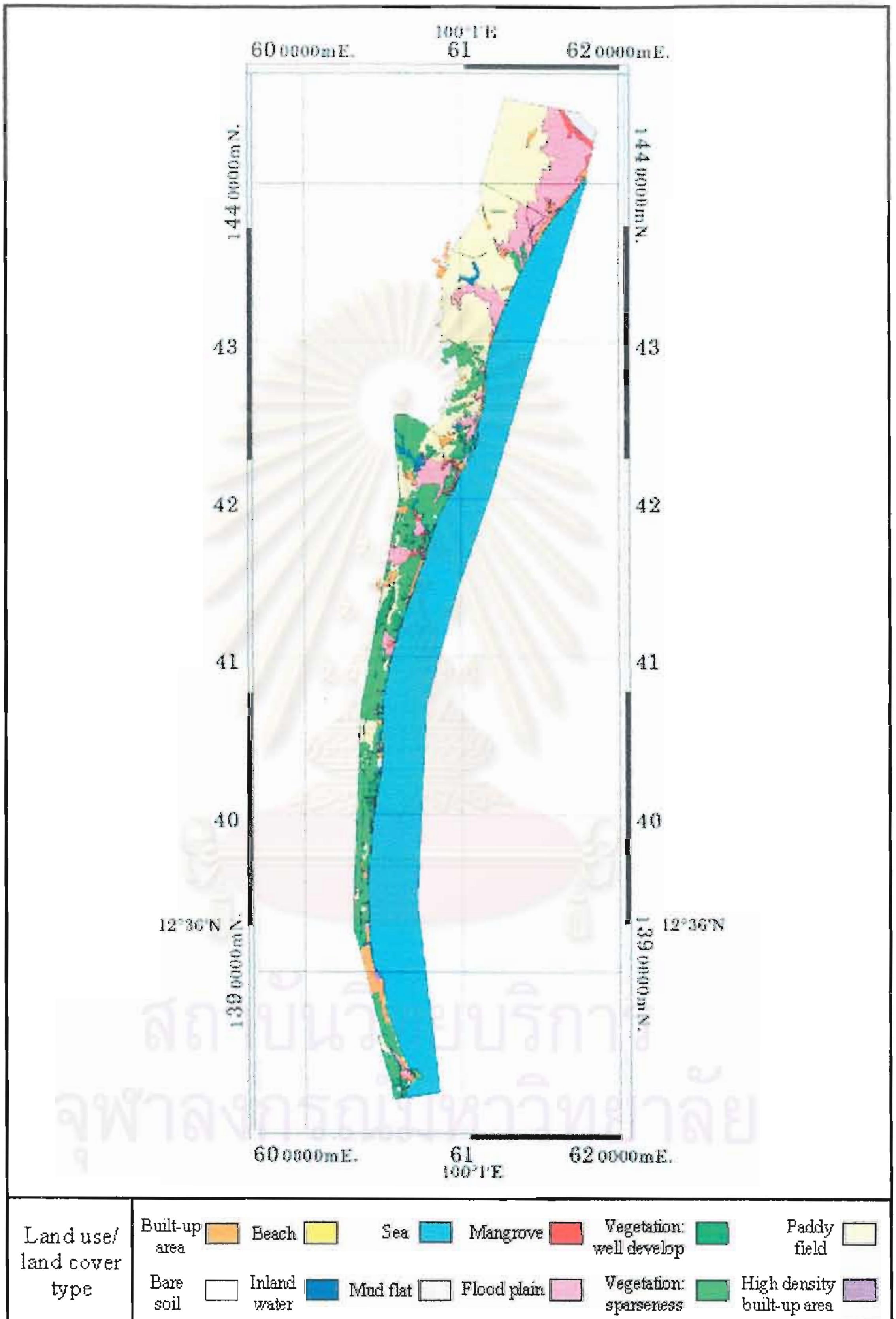
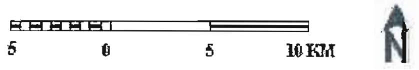
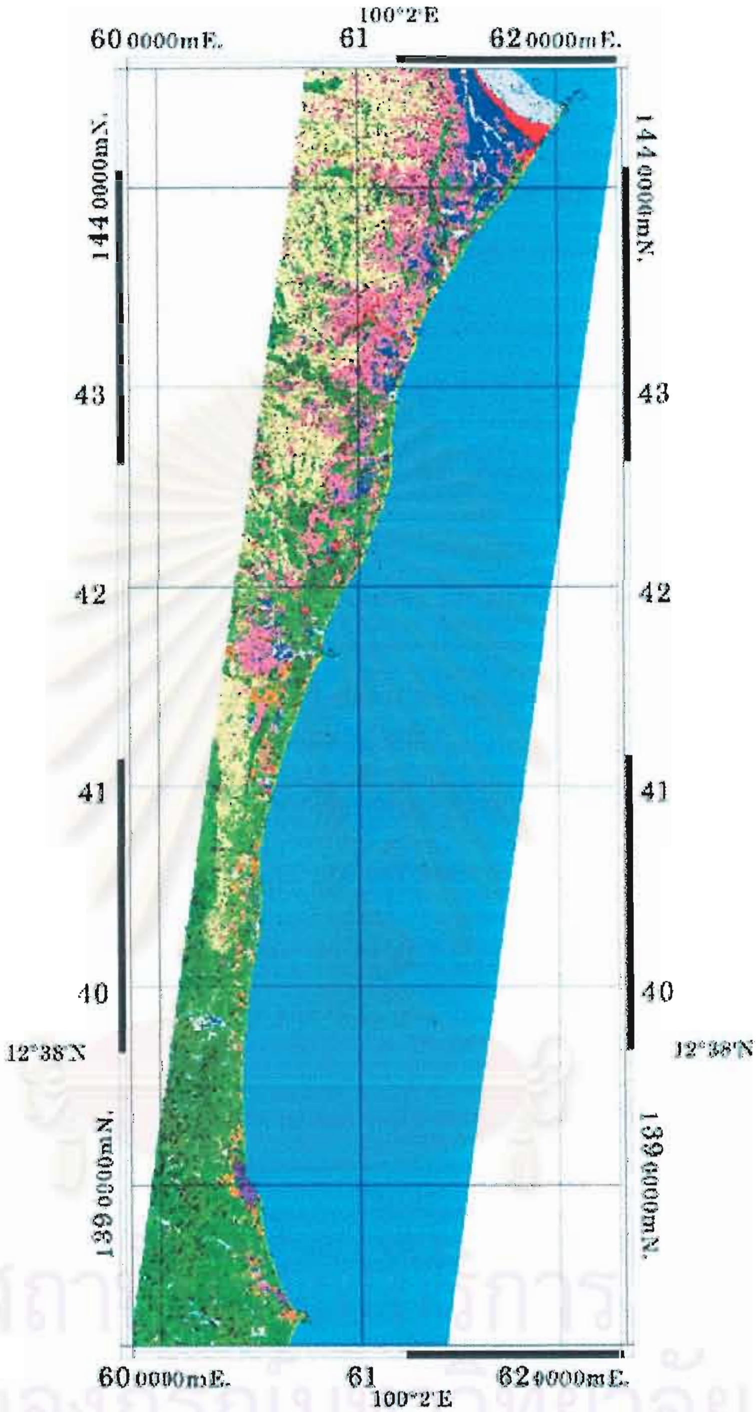


Figure 4.2: Land use/land cover classified from aerial photograph taken in 1954

Note: Aerial photograph taken on 23 December 1954





Land use/ land cover type						
	Built-up area	Beach	Sea	Mangrove	Vegetation: well develop	Paddy field
	Bare soil	Inland water	Mud flat	Flood plain	Vegetation: sparseness	High density built-up area

Figure 4.3: Pseudo-color image showing land use/land cover in 1991

Note: Landsat TM image acquired on 2 November 1991	5 0 5 10 KM N

$$\text{Producer's accuracy for class i} = x_{jj} / \sum_{i=1}^{k} x_{ij}$$

User's accuracy is measure of commission error and indicates the probability that a pixel classified into a given category actually represents that category on the ground. It defined as:

$$\text{User's accuracy for class i} = x_{ii} / \sum_{j=1}^{k} x_{ij}$$

where x_{ij} is a value of the contingency matrix for an element in column i row j

k is the number of classes

N is the total number of sampling cells

i is class i^{th} as classified by classified image

j is class j^{th} as classified by ground truth

Error matrix of the classified result and classification accuracy for 1991 and 1994 are summarized in Tables 4.1 and 4.2.

Table 4.1: Error (confusion) matrix of the 1991 classified image

Reference data	Classified data											
	HB	BU	BE	BS	MG	VW	VS	PF	FP	IW	HI	Total
HB	4	0	0	0	0	0	0	0	0	0	0	4
BU	0	45	1	5	0	1	10	2	0	1	0	65
BE	0	2	11	1	0	0	0	0	0	0	0	14
BS	0	13	2	17	0	0	0	0	0	0	0	32
MG	0	0	0	0	4	0	1	0	1	0	0	6
VW	0	0	0	0	1	23	2	6	2	0	0	34
VS	0	2	0	0	0	11	36	5	1	0	0	55
PF	0	0	0	0	0	1	2	28	0	0	0	31
FP	0	1	0	0	0	0	0	0	30	1	0	32
IW	0	1	0	0	0	0	0	0	10	13	0	24
HI	0	0	0	0	0	0	0	0	0	0	3	3
Total	4	64	14	23	5	36	51	41	44	15	3	300

Table 4.2: Classification accuracy assessment 1991 using ground truth data as the reference data

Class name	User's accuracy		Producer's accuracy	
	Ratio	%	Ratio	%
1. High density built-up area (HB)	4/4	100.00	4/4	100.00
2. Built-up area (BU)	45/64	70.31	45/65	69.23
3. Beach (BE)	11/14	78.57	11/14	78.57
4. Bare soil (BS)	17/23	73.91	17/32	53.13
5. Mangrove (MG)	4/5	80.00	4/6	66.67
6. Vegetation: well develop (VW)	23/36	63.89	23/34	67.65
7. Vegetation: sparseness (VS)	36/51	70.59	36/55	65.45
8. Paddy field (PF)	28/41	68.29	28/31	90.32
9. Flood plain (FP)	30/44	68.18	30/32	93.75
10. Inland water (IW)	13/15	86.67	13/24	54.17
14. Hill (HI)	3/3	100.00	3/3	100.00

Overall Accuracy : 71.33 %

4.3 Relationship between Land Use/Land Cover and Coastline Change

From the relationship analyzed by logistic regression, the probability of erosion and predicted group of each land use/land cover type in each case can be obtained follow these steps.

First, calculate $\hat{y}$ from this equation

$$\hat{y} = \beta_0 + \beta_1 (HB) + \beta_2 (BU) + \beta_3 (BE) + \beta_4 (BS) + \beta_5 (VW) + \beta_6 (VS) + \beta_7 (PF) + \beta_8 (FP) + \beta_9 (IW)$$

Where β_0 = constant term

β_1 = regression coefficient of HB

β_2 = regression coefficient of BU

β_3 = regression coefficient of BE

β_4 = regression coefficient of BS

β_5 = regression coefficient of VW

β_6 = regression coefficient of VS

β_7 = regression coefficient of PF

β_8 = regression coefficient of FP

β_9 = regression coefficient of IW

Then, the predicted probability of erosion is

$$e^{\hat{y}} / (1 + e^{\hat{y}})$$

Results of the model include predicted probability of erosion, predicted group (erode and non-erode), and results of logistic regression analysis.

The log-likelihood statistic, base on the difference of the -2LL for the two models, was tested for determining the significance of land use/land cover in predicting the coastline change between the model with and without the predictor (called model chi-square) (see section 2.5.2).

The Wald statistic, a chi-square statistic with degrees of freedom equal to 1, was considered for significant testing of the partial effects of land use/land cover on coastline change. A significant Wald statistic (i.e., small significant value) suggests that a land use/land cover has an effect on coastline change.

Hypothesis I: considered that coastline change at any shore segment is depend on the type of land use/land cover at that shore segment by used one pixel at the same coastal segment in a line of land use/land cover closest to the sea.

Case 1A: Relation between land use/land cover type in 1954 and coastline change from 1945 to 1991

The results of case 1A were showed in Tables 4.3 and 4.4. From Table 4.3, most of the land use/land cover types are classified into non-erode group because their probability of erosion are less than 0.40 (cutoff value = 0.40), except paddy field and high density built-up area. While high density built-up area has the highest probability of erosion, mangrove and bare soil has the lowest probability.

Table 4.3: Predicted probability of erosion and predicted group of case 1A

Land use/land cover in 1954	Predicted group	Probability of erosion
Mangrove (MG)	non-erode	0.00074
Beach (BE)	non-erode	0.22235
Built-up area (BU)	non-erode	0.14063
Inland water (IW)	non-erode	0.33333
Paddy field (PF)	erode	0.57143
Vegetation: well develop (VW)	non-erode	0.05556
Flood plain (FP)	non-erode	0.34694
Bare soil (BS)	non-erode	0.00074
Vegetation: sparseness (VS)	non-erode	0.13889
High density built-up area (HB)	erode	0.87500

Table 4.4: Results of logistic regression analysis of case 1A

Variable	β	S.E.	Wald statistic	*df*	*p*-value
Land use/land cover			31.6355	9	0.0002
BE	5.9497	13.8553	0.1844	1	0.6676
BU	5.3916	13.8597	0.1513	1	0.6973
IW	6.5086	13.9091	0.2190	1	0.6398
PF	7.4894	13.8655	0.2918	1	0.5891
TW	4.3685	13.8932	0.0989	1	0.7532
FP	6.5692	13.8583	0.2247	1	0.6355
BS	-1.2E-11	15.1774	0.0000	1	1.0000
VS	5.3772	13.8578	0.1506	1	0.6980
HB	9.1476	13.8962	0.4333	1	0.5104
Constant	-7.2017	13.8550	0.2702	1	0.6032

MG is a reference category

N = 1166

-2 Log Likelihood (-2LL) 1130.277

Model chi-square 59.594 (*df* = 9, *P* = 0.0000)

From the analysis (Table 4.4), the model chi-square is equal to 59.594 with *df* = 9; *P* = 0.0000. That is, the model containing nine types of land use/land cover is significantly better than the null model, the model without the predictor.

For each land use/land cover type, Wald statistic was less than 0.4333 with *p*-value greater than 0.5104. This means that no single type of land use/land cover is significantly related to the coastline change.

Case 1B: Relation between land use/land cover type in 1954 and coastline change between 1945 and 1994

The results of this case were showed in Tables 4.5 to 4.6. As showed in Table 4.5, while the most of land use/land cover types are classified into non-erode group, paddy field and high density built-up area are classified into erode group. High density built-up area has the highest probability of erosion but mangrove and bare soil have the lowest probability.

Table 4.5: Predicted probability of erosion and predicted group of case 1B

Land use/land cover in 1954	Predicted group	Probability of erosion
Mangrove (MG)	non-erode	0.00027
Beach (BE)	non-erode	0.26754
Built-up area (BU)	non-erode	0.29688
Inland water (IW)	non-erode	0.33333
Paddy field (PF)	erode	0.57143
Vegetation: well develop (VW)	non-erode	0.05556
Flood plain (FP)	non-erode	0.32653
Bare soil (BS)	non-erode	0.00027
Vegetation: sparseness (VS)	non-erode	0.18519
High density built-up area (HB)	erode	0.99973

From Table 4.6, the model chi-square is equal to 63.288 with *df* = 9; *P* = 0.0000. That is, the model containing nine types of land use/land cover is significantly better than the null model.

Table 4.6: Results of logistic regression analysis of case 1B

Variable	β	S.E.	Wald statistic	*df*	*p*-value
Land use/land cover			14.5579	9	0.1038
BE	7.1953	22.841	0.0992	1	0.7527
BU	7.3402	22.843	0.1033	1	0.7480
IW	7.5093	22.874	0.1078	1	0.7427
PF	8.4901	22.847	0.1381	1	0.7102
VW	5.3692	22.864	0.0551	1	0.8143
FP	7.4785	22.843	0.1072	1	0.7434
BS	3.14E-10	25.021	0.0000	1	1.0000
VS	6.7209	22.842	0.0866	1	0.7686
HB	16.4049	31.276	0.2751	1	0.5999
Constant	-8.2025	22.841	0.1290	1	0.7195

MG is a reference category

N = 1166

-2 Log Likelihood (-2LL) 1250.844

Model chi-square 63.288 ($df = 9$, $P = 0.0000$)

For each land use/land cover type, Wald statistic was less than 0.2751 with *p*-value greater than 0.5999. This means that no single type of land use/land cover is significantly related to the coastline change.

Case 1C: Relation between land use/land cover type in 1991 and coastline change between 1991 and 1994

The results of case 1C were showed in Tables 4.7 to 4.8. From Table 4.7, the predicted probability of nearly all types of land use/land cover are greater than 0.4. Hence, they are classified into erode group while bare soil is classified into non-erode group. This case has incomplete results because the lack of samples of well developed vegetation and paddy field.

From the analysis (Table 4.8), the model chi-square is equal to 9.699 with $df = 7$; $P = 0.2063$. That is, the model containing seven types of land use/land cover is quite significant more than the null model.

For each land use/land cover type, Wald statistic was less than 1.9924 with p-value more than 0.1581. This means that no single type of land use/land cover is significantly related to the coastline change at significant value greater than 0.1581.

Table 4.7: Predicted probability of erosion and predicted group of case 1C

Land use/land cover type in 1991	Predicted group	Probability of erosion
Mangrove (MG)	erode	0.74957
Beach (BE)	erode	0.51474
Built-up area (BU)	erode	0.61538
Inland water (IW)	erode	0.79850
Paddy field (PF) *	-	-
Vegetation: well develop (VW) *	-	-
Flood plain (FP)	erode	0.44444
Bare soil (BS)	non-erode	0.28586
Vegetation: sparseness (VS)	erode	0.66664
High density built-up area (HB)	erode	0.73307

* *Remark: No sample*

Table 4.8: Results of logistic regression analysis of case 1C

Variable	β	S.E.	Wald statistic	*df*	p-value
Land use/land cover			8.7114	7	0.2740
BE	-1.0374	1.1560	0.8053	1	0.3695
BU	-0.6263	1.1887	0.2776	1	0.5983
IW	0.2806	1.6046	0.0306	1	0.8612
FP	-1.3195	1.3348	0.9771	1	0.3229
BS	-2.0119	1.4253	1.9924	1	0.1581
VS	-0.4033	1.4428	0.0781	1	0.7798
HB	-0.0861	1.2933	0.0044	1	0.9469
Constant	1.0963	1.1540	0.9025	1	0.3421

MG is a reference category

N = 1224

-2 Log Likelihood (-2LL) 1346.518

Model chi-square 9.699 (df = 7, P = 0.2063)

The results of hypothesis I, which summarized in Table 4.9, indicate that the land use/land cover types which always classified coastlines into erode and non-erode group were high density built-up area and bare soil respectively. It can be noted that the result of case 1B is similar to the case 1A because both of them used the same land use/land cover data. In addition, from section 4.1, erosion and accretion of coastlines detected by using 1954 shoreline as base data gave the same trend of coastline change.

Table 4.9: Summary of predicted groups of each land use/land cover type resulting from the model of hypothesis I

Land use/land cover type	Predicted group		
	Case 1A (1954-1991)	Case 1B (1954-1994)	Case 1C (1991-1994)
Mangrove (MG)	non-erode	non-erode	erode
Beach (BE)	non-erode	non-erode	erode
Built-up area (BU)	non-erode	non-erode	erode
Inland water (IW)	non-erode	non-erode	erode
Paddy field (PF)	Erode	erode	-
Vegetation: well develop (VW)	non-erode	non-erode	-
Flood plain (FP)	non-erode	non-erode	erode
Bare soil (BS)	non-erode	non-erode	non-erode
Vegetation: sparseness (VS)	non-erode	non-erode	erode
High density built-up area (HB)	Erode	erode	erode

Hypothesis II: considered that coastline change at any coastal segment depend on land use/land cover of the nearby as well as the updrift segments (southern segments in this study). This study arbitrarily considered 150 meter of shore length (3 pixels) from a line of land use/land cover closest on the sea.

Case 2A: Relation between land use/land cover type in 1954 and coastline change between 1954 and 1991

Tables 4.10 to 4.11 showed the result of case 2A. From Table 4.10, there are 78 patterns of land use/land cover. The model gave a positive prediction (i.e., more than 50% accuracy) for 70 patterns, 10 and 60 patterns for erosion and non-erosion respectively. The other 8 patterns are negative prediction (i.e., less than or equal to 50% accuracy).

Table 4.10: Predicted probability of erosion and predicted group of case 2A

Land use/land cover			Change		Predicted	Probability
South	⟶	North	Erode	Non-erode	group	of erosion
MG	MG	BE		2	non-erode	0.00000
	BE	BE		5	non-erode	0.00016
BE	MG	MG		2	non-erode	0.00000
		BE		3	non-erode	0.00030
	BE	MG		5	non-erode	0.00016
		BE	156	477	non-erode	0.23321
		BU	5	23	non-erode	0.16315
		PF	3	3	erode	0.44964
		VW	1	7	non-erode	0.08627
		FP		12	non-erode	0.24720
		BS		12	non-erode	0.00038
		VS	3	20	non-erode	0.21140
	BU	BE	2	12	non-erode	0.19029
		BU	2	14	non-erode	0.13093
		HB	1		erode	0.59392
	IW	BE	1		non-erode	0.28425
		IW		1	non-erode	0.34240
	PF	BE	4	1	non-erode	0.38027
		PF		2	erode	0.62241
	VW	BE	1	2	non-erode	0.12462
		VW		4	non-erode	0.04232
		VS		1	non-erode	0.11149
	FP	BE		5	non-erode	0.24809
		FP		7	non-erode	0.26268
	BS	BE		2	non-erode	0.00148
		BS		8	non-erode	0.00000
		VS		2	non-erode	0.00131
	VS	BE		16	non-erode	0.19320
		FP		1	non-erode	0.20544
		VS	3	11	non-erode	0.17428
BU	BE	BE	5	19	non-erode	0.21336
		BU		3	non-erode	0.14811
	BU	BE	2	11	non-erode	0.17327
		BU	2	13	non-erode	0.11844
		PF	1		non-erode	0.36021
		VW		1	non-erode	0.06109
		VS		1	non-erode	0.15593
	PF	PF	1		erode	0.59514
	VW	BU		1	non-erode	0.07526
	VS	VS		1	non-erode	0.15841
	HB	HB	1		erode	0.99994
IW	BE	BE	1	1	non-erode	0.31332
	IW	BE		1	non-erode	0.37336
PF	BE	BE	4	3	erode	0.43782
		PF	1		erode	0.67659
	PF	BE	1	2	erode	0.61109
		PF	2	1	erode	0.80847
VW	BE	BE	1	7	non-erode	0.07918
		VS		1	non-erode	0.07046
	BU	BU		1	non-erode	0.04086
	VW	BE		4	non-erode	0.03870
		VW		3	non-erode	0.01234
	VS	BE		1	non-erode	0.06341
FP	BE	BE	1	11	non-erode	0.39909
		IW	1		erode	0.46545
	FP	BE	1	6	erode	0.41878
		FP	17	10	erode	0.43756

Table 4.10: cont.

Land use/land cover			Change		Predicted group	Probability of erosion
South	——→	North	Erode	Non-erode		
BS	BE	BE		9	non-erode	0.00040
		VS		1	non-erode	0.00035
	VW	BE		1	non-erode	0.00019
	BS	BE		8	non-erode	0.00000
		VW		1	non-erode	0.00000
		BS		13	non-erode	0.00000
	VS	BE		1	non-erode	0.00032
		VS		1	non-erode	0.00028
VS	BE	BE	2	22	non-erode	0.15356
		IW		1	non-erode	0.19216
		VS		6	non-erode	0.13787
	VW	BE		1	non-erode	0.07828
	FP	FP		1	non-erode	0.17527
	BS	BS		1	non-erode	0.00000
	VS	BE	2	11	non-erode	0.12499
		VW		1	non-erode	0.04246
		BS		1	non-erode	0.00018
		VS	9	48	non-erode	0.11183
HB	BE	BE		1	non-erode	0.00015
	HB	BE	1		erode	0.59392
		HB	5	1	erode	0.90101

When the considered shore lengths compose of only one or different type of land use/land cover, the model yielded a positive prediction. For all patterns where mangrove area, bare soil, or both types of vegetation was present, they were all positive prediction as the non-erode group.

From the analysis (Table 4.11), the model chi-square is equal to 97.411 with $df = 27$; $P = 0.0000$. That is, the model containing more terms of land use/land cover is significantly better than the null model.

For each land use/land cover type, Wald statistic was less than 0.1475 with p-value greater than 0.7009. This means that no single type of land use/land cover is significantly related to the coastline change.

Table 4.11: Results of logistic regression analysis of case 2A

Variable (land use/land cover)	β	S.E.	Wald statistic	*df*	*p*-value
Adjacent segment			6.9532	9	0.6420
BE	7.5714	35.7332	0.0449	1	0.8322
BU	7.1267	35.7353	0.0398	1	0.8419
IW	7.8422	35.7597	0.0481	1	0.8264
PF	8.5595	35.7384	0.0574	1	0.8107
VW	6.4016	35.7489	0.0321	1	0.8579
FP	7.6481	35.7363	0.0458	1	0.8305
BS	0.8830	38.5752	0.0005	1	0.9817
VS	7.4452	35.7350	0.0434	1	0.8350
HB	9.3997	35.7683	0.0691	1	0.7927
Middle segment			2.5802	9	0.9786
BE	6.9242	33.3788	0.0430	1	0.8357
BU	6.6664	33.3816	0.0399	1	0.8417
IW	7.1910	33.4088	0.0463	1	0.8296
PF	7.6262	33.3852	0.0522	1	0.8193
VW	6.1652	33.3967	0.0341	1	0.8535
FP	7.0057	33.3837	0.0440	1	0.8338
BS	1.6020	35.9533	0.0020	1	0.9645
VS	6.6852	33.3813	0.0401	1	0.8413
HB	16.1260	77.0837	0.0438	1	0.8343
Updrift segment			9.0398	9	0.4336
BE	7.5714	35.7332	0.0449	1	0.8322
BU	7.4569	35.7351	0.0435	1	0.8347
IW	7.9770	35.7576	0.0498	1	0.8235
PF	8.5117	35.7383	0.0567	1	0.8118
VW	6.3082	35.7487	0.0311	1	0.8599
FP	8.3524	35.7359	0.0546	1	0.8152
BS	0.9395	38.5644	0.0006	1	0.9806
VS	7.0547	35.7352	0.0390	1	0.8435
HB	-0.0598	78.1187	0.0000	1	1.0000
Constant	-23.2573	60.5485	0.1475	1	0.7009

MG is a reference category

N = 1164

-2 Log Likelihood (-2LL) 1081.479

Model chi-square 97.411 (df = 27, P = 0.0000)

Case 2B: Relation between land use/land cover type in 1954 and coastline change between 1945 and 1994

Table 4.12: Predicted probability of erosion and predicted group of case 2B

Land use/land cover			Change		Predicted group	Probability of erosion
South	——→	North	Erode	Non-erode		
MG	MG	BE		2	non-erode	0.00000
	BE	BE		5	non-erode	0.00016
BE	MG	MG		2	non-erode	0.00000
		BE		3	non-erode	0.00030
	BE	MG		5	non-erode	0.00016
		BE	188	445	non-erode	0.27501
		BU	8	20	non-erode	0.29853
		PF	3	3	erode	0.45585
		VW	1	7	non-erode	0.08666
		FP		12	non-erode	0.19570
		BS		12	non-erode	0.00038
		VS	2	21	non-erode	0.24441
	BU	BE	2	12	non-erode	0.27651
		BU	5	11	non-erode	0.30011
		HB	1		erode	0.99943
	IW	BE	1		non-erode	0.31889
		IW		1	non-erode	0.31627
	PF	BE	4	1	erode	0.40793
		PF		2	erode	0.60342
	VW	BE	1	2	non-erode	0.12210
		VW		4	non-erode	0.03362
		VS		1	non-erode	0.10602
	FP	BE	1	4	non-erode	0.35165
		FP		7	non-erode	0.25810
	BS	BE		2	non-erode	0.00152
		BS		8	non-erode	0.00000
		VS		2	non-erode	0.00129
	VS	BE		16	non-erode	0.22158
		FP		1	non-erode	0.15439
		VS	1	13	non-erode	0.19532
BU	BE	BE	6	18	non-erode	0.28620
		BU		3	non-erode	0.31026
	BU	BE	4	9	non-erode	0.28774
		BU	6	9	non-erode	0.31188
		PF	1		erode	0.47150
		VW		1	non-erode	0.09178
		VS		1	non-erode	0.25622
	PF	PF	1		erode	0.61661
	VW	BU		1	non-erode	0.14158
	VS	VS		1	non-erode	0.20418
	HB	HB	1		erode	0.99944
IW	BE	BE	1	1	non-erode	0.31758
	IW	BE		1	non-erode	0.36484
PF	BE	BE	4	3	erode	0.45876
		PF	1		erode	0.65179
	PF	BE	1	2	erode	0.60623
		PF	2	1	erode	0.77273
VW	BE	BE	1	7	non-erode	0.07944
		VS		1	non-erode	0.06854
	BU	BU		1	non-erode	0.08888
	VW	BE		4	non-erode	0.03067
		VW		3	non-erode	0.00785
	VS	BE		1	non-erode	0.06082
FP	BE	BE	2	10	erode	0.44581
		IW	1		erode	0.44282
	FP	BE	2	5	erode	0.53493
		FP	16	11	erode	0.42455

Table 4.12: cont.

Land use/land cover			Change		Predicted group	Probability of erosion
South	⟶	North	Erode	Non-erode		
BS	BE	BE		9	non-erode	0.00041
		VS		1	non-erode	0.00035
	VW	BE		1	non-erode	0.00015
	BS	BE		8	non-erode	0.00000
		VW		1	non-erode	0.00000
		BS		13	non-erode	0.00000
	VS	BE		1	non-erode	0.00031
		VS		1	non-erode	0.00026
VS	BE	BE	2	22	non-erode	0.24313
		IW		1	non-erode	0.24091
		VS		6	non-erode	0.21502
	VW	BE		1	non-erode	0.10537
	FP	FP		1	non-erode	0.22757
	BS	BS		1	non-erode	0.00000
	VS	BE	1	12	non-erode	0.19424
		VW		1	non-erode	0.05687
		BS		1	non-erode	0.00024
		VS	17	40	non-erode	0.17051
HB	BE	BE	1		erode	0.99944
	HB	BE	1		erode	0.99943
		HB	6		erode	1.00000

As showed in Table 4.12, there are 78 patterns of land use/land cover. The model gave a positive prediction for 71 patterns; 13 and 58 patterns for erosion and non-erosion respectively. The other 7 patterns are negative prediction.

When the considered shore lengths compose of only one or different type of land use/land cover, the model yielded a positive prediction. For all patterns where mangrove area, bare soil, or both types of vegetation was present, they were all positive prediction as the non-erode group.

From Table 4.13, the model chi-square is equal to 107.585 with df = 27; P = 0.0000. That is, the model containing more terms of land use/land cover is significantly better than the null model.

For each land use/land cover type, Wald statistic was less than 0.1537 with p-value greater than 0.6950. This means that no single type of land use/land cover is significantly related to the coastline change.

Table 4.13: Results of logistic regression analysis of case 2B

Variable (land use/land cover)	β	S.E.	Wald statistic	*df*	*p*-value
Adjacent segment			4.8533	9	0.8469
BE	7.7889	35.6741	0.0477	1	0.8272
BU	7.9040	35.6754	0.0491	1	0.8247
IW	7.7768	35.6995	0.0475	1	0.8276
PF	8.5812	35.6792	0.0578	1	0.8099
VW	6.4032	35.6896	0.0322	1	0.8576
FP	7.3449	35.6774	0.0424	1	0.8369
BS	0.8723	38.5057	0.0005	1	0.9819
VS	7.6296	35.6757	0.0457	1	0.8307
HB	16.217	50.8911	0.1015	1	0.7500
Middle segment			2.9133	9	0.9676
BE	7.1378	33.2578	0.0461	1	0.8301
BU	7.1453	33.2597	0.0462	1	0.8299
IW	7.3483	33.2871	0.0487	1	0.8253
PF	7.7346	33.264	0.0541	1	0.8161
VW	6.1344	33.2753	0.034	1	0.8537
FP	7.4953	33.2624	0.0508	1	0.8217
BS	1.6179	35.8236	0.002	1	0.9640
VS	6.8506	33.2599	0.0424	1	0.8368
HB	7.1138	53.6417	0.0176	1	0.8945
Updrift segment			7.2118	9	0.6151
BE	7.7889	35.6741	0.0477	1	0.8272
BU	7.8443	35.6755	0.0483	1	0.8260
IW	7.9934	35.6984	0.0501	1	0.8228
PF	8.5930	35.6792	0.0580	1	0.8097
VW	6.3083	35.6895	0.0312	1	0.8597
FP	8.5407	35.6768	0.0573	1	0.8108
BS	0.9649	38.4844	0.0006	1	0.9800
VS	7.6227	35.6756	0.0457	1	0.8308
HB	16.2485	51.0984	0.1011	1	0.7505
Constant	-23.6850	60.4149	0.1537	1	0.6950

MG is a reference category

N = 1164

-2 Log Likelihood (-2LL) 1195.134

Model chi-square 107.585 (df = 27, P = 0.0000)

Case 2C: Relation between land use/land cover type in 1991 and coastline change between 1991 and 1994.

Table 4.14: Predicted probability of erosion and predicted group of case 2C

Land use/land cover			Change		Predicted group	Probability of erosion
South	——▶	North	Erode	Non-erode		
BE	MG	MG	1		erode	0.98491
	BE	MG	1	1	erode	0.50000
		BE	283	228	erode	0.55355
		BU	12	8	erode	0.53342
		IW	1	1	erode	0.50000
		FP	2	2	erode	0.52662
		BS	1	3	non-erode	0.39146
		VS	2	1	erode	0.82246
		HB	1	1	erode	0.48944
	BU	BE	11	10	erode	0.51193
		BU	3	2	erode	0.49165
		FP		1	erode	0.48483
	IW	BE	1	1	erode	0.66675
	FP	BE	1	1	erode	0.59661
		BU		1	erode	0.57694
		FP	1	1	erode	0.57026
		BS	1		erode	0.43417
	BS	BE	1	2	non-erode	0.33333
	VS	BE	2	1	erode	0.66667
	HB	BE	1		erode	0.64449
		HB	2	2	erode	0.58362
BU	BE	BE	13	8	erode	0.55325
		BU	1	4	erode	0.53313
	BU	BE	3	2	erode	0.51164
		BU		1	erode	0.49136
	IW	BE	1		erode	0.66649
IW	BE	BE	1	2	erode	0.50507
		BU	1		erode	0.48479
FP	BE	BE		2	non-erode	0.28997
		FP	1		non-erode	0.26816
		HB		1	non-erode	0.23998
	BU	BE		1	non-erode	0.25677
	FP	BE	1	1	non-erode	0.32757
BS	BE	BE	1	1	erode	0.67270
		BU	1		erode	0.65460
VS	BE	BE		2	non-erode	0.23370
		VS	1		erode	0.53260
HB	BE	BE	1	2	erode	0.51077
		HB	1		erode	0.44666
	HB	BE	3	2	erode	0.60420

From Table 4.14, there are 40 patterns of land use/land cover. The model gave a positive prediction for 13 patterns; 8 and 5 patterns for erosion and non-erosion respectively. The other 27 patterns are negative prediction.

When considered the composition of land use/land cover pattern, there is no strong evidence of relation between land use/land cover pattern and coastline changes. The land use/land cover patterns are uncertainty.

Table 4.15: Results of logistic regression analysis of case 2C

Variable (land use/land cover)	β	S.E.	Wald statistic	*df*	*p*-value
Adjacent segment			1.7120	7	0.9741
BE	0.2150	1.4169	0.0230	1	0.8794
BU	0.1339	1.4591	0.0084	1	0.9269
IW	9.58E-14	2.0000	0.0000	1	1.0000
FP	0.1066	1.5997	0.0044	1	0.9469
BS	-0.4412	1.6913	0.0680	1	0.7942
VS	1.5331	1.9262	0.6335	1	0.4261
HB	-0.0423	1.6408	0.0007	1	0.9795
Middle segment			1.5872	7	0.9791
BE	-4.1788	8.3249	0.2520	1	0.6157
BU	-4.3461	8.3327	0.2720	1	0.6020
IW	-3.7003	8.4156	0.1933	1	0.6602
FP	-4.0025	8.3623	0.2291	1	0.6322
BS	-5.0870	8.4150	0.3654	1	0.5455
VS	-3.7007	8.4150	0.1934	1	0.6601
HB	-3.7989	8.3688	0.2061	1	0.6499
Updrift segment			2.8512	6	0.8273
BU	-0.0012	0.3676	0.0000	1	0.9974
IW	-0.1947	1.0068	0.0374	1	0.8466
FP	-1.1105	0.8832	1.5809	1	0.2086
BS	0.5054	1.2328	0.1681	1	0.6818
VS	-1.4025	1.3922	1.0148	1	0.3137
HB	-0.1719	0.8037	0.0458	1	0.8306
Constant	4.1788	8.2039	0.2595	1	0.6105

MG is a reference category

N = 1164

-2 Log Likelihood (-2LL) 893.577

Model chi-square 7.173 ($df = 20, P = 0.9961$)

From Table 4.15, the model chi-square is equal to 7.173 with df = 20; P = 0.9961. That is, the addition of the twenty predictors was not result in significant improvement of the model.

For each land use/land cover type, Wald statistic was less than 1.5809 with *p*-value greater than 0.2086. This means that no single type of land use/land cover is significantly related to the coastline change at significant value greater than 0.2086.

The coastline changes which detected from aerial photographs and calculated from logistic regression model were showed in Figures 4.4 to 4.6. Each figure composes of three charts of shoreline. The first chart was the coastline detected from aerial photographs, called observed coastline hereafter. The second and third charts were the coastline calculated by logistic regression model under the conditions of hypothesis I and II, called calculated coastline I and II, respectively.

When considered Figures 4.4 and 4.5, most of the calculated coastline I and II were non-erode. The eroded coastlines from the model were well corresponded with the observed coastline, such as beach areas at north and south of Puk Tian beach and at Hua Hin piers. The calculated coastline II was better than calculated coastline I. The model yielded a similar result for the same hypothesis conditions. Figure 4.6 showed that most coastlines were eroded. Chart (c) showed a lot of missing values cause by unclassified pixels, which affect the predicted results of the model.

The number of erosion or non-erosion cases in each data set affects the result of the model because the model is generally created to fit the observed data. As a result, the model showed that most of the land use/land cover categories in 1954 induce non-eroded coastline, while nearly all land use/land cover categories in 1991 induce erosion.

When considered the results of the models between cases 1A and 1B and cases 2A and 2B, which used the same land use/land cover data and a similar tendency of coastline change (as discussed in section 4.1), each model gave the same pattern of change. But for the cases 1C and 2C which used the different set of land use/land cover data and tendency of coastline change, the model gave the different patterns of change. This difference may be caused by the time interval of the study of relationship between land use/land cover in 1954 and coastline changes from 1954 to 1991 and 1954 to 1994. Since the time intervals are too long, 37 and 40 years respectively, land use/land cover in 1954 may not reflect the real land use/land cover which affect the changes of coastline.

From logistic regression model, although land use/land cover showed a significant effect on the coastline change at significant value less than 0.2063 (except case 2C (P = 0.9961), the model has limitations when it is used to describe the effect that individual land use/land cover has. The analysis revealed that no single land use/land cover type is significantly related to the coastline change at significant value greater than 0.1581.

To compare a model under hypothesis I conditions to a model under hypothesis II conditions, the log-likelihood statistic test based on the difference in the values of -2LL for the two models was tested. The model under hypothesis I conditions is the simpler model, and the model under hypothesis II conditions is the complex model. Results of the comparison are as following.

Comparison of the models in case 1A with 2A:

The model in case 1A has -2LL = 1130.277. After adding 18 predictors to the model, -2LL drops to 1081.479. The difference (1130.277 – 1081.479) = 48.798 is a chi-square statistic with df = 18. This shows strong evidence of a better fit for the model in case 2A ($P < 0.005$).

Comparison of the models in case 1B with 2B:

The model in case 1B has -2LL = 1250.844. After adding 18 predictors to the model, -2LL drops to 1195.134. The difference (1250.844 – 1195.134) = 55.71 is a chi-square statistic with df = 18. This shows strong evidence of a better fit for the model in case 2B ($P < 0.005$).

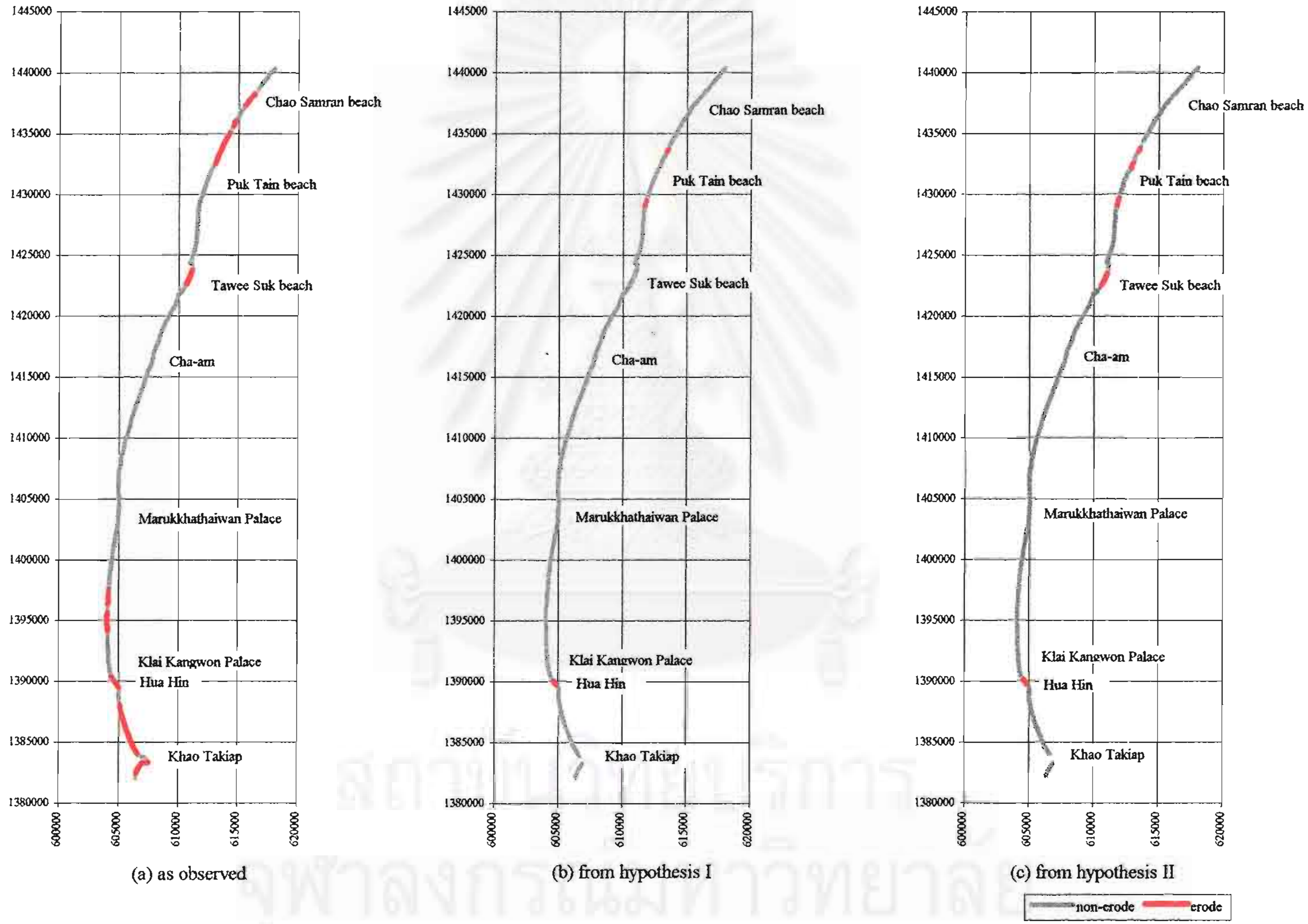
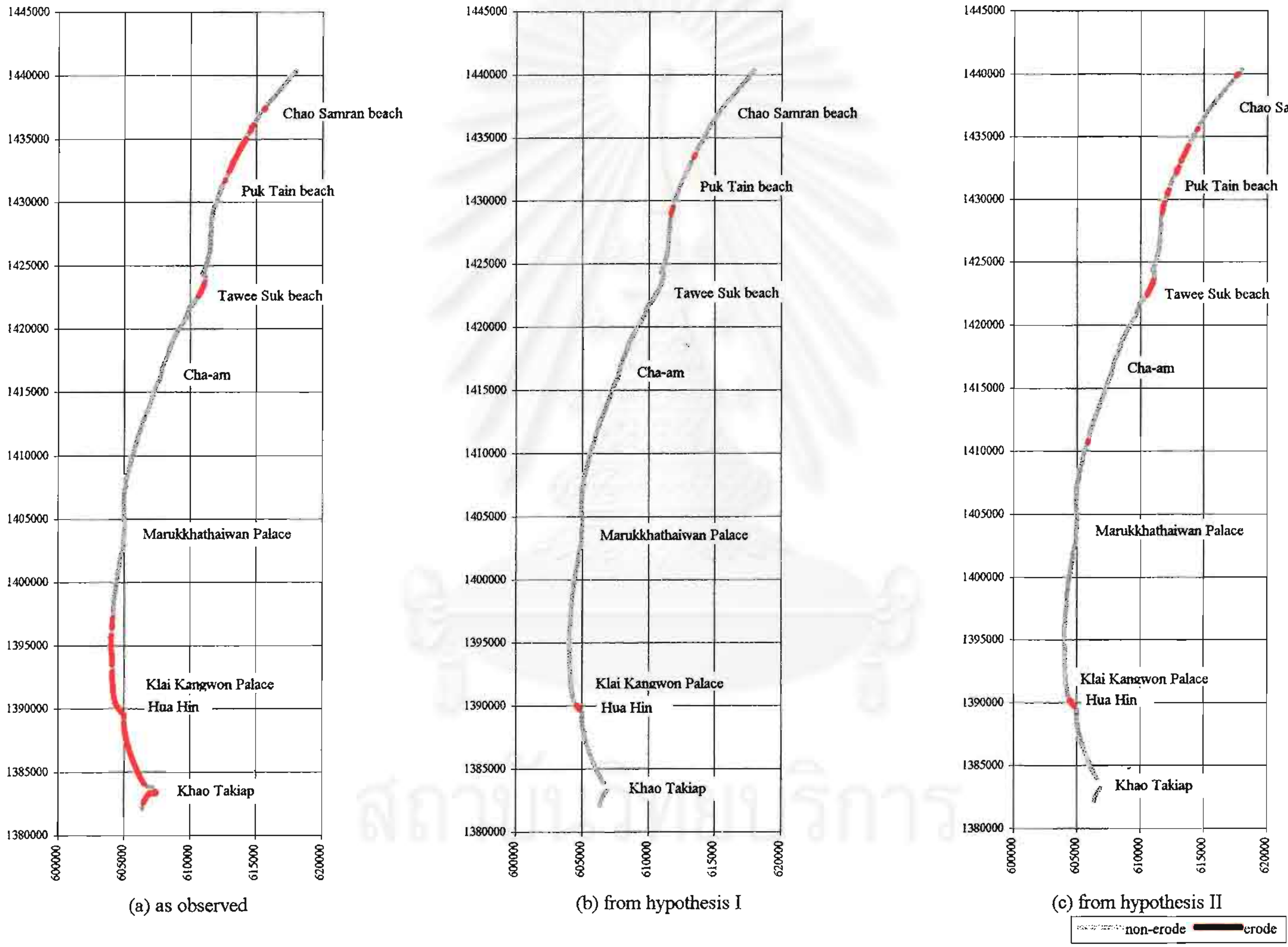


Figure 4.4: Comparison between detected and predicted coastline change (1954 to 1991)



(a) as observed (b) from hypothesis I (c) from hypothesis II

Figure 4.5: Comparison between detected and predicted coastline change (1954 to 1994)

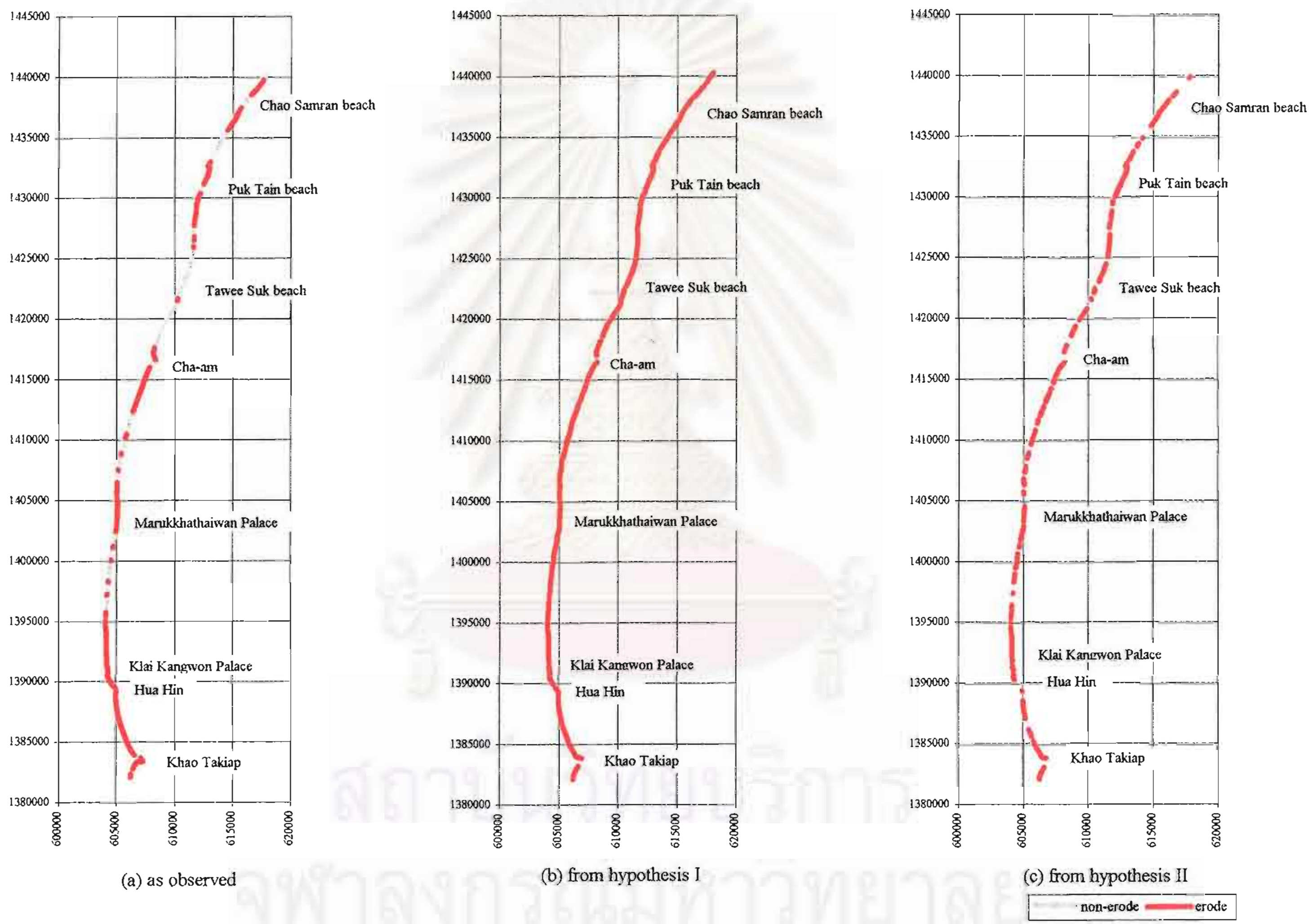


Figure 4.6: Comparison between detected and predicted coastline change (1991 to 1994)

Comparison of the models in case 1C with 2C:

The model in case 1C has -2LL = 1346.518. After adding 13 predictors to the model, -2LL drops to 893.577. The difference (1346.518 – 893.577) = 452.941 is a chi-square statistic with $df = 13$. This shows strong evidence of a better fit for the model in case 2C ($P < 0.005$).

Results of the model comparison were showed in Table 4.16. It can be concluded that the land use/land cover types at the updrift segment provided an improvement in predictive power.

Table 4.16: Results of the model comparison

Comparing model	$-2LL_{diff}$	*df*	Interpretation
1A – 2A	48.798	18	Complex model is better fit at significant value < 0.005
1B – 2B	55.710	18	Complex model is better fit at significant value < 0.005
1C – 2C	452.941	13	Complex model is better fit at significant value < 0.005

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study used remote sensing technique for detection of coastline changes and classification of land use/land cover along the part of coastline of Phetchaburi and Prachuap Khiri Khan provinces, from Hat Chao Samran to the north of Khao Ta Kiap. The land use/land covers were classified from Landsat-5 TM image and aerial photographs. The coastline changes were detected from aerial photographs. Dependent of coastline change on land use/land cover was determined from the remotely sensed data and shows that:

1) Between 1954 to 1991 most of the shoreline in the study area was accrete. Then, between years 1991 to 1994 it was suffered from erosion. The overall pattern of coastline change from 1954 to 1994 was non-erosion.

2) Logistic regression model can be used to evaluate the dependent of land use/land cover on coastline change. It was significantly valid and fit to the data at significant value less than 0.2063. A more complex model yielded the significantly prediction better than a simpler model.

3) When considered that coastline change at any shoreline segment is depend on the type of land use/land cover at that shoreline segment, high density built-up area and bare soil were always classified into erode and non-erode group respectively.

4) No single land use/land cover type is significantly related to the change of the coastline at significant value greater than 0.1581.

5.2 Recommendations

For the study of coastline changes from aerial photographs, the flight path, tidal conditions, and scanned quality should be concerned.

Accurate and adequate ground control points are essential for the registration and restoration process of aerial photograph. In addition, only the effective area of the photograph should be used to minimize distortion effect of the photo.

The consideration for land use/land cover, which classified from satellite image, from an individual pixel may not represent the true land use/land cover type because some pixel may contain noise. Post filtering or smoothing should be considered to eliminate the noise.

Although the logistic regression model that used to evaluated the relationship between only land use/land cover type and coastline change indicated the significantly relation of land use/land cover with coastline change. But for the determination of the effect that individual land use/land cover has on the coastline change, it appeared no significant relation. In order to obtain a more useful model more predictors are needed. Potential predictors may include sea conditions, beach slope, storm event, shore protection structure, etc.

As the land use/land cover has a significant effect on the coastline change, the land use development along the coastal area should be concerned. The coastal management scheme according to the land use along the coastline is required to minimize the adverse impacts of land use and ensure the prevailing of the scenic and natural qualities of the coastal area.

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BIOGRAPHY

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