COASTAL WETLAND DETECTION BY REMOTE SENSING IN PHETCHABURI BASIN

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Thesis
entitled

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ABSTRACT

Surveying and studying the ecological characteristics of wetlands is the most important priority for wise use and sustainable management in order to conserve the coastal wetland resources in Phetchaburi basin. The main objective of this research was to study some characteristics of the coastal wetlands area with a field survey. Additionally, we aimed to study the spectral reflectance of coastal wetlands with their various ecological characteristics to create a knowledge-base from satellite image processing, as was applied for detection and identification of regions and coastal wetland types.

By surveying some ecological characteristics and considering field indicators of wetland vegetation, wetland soil, and wetland hydrology, it was possible to identify the coastal wetland types according to the class of land cover. The selection of a specific representative sample area, and accuracy assessment in supervised classification method, relied upon a predetermined maximum likelihood criteria to detect and identify coastal wetland types using satellite imagery data from two sources: Landsat 5-TM and SPOT-5 remote sensors.

The results of the analysis showed it was possible to detect and identify the various coastal wetland areas and divide them into 6 categories: open water, farmland, forest, paddy field, scrub and emergent. Accuracy assessment via satellite imagery classification was then conducted on both the Landsat 5-TM and SPOT-5 images, using error matrix detection of coastal wetland, which found that the overall accuracy was 90.63 and 78.13 percent, respectively. For coastal wetlands the identification accuracy assessment found that the overall accuracy was 81.25 and 65.63 percent, respectively. Finally, accuracy assessment of image classification of Landsat 5-TM and SPOT-5 images was performed using Kappa's coefficient for reliability. It was found that the Kappa's coefficients were 0.7722 and 0.5926, respectively. The study found that the ecological characteristics of coastal wetlands could be indicated by position, boundary, and the identified coastal wetland types in the Phetchaburi basin.

KEY WORDS: COASTAL WETLAND / REMOTE SENSING / SPECTRAL REFLECTANCE/ CLASSIFICATION METHOD/ MAXIMUM LIKELIHOOD

97 pages

การตรวจหาพื้นที่ชุ่มน้ำชายฝั่งทะเล ด้วยการสำรวจระยะไกล บริเวณลุ่มน้ำเพชรบุรี
COASTAL WETLAND DETECTION BY REMOTE SENSING IN PHETCHABURI BASIN

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บทคัดย่อ

การสำรวจและศึกษาคุณลักษณะทางนิเวศของพื้นที่ชุ่มน้ำมีความสำคัญสำหรับการจัดการพื้นที่ชุ่มน้ำอย่างชาญลาดและยั่งยืน เพื่อที่จะอนุรักษ์ทรัพยากรพื้นที่ชุ่มน้ำชายฝั่งทะเลบริเวณลุ่มน้ำเพชรบุรี งานวิจัยนี้มีวัตถุประสงค์เพื่อการศึกษาคุณลักษณะนิเวศบางประการของพื้นที่ชุ่มน้ำชายฝั่งทะเลด้วยการสำรวจภาคสนามร่วมกับการศึกษาค่าสถิติการสะท้อนของพื้นที่ชุ่มน้ำชายฝั่งทะเลตามคุณลักษณะนิเวศแบบต่างๆ เพื่อสร้างฐานความรู้การประมวลผลข้อมูลภาพถ่ายดาวเทียม สำหรับการประยุกต์การตรวจหาและการบ่งชี้ประเภททรัพยากรพื้นที่ชุ่มน้ำชายฝั่งทะเลได้

การสำรวจลักษณะนิเวศบางประการ พิจารณาจากดัชนีชนิดพืชพรรณ ดิน และการท่วมขังของน้ำเพื่อนำรูปแบบดัชนีมาบ่งชี้ประเภทพื้นที่ชุ่มน้ำชายฝั่งทะเลตามสิ่งปกคลุมดิน สำหรับการกำหนดพื้นที่ตัวแทนและการตรวจสอบความถูกต้องของการจำแนกประเภทข้อมูลแบบควบคุม ด้วยกฎเกณฑ์การตัดสินใจทางสถิติแบบความน่าจะเป็นไปได้สูงสุด เพื่อนำมาตรวจหาและบ่งชี้ประเภททรัพยากรพื้นที่ชุ่มน้ำชายฝั่งทะเล โดยใช้ข้อมูลภาพถ่ายดาวเทียม 2 ประเภท คือ Landsat 5-TM และ SPOT-5

ผลการศึกษาสามารถตรวจหาและบ่งชี้ประเภทพื้นที่ชุ่มน้ำชายฝั่งทะเลได้ 6 ประเภท ได้แก่ แหล่งน้ำเปิด, ฟาร์มในพื้นที่ชุ่มน้ำ, ป่าชุ่มน้ำ, นาข้าว, ไม้พุ่ม และพืชโผล่เหนือน้ำ เมื่อนำมาตรวจสอบความถูกต้องการจำแนกข้อมูลภาพดาวเทียมทั้ง Landsat 5-TM และ SPOT-5 ด้วยการตรวจสอบแบบตาราง การตรวจหาพื้นที่ชุ่มน้ำชายฝั่งทะเล พบว่า มีค่าความถูกต้องโดยรวมร้อยละ 90.63 และ ร้อยละ 78.13 ตามลำดับ สำหรับการตรวจสอบความถูกของการบ่งชี้ประเภทพื้นที่ชุ่มน้ำชายฝั่งทะเล พบว่า มีค่าความถูกต้องโดยรวมร้อยละ 81.25 และร้อยละ 65.63 ตามลำดับ สุดท้ายค่าความถูกต้องของผลการจำแนกข้อมูลภาพดาวเทียม Landsat 5-TM และ SPOT-5 นำมาตรวจสอบความน่าเชื่อถือด้วยค่าสัมประสิทธิ์ Kappa พบว่า มีค่าสัมประสิทธิ์ Kappa เท่ากับ 0.7722 และ 0.5926 ตามลำดับ จากการศึกษาแสดงให้เห็นว่า คุณลักษณะนิเวศของพื้นที่ชุ่มน้ำชายฝั่งทะเลสามารถบ่งชี้ตำแหน่ง ขอบเขตบริเวณ จนถึงการบ่งชี้ประเภทพื้นที่ชุ่มน้ำชายฝั่งทะเลบริเวณลุ่มน้ำเพชรบุรีได้

97 หน้า

CONTENTS

CONTENTS (cont.)

LIST OF TABLES

LIST OF TABLES (cont.)

LIST OF FIGURES

LIST OF FIGURES (cont.)

CHAPTER I
INTRODUCTION

1.1 Background Justification

Wetland is an ecosystem that takes responsibility of value and important for human's life, plants and animals include in ecology, economics, social, and politic among regional, national and international scale (1). Thailand uses the benefit from various wetland types, such as river, canal, stream, bog, highland, estuary, and sea, etc. Peoples use benefit of them as home stay, foods, traffic for a long time. When increasing of population, the beneficial using of wetland is more increasing (2,3). The impact reasoning of deteriorating and losing of wetland will be different depending on the types of their areas and problem of severed level. To sum up, occurring the characteristic of activity and impact on wetland problem are followed: agriculture and livestock, fishery, living area, industry, public utility, and tourism. The situation of wetland in Thailand has area about 36,616 square kilometer or approximately 7.5 percentage of total area, it is divided into freshwater wetlands of 45 percentage, such as canal, river, lake and peat swamp forest, and 55 of percentage remaining of coastal wetlands as estuary, sand and mud on coastal, mangrove forest, coral reef, and sea grass resources (4).

Coastal wetland is located in the transitional zone between dry land and the ocean (5). Along the coastal line, lake, gulf, and estuary of river before going out the ocean, there are variety of forestry, wild life and plants, fishery, agriculture, water, and tourism resources that they are income resources. Moreover, coastal wetland is the last barrier of basin area before, flow go out to the sea. Its role is important to protect the intrusion of salted water through the land, to reduce the land along the coastal line's collapse, to help slow down of water, to support the water to be less shallower and conserve the quality of sea water. In present, the coastal wetlands are endanger increasingly, even though some area will be protected as the conserved area, national

park, or wetland area as the announcement of the national wetland inventory in Ramsar Convention.

In present, coastal wetlands are impacted from the development and benefit of human's activities that affect to destroy and loss a lot of its area's reducing (6). Especially, coastal wetlands in Phetchaburi basin presents the impact of beneficial development on agriculture, industry, tourism, expanded community. Those activities effect on the role, value of wetland, and human's benefit, for example, mangrove forest lose bring on the shoreline erosion of Phetchaburi river, water quality's deterioration at Pak Klong Ban Lham and Pak Klong Bang Ta Boon, garbage and waste water problems at Buk Tein Beach, Cha-Um Beach, to be shallow of river, and riparians destroy, etc. (7). Therefore, detect and inventory of coastal wetlands are the important to assessment and monitoring for management planning process. Remote Sensing is the effective tool extraction of detailed information of wetland: size, shape, types, and extent (8), especially study the large area in basin scale (9). Remote sensing data is relevant applying use for survey, monitor, and wetland mapping education to conserve and manage the wetland under the Ramsar Convention (10).

Surveying by detection and identification of coastal wetland types in Phetchaburi basin is the basic study of monitor the status the coastal wetland areas by ecological characteristic that helps to support the understanding and lead to manage the supreme sustainability in local and national scale.

1.2 Objectives

1.2.1 To study some ecological characteristics of coastal wetlands in Phetchaburi basin.

1.2.2 To study a relationship between some ecological characteristics and spectral reflectance of coastal wetlands in Phetchaburi basin.

1.2.3 To study a classification of coastal wetland types in Phetchaburi basin.

1.3 Conceptual Framework

Conceptual framework of this research is to describe the presented as figure 1.1.

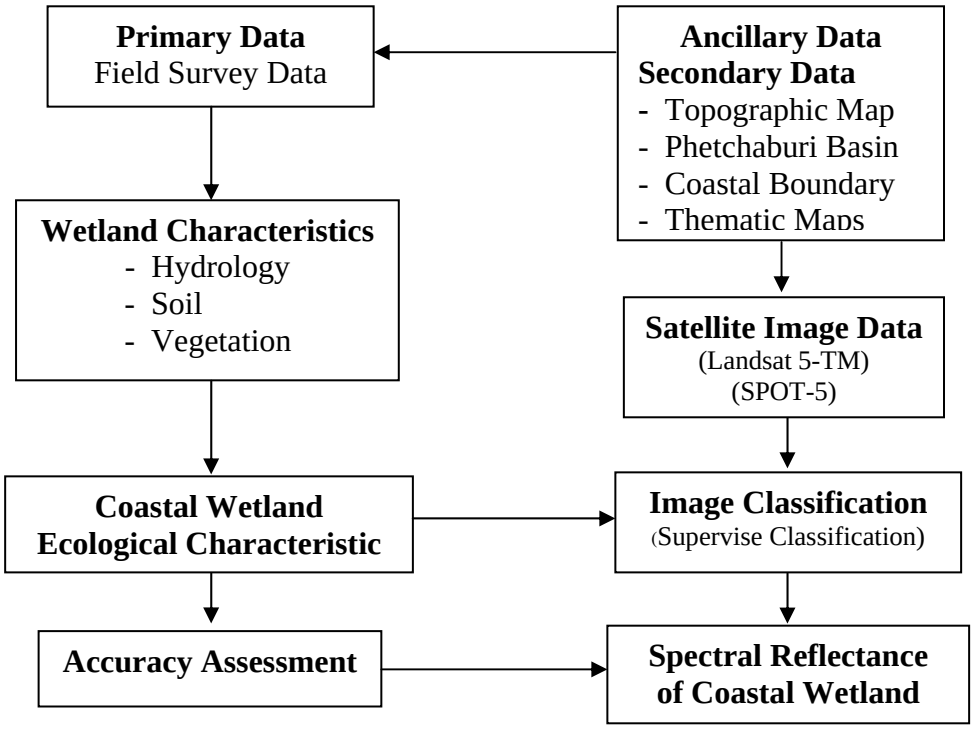

Figure 1.1 Conceptual Framework Diagram

1.4 Research Question

1.4.1 How are the relationship between the spectral reflectance and coastal wetland characteristics?

1.4.2 How much are correctly the spectral reflectance on studying of coastal wetland detection and coastal wetland identification?

1.5 Scope of Study

1.5.1 Study design

It used a remote sensing technology to detect and identify the coastal wetland types in Phetchaburi basin. First part of study, an ecological characteristic of coastal wetlands consisted of index indicators: wetland vegetation, hydric soil and wetland hydrology, in which indicated this case study as the coastal wetlands, up to classified the coastal wetland types. The first part of resulted study would bring to analyze with the second part of studying that related to relationship between the spectral reflectance and coastal wetland ecological characteristic, with applied for remote sensing technique for coastal wetland detection and coastal wetland identification, it used the satellite remote sensors of Landsat 5-TM and SPOT-5.

1.5.2 Study Site

The study on this research is coastal wetland in Phetchaburi basin that it covers 4 sub-Distinct of Phetchaburi Province: Ban Lham, Muang Phetchaburi, Ta Yang, and Cha-Um. Total area is 1872.53 km^2 (1,170,330 rai) (11).

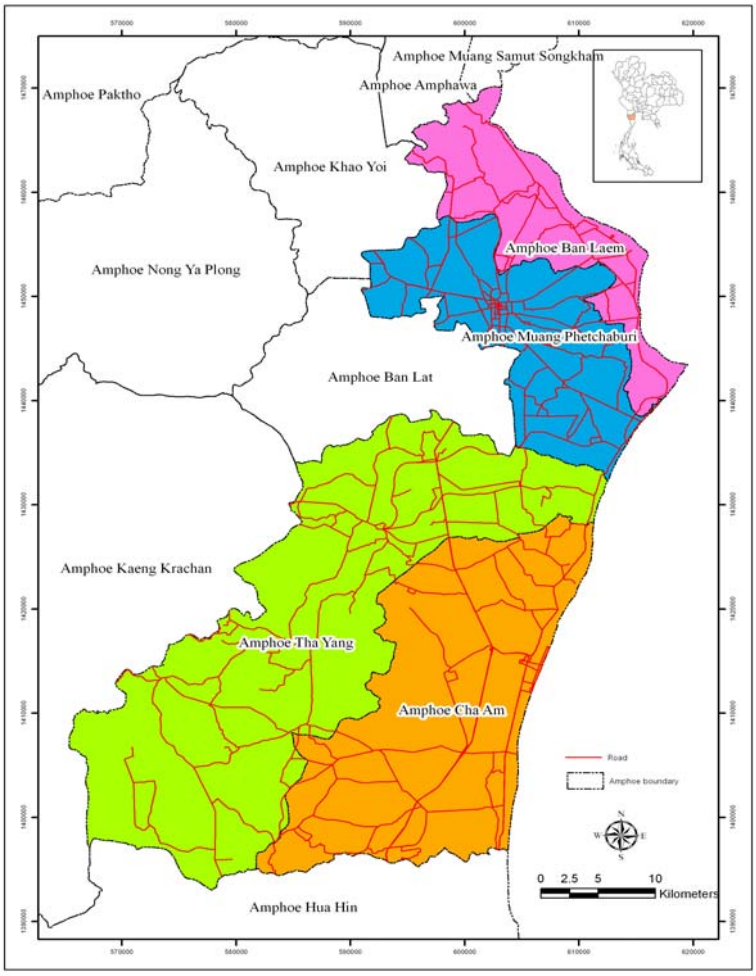

Figure 1.2 Coastal wetland area in Phetchaburi Basin.

1.6 Expected Results

1. Understand the basically characteristic of physical and ecological coastal wetlands in Phetchaburi basin.

2. Understand the spectral reflectance of Landsat 5-TM and SPOT-5 satellite imageries of coastal wetlands in Phetchaburi basin.

3. Understand the types of coastal wetland in Phetchaburi basin.

1.7 Definition of terms

Wetland Detection is defined as remote sensing technique find to boundary coastal wetland using a relationship of ecological characteristics and spectral reflectance.

Wetland Identification is defined as remote sensing technique identify to coastal wetland category using a relationship of ecological characteristics and spectral reflectance.

Coastal Wetland Ecological Characteristic is defined as delineation about biological soil and hydrological of coastal wetlands.

Coastal Wetland Category is defined as the class of land cover on coastal wetlands for example ,open water, forest, farmland, scrub and emergent.

Emergent Wetland is defined as plant growing in water or on a substrate which characterized by erect, rooted, herbaceous hydrophytes.

Scrub Wetland is defined as a plant which at maturity is usually less than 6 m. tall and bushy appearance for example, tree shrubs, young trees, and trees or shrubs.

Forest Wetland is defined as a plant which at maturity is usually more than 6 m. tall for example, mangrove.

Farmland Wetland is defined as agriculture area have wetland vegetations can grow.

Open Water is defined as area of water resource both natural water resource and man-made water resource until to shoreline.

Spectral Reflectance is defined as the electromagnetic response to coastal wetland which different land cover class.

Satellite Image Data is defined as Landsat5-TM imagery and SPOT-5 satellite imagery.

CHAPTER II
LITERATURE REVIEWS

2.1 Wetland

2.1.2 The Definition of Wetland

Wetland calls the ecosystem that fundamental process or condition related on water. Lyon (13) defined as area that mostly controls the surface or groundwater at frequency and duration sufficient to support and transition areas between terrestrial and aquatic ecosystems. Generally, wetland ecosystems finds around marsh, swamp, bog, or similarly areas, a prevalence of hydrophytic vegetation typically adapted for life in saturate soil condition and hydric soil that are inundated or saturated (14,15). The defined wetland clearly is difficult because it is not indicate boundary exactly. Ramsar Convention (16) defined wetland very most widely and understood world wide as articles 1.1 and 2.1 “wetland means marsh, fen, bog, peatland or water, whether natural or artificial, permanent or temporary, static and flowing, freshwater, brackish water, and salty water, including in coastal line since low tide area that has level do not exceed six meters, and also riverside, seashore connected to wetland, island, or sea do not exceed six meters inside that wetland area”.

2.1.2 The Value of Wetland

Each wetland types and some areas has role, special qualification, and different production, therefore the value is different. Department of Water Resources (17) said that value and important of beneficial wetland is necessary to control the procedure’s direction in wetland management, its value is divided broadly as its role and beneficial uses (18) as this follow:

1) Beneficial consumption in direct uses for productive factor on goods and services, such as forestry, wildlife animal, fishery, vegetation, water, and energy resources, etc.

2) Beneficial useful indirect in the role of ecosystem in community and social, such as flooding protection, conserving the balance of seashore and protecting soil erosion, conveying the water into underground, controlling the rate of river current, storm prevention and server wind reduction, water transportation, recreation and tourism, etc.

3) Non beneficial Value, that is to conserve the biodiversity, cultural and natural heritage, etc.

2.1.3 Wetland Classification

Wetland classification is important on its management, Lyon (13) said that comprehensive wetland ecosystem would help to manage, monitor, survey include in conservation and wetland mapping. The wetland classification is management as hierarchical classification. Phanawon (19) said that wetland classification improvement and development came from IUCN's wetland area classification system that used in the lower MaeKhong river basin and Ramsar Convention. Siripong (20) said that the relevant natural characteristic indicated the classification, such as characteristic of water, land form, and land use or land cover. Those physical and chemical factors indicated the habitats on plants, animals, and living things in wetland (9). It see that identifying wetland as Ramsar Convention consisted of inland wetland (for instance, marsh, swamp, lake, river, peat area, inland reservoir), coastal wetland and seashore nearby (for instance, coral reef, mangrove forest, seaweed, and estuary) including in man-made wetland (for instance, paddy field, dam, reservoir, fishery farming, shrimp farming, salty farming).

Phanawon (19) and Office of Natural Resources and Environmental Policy and Planning (original) divided wetland into two groups of that rely on salt water criterior: freshwater with salty less than 0.5 parts per thousand, seashore system part and land with salty more than 0.5 parts per thousand, and classified into subsystem by supporting of surface, inundation, or plant types as this:

Salt Water Type is diving into 4 systems as:

1) Marine/Coastal is not influence the water current of river, such as lagoon, brackish water, beach, coral reef, etc.

2) Estuarine is freshwater come from river and sea merging, and salt water in between sea water and freshwater, such as Delta, Tidal Marsh, Mangrove Forest, Mud Flat, Seagrass Bed, etc.

3) Coastal Lagoon

4) Inland Salt Lake

Fresh Water Type is diving into 3 systems as:

1) Riverine: river, stream, canal, swamp with water flowing through the year or some seasons. Riverside, river beach, or dune mean river basin, such as grass or grass peat swamp, peat swamp forest, boundary of river has temporal bog water, such as swamp, purl in river, fresh water swamp, etc.

2) Lacustrine is a huge water source or bog water permanently or some season with less flowing of water, deep with more than 2 meters and aquatic plants less than 30 percentage of surface water, such as lake, marshes, etc.

3) Palustrine is area that always has bog or some season with deep not more than 2 meters, and aquatic plants grow up more than 30 percentage of water surface, such as marsh, bog, and swamp, etc.

2.1.3 Wetland Identification

Consideration or indicated any wetland is very useful to the conservation action and control the wetland losing. By survey and study the ecological characteristic is composition and process occurring the wetland area. Sansanee (4) said that considerate criteria of it will work on components of physical ecology and hydrology. By wetland must consists of 1in 3 criteria (8,21) as this:

1) At least periodically water, sign of influence of shallow water on surface or inundated by groundwater, depth level and waterlogging, or hydric soil. The drainage system from other wetland area and itself, it means hydrologic characteristic reach to wetland system as rainfall, surface water, river, or flowing water from other wetland areas, such as river, stream, and losing the water from wetland system. It is studying on field indicators of wetland hydrology for example, visual observation of inundation, visual observation of soil saturation, watermark, drift lines, sediment deposits and drainage patterns within wetlands.

2) Soil condition. It is appearing hydric soil that differ from upland area. Hydric soil is a soil that saturated, flooded, or ponded long time enough to develop anaerobic condition. Forestry Faculty, Kasetsart Univeristy (23) for example, muddy soil, peat soil, its matrix color is gray or dark that present on the soil having anaerobic condition. It could observe field indicator from the mottled colors, its characteristic has iron oxide mottling, and it depended on some condition of soil as well. Department of Environmental Quality Promotion (24) for instance, flooding condition would make the matrix color to be gray or darkish, good drainage condition made the matrix color to be yellow or red. If it is always switching of flooding and draining, the soil has mottled colors in yellow color or red on matrix soil. It is studying on field indicators of wetland soil for example, organic soils, histic epipedon, sulfidic material, aquic or peraquic moisture regime, reducing soil conditions and soil colors.

3) Living things, animals, and plants can adapt their condition within waterlogged or hydric soil called aquatic life. Tiner (25) said that plants must adapt themselves living on various water, such as pneumatophores, still root, buttresses, stem with breath gap, floating stem or under the water, for instance, floating plants, submerged plants, emerged plants, riparian plants. Part of animal can adapt themselves to waterlogged, such as group of Waterfowl, shrimp, shell, fish, etc. It is studying on field indicators of wetland vegetation.

2.2 Remote Sensing

Remote Sensing is a tool or technique use for measuring the quality of electromagnetic energy on reflection or spread into objects, phenomena passing the system of data acquisition from platform, such as spaceship, aircraft or satellite by without touching on the target objects. It takes in data analysis by computing on statistic or geometry principle, both in visual interpretation or/and digital analysis to distill the information accuracy, reliable on applying of its objective’s work (27,28,29,30,31). Remote Sensing is science, art, and technology applying on observation, detection, and analysis by receiving natural and environmental data, on culture or processes.

Geo-Informatics and Space Technology Development Agency (32) said that remote sensing identified and comprehended objects or various environmental condition from special characteristic to respond the spectral resolution in different objects. With spectral resolution (such as size, figure, construction, order pattern of objects) help to identify what the object is but it cannot answer overall question in research, for instance, physical, ecology, social that rely on the study on Ancillary data; geography map, land map, land use map, plant calendar, statistic data, field survey data, etc.

2.2.1 Satellite Sensor

Landsat Satellite Data is a satellite orbiting the sun's relation with frequency on taking photo in every 16 days that can shoot both of Multi-Spectral Scanner and Panchromatic with system of MSS and TM (Thematic Mapper). The MSS system has image size covered 185x185 square kilometer, detailed data 80x80 meters, with 4 bands, and thematic mapper system has detailed data 30x30 meters with 7 bands. Nowaday there is Landsat-5 satellite data and Landsat-7 satellite data working on. Landsat-5 satellite data likes to use for survey and natural resources and environmental management.

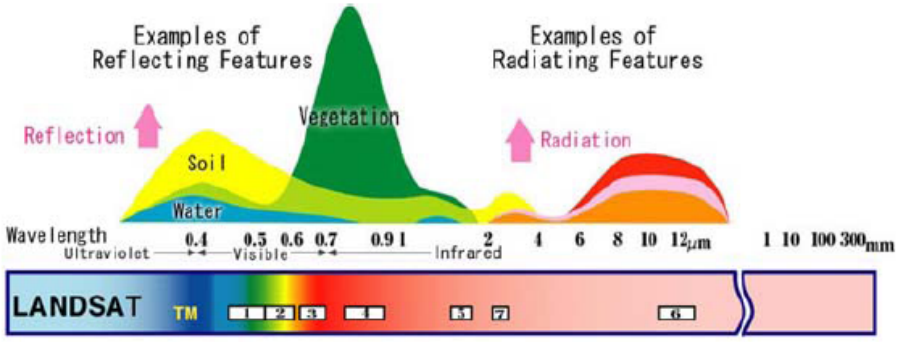

Figure 2.1 Spectral Resolution of Landsat-TM Satellite Data

Source : www.gistda.or.th (28)

SPOT Satellite Data is a satellite orbiting the sun's relation with frequency on taking photo in every 26 days, its recording of SPOT is HRV (High Resolution Visible) camera that can take a photo as lean and learn on three dimension. multispectral mode has 3 bands with detailed data 20x20 meters, and panchromatic

mode has detailed 10x10 meters. It uses for study on survey area and separate the forest types, fire forest monitoring, land use mapping, geology, hydrology, water sources, erosion and sediment, and also monitor the assessment of environmental impact, urban expanding, etc.

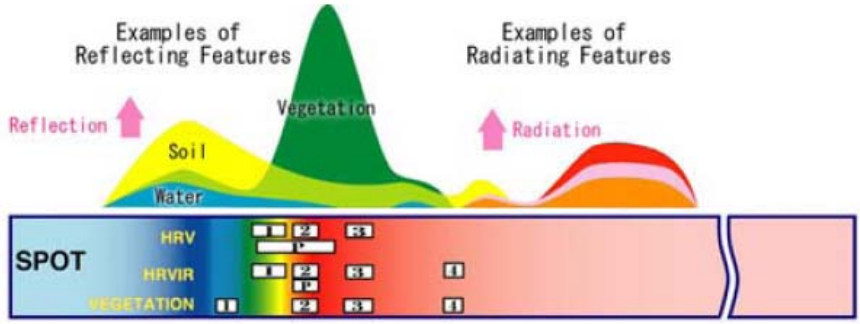

Figure 2.2 Spectral Resolution of SPOT Satellite Data

Source : www.gistda.or.th (28)

2.2.2 Satellite Image Data

Remote Sensing data is raster data that collect the cell-based data in grid cell to substance in earth's objects. By collecting as array of pixel has position reference in row and column, each pixel will represent as gray scale or brightness value (33). Pixel value is called digital number (DN) (Figure 2.3) representing the detail of Spectral Resolution with the different on Multi spectral bands and Radiometric Range. The user selects the suitable wave with the study or applies' use according to potential beneficial uses of spectral characteristics, for example the popular satellite uses for study of resource and environment in Thailand, such as Landsat 5-TM and SPOT-5 satellite that has grayscale value on 256 level (0-255).

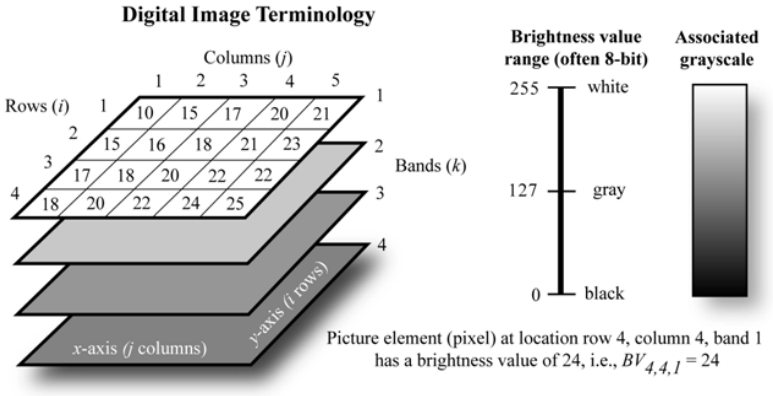

Figure 2.3 Remote Sensing Raster Data

Source : Charunthorn (33)

2.2.3 Satellite Image Classification

Satellite image data classification is digital image processing a whole divided into sub group by statistic at the same direction, spectral reflectance that use the statistic identify the different the pixel class from univariate statistics method to multivariate statistics method (32,34). Therefore, studying of remote sensing should consider about image assessment and statistical evaluation statistic at least some data as probability distribution, hypothesis testing, sampling, and regression, the choosing the technique depends on the result needs in the study.

Veeraphas (35) said that study on image data statistic needing on remote sensing data's assessment, it was useful on relation study between typed data, such as autocorrelation matrix, separability matrix, and selecting of band suites, by study the basic statistic of satellite image data, for instance:

1) Minimum-Maximum is spectral reflectance of image data what spectral value fall in between 0-255 if it is very close to 0. It means wave providing the data about absorbing objects. If it is close to 255, that means it gives the high spectral objects' data. And if the data is much distributed, its present high various spectral reflectance.

2) Mean is average on spectral reflectance of pixel in each wave, it can represent a whole pixel.

The *mean* (m_k) of a single band of imagery composed of *n* brightness values (BV_{ik}) is computed using the formula:

$$\mu_k = \frac{\sum_{i=1}^{n} BV_{ik}}{n}$$

Mean is most likely to study the Spectral pixel, considering spectral signature as shown on the histogram to see the different and familiar among the typed data. The good mean will present the pixel as Symmetry Distribution or Normal Distribution as shown in Figure 2.4.

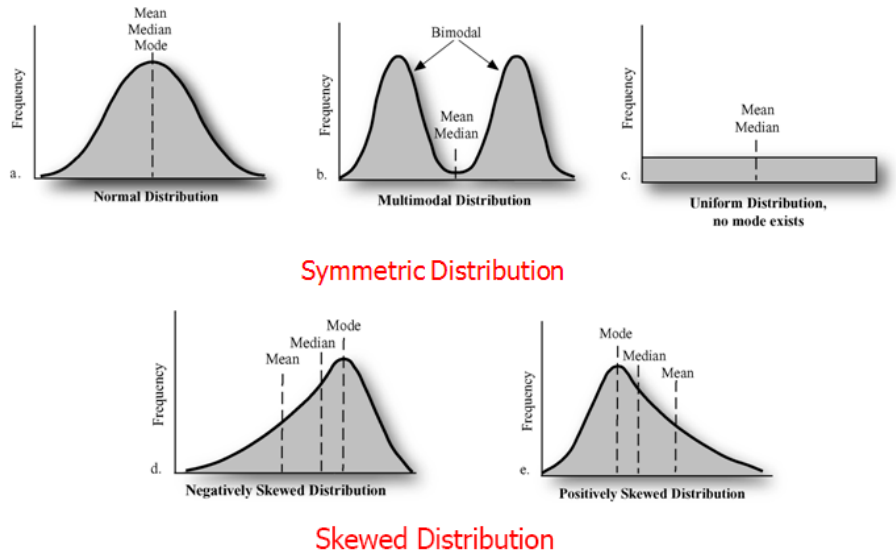

Figure 2.4 Histogram of Symmetric and Skewed Distributions

Source : Charunthorn (33)

3) Standard Deviation (S.D.) is measure the distribution popularly on computing of spectral pixel in each band. The standard deviation of the pixel brightness values in a band of imagery, s_k, is computed using the formula:

$$s_k = \sigma_k = \sqrt{\text{var}_k}$$

4) Median is measure the tendency going to center that use spectral pixel order from lowest to highest, the value set at between median of whole data will be represented all Spectral pixel in each band.

5) Mode is a measure the tendency going to center that look at the spectral frequency having highest frequency.

6) Variance is measure the distribute or different of image data as same as mean. It presents the data of homogeneous.

The variance of a band of imagery, var_k, is computed using the formula:

$$\text{var}_k = \frac{\sum_{i=1}^{n} (BV_{ik} - \mu_k)^2}{n}$$

7) Covariance is measure the relation of data up to 2 series by computing the correlation coefficient since 0 – 1. It closes to 1 as high correlation data and closes to 0 as high correlation data. This coefficient is very benefit on checking to select the spectacle for image data classification process that can study in the cross tabulation to present the spectacle pixel distribution on graph two axis of spectacle that need study on correlation.

2.2.3 Maximum Likelihood Decision Rule

Typed data classification by considerate the value of mean vector and covariance matrix in each of them. By hypothesis, each data is the normal distribution, computed the probability function in each of image pixel where the data is classified. Akgun (36) said that this classify give the most accuracy but use a lot of time computing, the popular method is used having the formula as this:

$$D = \ln(ac) - [0.5 \ln(|Covc|)] - [0.5 (X\text{-}Mc)T (Covc\text{-}1) (X\text{-}Mc)]$$

Where:

D = weighted distance (likelihood)

C = a particular class

X = the measurement vector of the candidate pixel

Mc = the mean vector of the sample of class *c*

ac = percent probability that any candidate pixel is a member of class *c* (defaults to 1.0, or is entered from *a priori* knowledge)

Covc = the covariance matrix of the pixels in the sample of class *c*

|*Covc*| = determinant of *Covc* (matrix algebra)

Covc-1 = inverse of *Covc* (matrix algebra)

ln = natural logarithm function

T = transposition function (matrix algebra)

2.2.4 Accuracy Assessment of Satellite Image Classification

United States Environmental Protection Agency (37) is the most of important process on image data classification to accuracy assessment related on presenting the mistaken value of each reference classified data with real underground data. By relevant hypothesis of mistaking and correction's classification with the original image data, such as reference data, mistaken position, mistake on smallest point of map. And to classify the correction of reference data characteristic, such as identify the sampling are from data group that refer to criterion of corrected data on real underground data.

Confusion/ Error Matrix is to assess the correction or mistaking of classified process that table result in the row is overlap on the real condition area data along the column in order to explain the classified correction or mistaken data in each of them. With comparing all data in each row and column as shown in table 2.1 that compare into two types as:

1) User's accuracy is percentage of relation between each pixel by comparing classification with the whole reference underground data in that column. The statistic accuracy is called omission error, its mean the mistaken value of identify over. If there are much of user's accuracy, the data has high similar details.

2) Producer's accuracy is percentage of relation between each pixel by comparing classification with the whole reference underground data in that column. The statistic accuracy is called commission error, its mean losing the mistaken value by classification.

Table 2.1 Contingency Table

	Ground Reference Test Information					
	Class	1	2	3	k	**Row total**
Remote Sensing Classification	1	$x_{1,1}$	$x_{1,2}$	$x_{1,3}$	$x_{1,k}$	x_{1+}
	2	$x_{2,1}$	$x_{2,2}$	$x_{2,3}$	$x_{2,k}$	x_{2+}
	3	$x_{3,1}$	$x_{3,2}$	$x_{3,3}$	$x_{3,k}$	x_{3+}
	k	$x_{k,1}$	$x_{k,2}$	$x_{k,3}$	$x_{k,k}$	x_{k+}
	Column total	x_{+1}	x_{+2}	x_{+3}	x_{+k}	N

Producer's Accuracy

User's Accuracy

Finally, summary result of report on overall classification accuracy is called overall Accuracy. It calculates from its result of diagonal data in the error matrix ($x_{1,1}$-$x_{k,k}$) comparing to the summary of overall classification in the row and column (N).

Kappa Statistic is to find the accuracy of each classification's data by analyzing with Kappa Statistic (KHAT) to find the coefficient that indicate the accuracy between each typed data received classify with the reference real underground data and overall classification in row and column. To calculate KHAT coefficient can explain the propotion relationship of accuracy assessment that expect to get from the classify, its coefficient is between 0-1 that can calculate by formula as:

$$\hat{K} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k}(x_{i+} \times x_{+1})}{N^2 - \sum_{i=1}^{k}(x_{i+} \times x_{+1})}$$

where k is the number of rows (land-cover classes) in the matrix,

xii is the number of the observation in row i and column i

xi+ is the marginal totals for row i

x+I is the marginal totals for column i

N is the total number of observations.

If K values > 0.75 represent strong agreement, values between 0.40 to 0.75 represent moderate agreement and values < 0.40 represent poor agreement

2.3 Study Area

2.3.1 Location and boundary

Phetchaburi basin is located in the lower center with total area 6,255 square kilometer (40), it covers the most area of Phetchaburi Province and some part of Rajdhaburi. Its figure is rectangle, lie down in west-east. North connects on MaeKlong river, South connects on basin- western coastline, West connects on Burma, and East connects on Thai Gulf.

2.3.2 Geography condition

This basin's geography condition in the west is highland and high deep mountain, such as ThaYang District, NogYaPlong in KhangKajan District that is original of Phetchaburi River. This area is fully abundant of forest and mineral resources, but a few of population. The central part of basin is flat area, such as Ban Lad district, ThaYa District, this area is agriculture with density of population. The lower part of eastern basin is low coastlines area, such as Ban Lham District, Muang Phetchaburi District, and Cha-Um District that it is the important economic sources on fishery and tourism (40).

2.3.3 Climatic condition

Temperature get influence on the southeastern monsoon in rainy season, and northeastern monsoon in winter that can divide into three seasons (41,42) as:

Summer is starting from March to April, with temperature average through the year around 31.5 ^{o}C.

Rainy is starting from May to November, with rainfall average per year at 926.4 millimeter.

Winter is starting from December to February, with temperature average through the year around 24.48 ^{o}C.

2.3.4 Hydrological condition

Phetchaburi basin is the main river and sub-river 4 branchs: MaePrachun sub-river, Pak sub-river, MaePradon sub-river, and Bang Kruan River. Its original

came from high mountain at the upper basin area, passing the main western-eastern basin, and merge on MaePrachun sub-river at Ban ThaSak, ThaYa District, and then return to the north before flowing into the Thai Gulf at Ban Lham District, with the total around 210 square kilometer. Phetchaburi basin can divide into 4 sub-river: upper Phetchaburi basin, lower Phetchaburi basin, center Phetchaburi basin, and coastline Phetchaburi basin. It has fluctuate rainfall quality 900-1,400 millimeter, quality of natural water average around 1,400 million cubic meters (40).

2.3.5 Geological Condition

Geological characteristic of Phetchaburi basin can divide as structural geology into 3 types (43) as this:

1) Coastal area

Its characteristic is lowland with accumulation of alluvial deposit consisted of river, fine sand, soil, and mud.

2) Flat area

It is the older terrace and higher terrace in some area layer of sandstone consisted of conglomerate, slate, sandstone, and granite along hillside. In addition it found some rouge located in the highland.

3) High mountain area

It is mostly high land with dip since 30-70 ^{o}C consisted of mud rock, sand, quartzite, granite, slate, limestone, etc. The northwestern and southwestern found the fault passing, mostly they are unite of stones that found northeastern of KangKrajan.

2.3.6 Structural Geology Condition

Soil in Phetchaburi basin, as classifying soil of geology characteristic, structure, and original object, in the western highland is clay mixed small rock, clay to gravel combination of lose soil and debris. The central flatland is clay and sand clay, some part of eastern coastal flatland is clay combination of loose soil (41).

2.4 Case Study Reviews

Surveying and monitoring wetland uses the benefit of remote sensing in many studies, in both study large and small area. Stacy (44) said that using satellite image data would save the budget and time in analyzing due to difference on wetland characteristic of plants, soil, and water. It could measure the qualification of spectral signature. Opeyemi (45) showed the wetland area characteristic of land cover categories, there are related research as:

Conchedda et al. refer in (25) the study used object-base approach to create map and monitor mangrove forest changing at Low Casamance in Senegal. It used two images of SPOT imagery with different in time for 20 years. Land cover classification of mangrove forest and image classification with comparing to mangrove forest changing, the result study found that the method of object-base approach could study their changing but not suit in classification of mangrove forest types.

Mharapara et al. (46) studied by survey and wetland mapping of Dambo in Mashonaland at East Province was used Landsat 5-TM imagery in summer time (Nov-Mar) and in rainy (Apr-Oct) selecting the band 3-4-5 for suitable wetland classification. Then, taking them analyze by technique of supervised classification with identify training site as geology characteristic in study area. By hypothesis of geology pattern on different humidity and used selecting on Maximum Likelihood algorithm, the result of classify was corrected assessment as reference point of field survey in sampling 89 point, with contingency table, it found the accuracy in 96%.

Rebelo L.M. et al. (47) studied by survey and mapping the change detection of wetland to decision making the wetland management on ecology, economy, and social in Muthurajawela March and Negombo Lagoon at western coastline of Sri Lanka with the total area approximately 12,000 hectare. It used Landsat 5-TM imagery in 1992 and 2002 to identify the land cover and land use with supervised classification and maximum likelihood algorithm. The examined the additional classified result, such as topographical and land survey map. Its result found that losing the wetland with type of deep water area 33%, mangrove 49%, and marsh

40%, classified accuracy 86% ,and found the confusion in classified wetland in marsh and shrub patches and, open moist area, shrubs.

Kitiya Ninpat and Yongyuth Trisurat (48) studied by making GIS database for wetland in Bangkok and urban 2,460 square kilometer, and wetland mapping as classified wetland in Thailand by GIS application, used Landsat 5-TM imagery in 2004, in rainy and dry season to visual interpretation, its objective 1) land use 2) water body status 3) water body size and collect data on the field survey 4) salty of water and 5) water supply canals, then take all data analyzing the area as classified wetland's condition. The result found that Bangkok and urban consisted of 15 sub-level wetland, with the total area 1,505 square kilometer, 61.2 percentage of study area, freshwater area 10 sub-level and salt water 5 sub-level. Sub-level wetland as paddy field was the most area in 712 square kilometer, secondly perennial plant, crops, and aquatic farming with total area of 223, 189 , and 185 square kilometer, respectively, sub-level waterway has the smallest that water flow in some season equal to 0.5 square kilometer, and could classify 11 types of land use/land cover, such as mangrove, nipa forest, fruit tree and mixed orchard, upland crop/grassland, shrub, paddy field, aquaculture, river, water body, mud flat, and build-up area.

Phanawon Chansaku (19) studied on wetland classification and mapping at Tung Kula Ronghai by using Landsat 5-TM imagery in 2000, in two dates: 14 February and 27 October with visual interpretation and satellite image processing on unsupervised classification from nine layer of data, such as study area, water body size, water body status, river status, water supply canals, water supply area, soil characteristics, land use and land form. The result found that Tung Kula Ronghai has 22 wetland types with total area 3,168.43 square kilometer; 21 types of freshwater wetland types and 1 salt water wetland types, it could divide into 3 systems as: Riverine, Lacustrine, Inland Salt Lake, and Non-wetland, but it was not found Palustrine wetland types on this study.

By reviewing the related research on wetland study with remote sensing it found that hydrology characteristic, soil characteristic, land use, wetland types presenting the wetland ecosystem characteristic. It noticed that visual interpretation that rely on specialist relevant, spend a lot of time to assess, easy on mistaken and hardly in accuracy assessment. Therefore, compute classification by satellite image

processing reduce in analysis time and more accuracy rate that should consider the study research under the principle of spectral signature on satellite image data and wetland characteristic.

CHAPTER III
MATERIALS AND METHODS

3.1 Materials

3.1.1 Hardware

1) Personal Computer with a specification of Intel Core 2 Duo Processor 1.66 GHz, 2048MB SDRAM, 80 GB hard disk

2) Printer and Plotter

3) Scanner

4) Digital Camera

3.1.2 Software

1) Image Analysis software: Erdas Imagine Version 9.2

2) GIS software: ArcGIS version 9.2

3.1.3 Materials for Field Survey and Samples Collection

1) Auger , Shovel

2) The Munsell soil Color Chat

3) Salinity Meter

4) Aquatic Plants Guide Book

5) Mangrove Forest Plants Guide Book, Department of Marine and Coastal Resources

6) List of Plant's types located in wetland area in central and eastern parts, Office of Natural Resources and Environmental Policy and Planning

7) Field Data Form Wetland Determination

8) Global Position System : GPS

9) Compass

10) Digital Camera

3.2 Data Sources

The main data in this research is satellite data and additional data as table 3-1 shown the qualification and details

Table 3.1 Various data sources for the study

Satellite Image Data						
Data	Path/Row	Scene	Bands	Resolution	Date	Source
Landsat 5-TM	129/051,130/051	1	1-7	30	25 April 2009	GISTDA[1]
SPOT-5 Panchromatic	K-J 260-324/325 K-J 261-324/325	4	1-3	2.5	08 Jan 2006	GISTDA[1]
Map Data						
Data	Data Type	Unit	Scale		Date	Source
Topograghic Map	Digital, Hard copy	12 sheet	1 : 50000		1993	RTSD[2]
Phetchaburi Basin	Digital map	-	1 : 500000		Not reference	DEQP[3]
Transportation	Digital map	1 layer	1 : 500000		Not reference	DEQP[3]
Stream	Digital map	1 layer	1 : 500000		Not reference	DEQP[3]
Land use	Digital map	1 layer	1 : 250000		2001	LDD[4]
Coastline	Distance in metres	4 amphoe	-		Not reference	DMCR[5]

1 Geo-Informatics and Space Technology Development Agency (Public Organization)

2 Royal Thai Survey Department

3 Department of Environmental Quality Promotion

4 Department of Land Development

5 Department of Marine and Coastal Resources

3.3 Research's Procedure

It consists of 2 main parts: studying the coastal wetland ecological characteristic area by using of field survey to get its data's characteristic, and analyzing satellite acquisition from both of Landsat 5-TM satellite and SPOT-5 satellite is to compare spectacle reflectance of coastal wetland area that presented in figure 3-1.

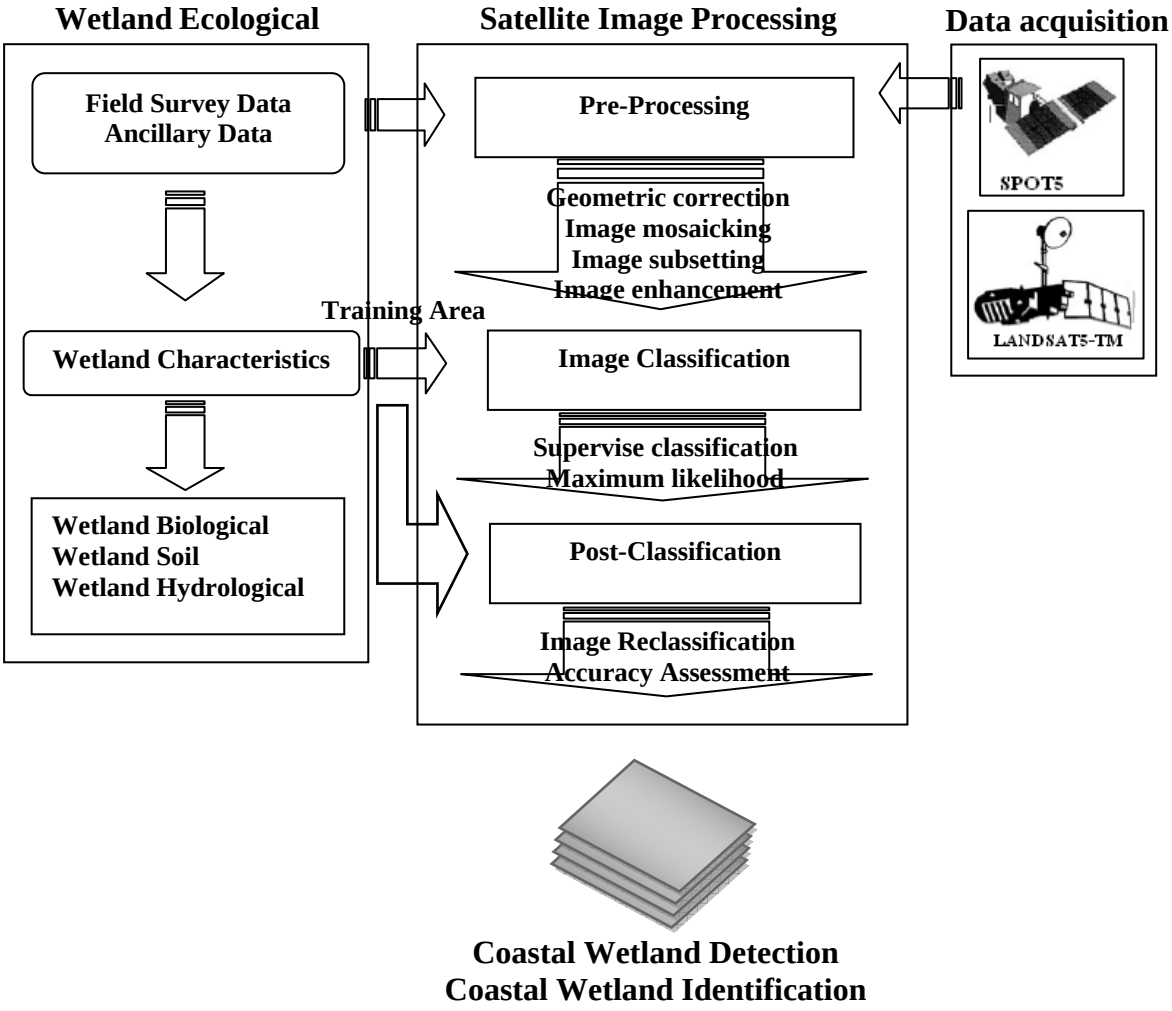

Figure 3.1 The study design diagram

3.4 Wetland Ecological Characteristic

Studying field survey on coastal wetland characteristics by using wetland survey form as a tool is to collect data consisted of 4 process in study that has detailed as this follow:

3.4.1 Collecting fundamental mapping data is presented in table 3-1 that uses for fundamental data shown the study area, such as physical characteristic and study area boundary, and set up the plan for field survey.

3.4.2 Creative field data form on coastal wetland area is used for recording data of it. It consists of 4 parts: geography characteristic, ecological characteristic, pedological characteristic, and hydrological characteristic (shown in Appendix A).

3.4.3 Field Survey. Coincidental sampling collection and step priority to be covered the study area, it identifies the sampling group into 5 types: open water, forest, farmland, scrub and Emergent according to collect spatially position with GPS that uses for identify training area and accuracy assessment with satellite data's assessment by computer.

3.4.4 Making database table in survey data of coastal wetland area is to describe and present the characteristic of ecological coastal wetland area in Phetchaburi basin consisted of Biological characteristic, Soil characteristic and Hydrological characteristic.

3.5 Satellite Image Processing

Study on satellite data analyze both in Landsat 5-TM and SPOT-5 imageries is consisted of 6 study processes as this detailed following:

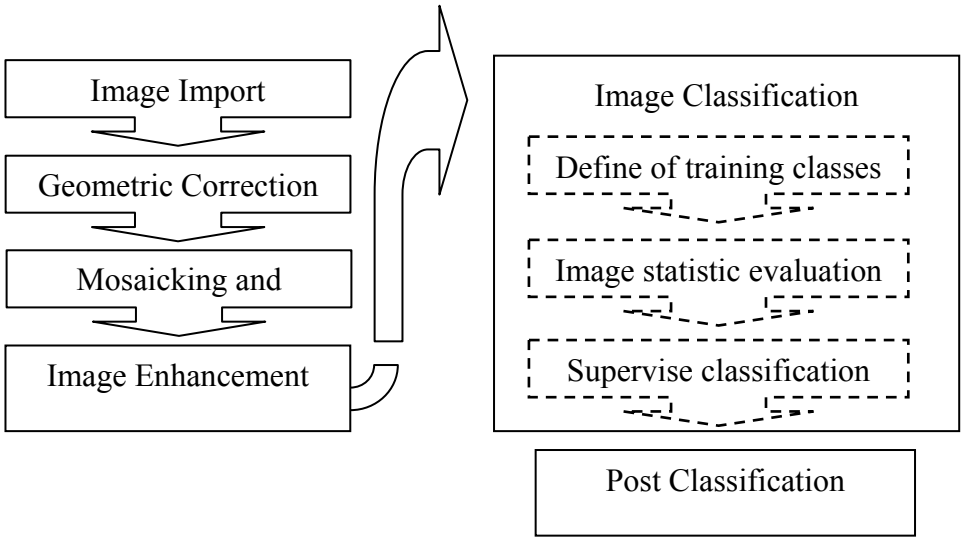

Figure 3.2 Satellite image processing diagram

3.5.1 Image Import

Collecting satellite image data both in Landsat 5-TM and SPOT-5 as shown in table 3-1, basically do the layer stacking by recording data in the same file, using program of Erdas Imagine 9.2 because of Landsat 5-TM's satellite image data has 7 bands and SPOT-5's satellite image data has 3 bands that convenient on analyze and show the mixed color image for technique of image enhancement.

3.5.2 Geometric correction

Geometric correction and distortion are happened in both of satellite image Landsat 5-TM and SPOT-5 to adapt the rectified image as a real reference image, and can make overlay with the database mapping and survey field data. By using program of ArgGIS 9.2 with image to map correction from identifying the Ground control point (G.C.P), it understands spatial of transportation route data layer. Then, it brings the spatial computing with Polynomial function to find spatial of satellite image data. By computing of Least square method is able to identify the exactly level by order of polynomial function, number, and spreading the G.C.P. that the computing is consisted of 3 processes:

1) Geometric coordination transformation is to calculate between image data's needs to edit (x^1,y^1) and reference image (x,y) by using the linear equation formula to search the new spatial called "Spatial Interpolation" that has formula as:

$$x^1 = a_0 + a_1x + a_2y$$

$$y^1 = b_0 + b_1x + b_2y$$

where : x^1 = column pixel of output image

y^1 = column pixel of output image

x = column pixel of original input image

y = column pixel of original input image

2) Least square regression method is find the root mean square error (RMS_{error}) of each ground control points with the value of RMS_{error} that accept the correction ± not over 1 pixel of satellite image data in this study's using. The formula is computes as:

$$RMS_{error} = \sqrt{(x^1 - x_{orig})^2 + (y^1 - y_{orig})^2}$$

where : x_{orig} , y_{orig} = original row and column coordinates of the GCP in the image

x',y' = compute coordinates in the original image

3) Interpolation is calculating a value of new image pixel after adapt spatial position. For this study uses computing on the nearest neighborhood that this method is to conserve mostly brightness value.

3.5.2 Mosaicking and Image Subsetting

Mosaicking and image subsetting (scene) for satellite image data up to 2 images with pixel size equally, and system of image spatial in familiar. For this process used for especially satellite image SPOT because there are 4 mosaicks by using program of Erdas Imagine 9.2. Then, editing satellite image data both of Landsat 5-TM and SPOT-5 with mapping data of coastal wetland boundary is reference in order to reduce data quality and saving time of computation.

3.5.3 Image enhancement

Image enhancement and shaping the satellite image data in study area that it is help to be visual interpretation. By classifying the land cover in the process of training area's identify on image processing mostly effective is to select the method of color composition of program of Erdas Imagine 9.2.

3.5.4 Image Classification

This study defines the classification class into 2 groups:

- Coastal Wetland defines the classification of land cover class of ecological coastal wetland characteristic by spectacle reflectance differently 6 types: Open Water, Farmland, Forest , Paddy Field, Scrub and Emergent. Some data are used for process correction.

- Nonwetland defines on mapping data of land use, such as Deciduous, Agriculture, Grass and Urban to distill the wetland data to be classified area exactly mostly. By training area of this group will help to protect other area away from wetland at 50 number of training site.

Classification Process has step as this following:

1) Define of training classes

It is process to bring the sampling of training data by GPS position identify of training area of color composite image on define of classification classes, select the training area with the same type distributed in studying area, and select pixel point more than 30 points to be represented in the best statistic of distributed normal. Its especially selection in the same group is to get sample of homogeneous.

2) Image statistic evaluation

It brings the training area data in each types to analyse by the fundamental statistic, such as Min-Max, Mean, Standard Deviation, Variance, Covariance in each types. By presenting histogram or Mean Plot of the spectral reflectance is to analyze the correlation between coastal wetland and qualitative testing of training sample with statistic value mixing in each class or not. This process is brought to select suitable band in classification.

3) Supervise classification

Supervise classification method uses the Decision Rule on Maximum Likelihood by taking the spectral reflectance to be index in classifying consideration on the data's types. For pixel is not in any statistic range that is selected into the unclassified group.

4) Post Classification

Image Reclassification is image filtering is a process of image filtering to remove the spot data of post-classification image with supervise classification by deciding statistic of majority to make more images smoothly.

3.6 Validation of Classification Result

Accuracy assessment on the result of satellite image data's classification by using the statistic's analyze of Confusion/ Error Matrix and Kappa Statistic , both of Landsat 5-TM and SPOT-5. It uses reference from GPS spatial by field survey in all ecological coastal wetland area in study area to present its effective how much the value of correction for the wetland detection and the wetland identification is getting.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Coastal Wetland Characterisitics

Surveying coastal wetlands in Phechaburi basin from 4 Districts, such as Ban Lham District, ThaYang District, Muang Phetchaburi District that consist of various coastal wetland types: open water, farmland, forest, scrub and emergent. The results of the study was found both of natural wetland and human-made wetland with 95 sampling points. Coastal wetlands found the most in Cha-Um District, Muang Phetchaburi District, ThaYang District, Ban Lham District, respectively. As shown in the table 4.1 by coastal wetland ecological characteristic as this:

Table 4.1 Coastal wetland types in study area

Coastal wetland types	Sample point		Description
	point	%	
Open Water	15	16	reservoir/ pond/ river/ sandy beach/ estuary
Farmland	23	24	aquaculture /salt farm/ paddy field
Forest	12	13	mangrove forest/ tree
Scrub	18	19	tree / shrub
Emergent	27	28	grassland/ sedge

4.1.1 Open water wetland

Open water found in both the natural water resource and human-made water resource. The 15 samples found in 6 sample of ThaYang District, 5 sample of Cha-Um District, 3 samples of Ban Lham District, and 1 samples of Muang Phetchaburi District, respectively. Open water has condition as river and water source with shallow water, deep water, and open coast sea. It can divided into 5 types: reservoir, pond, river, estuary, and sand. ThaYang District and Cha-Um District are

medium reservoir and beach, other open water will be pond or small pond. As shown in the table 4.2 by the open water characteristics as this:

Table 4.2 Open water wetland in study area

Open water class	Sample point	Description
Reservoir	4	NogTaBad reservoir, PuhWhai reservoir, WatNogRong reservoir, HuaySogSai reservoir
Pond	5	ThaYang pond, Huay ThaKaa pond, SonSirithron pond, Cha-Um well, Preda Swamp
River	1	Phechaburi River
Sandy beach	4	ChaoSomRan beach, LhamLuang beach, Cha-Um beach, PuakTein beach
Estuaries	1	Ban Lham estuary

1) Biological characteristic: The vegetations found to small size up to big size. The most of open water is deep more than 2 meter, that found the vegetations spreading around 10-30% on water surface or riverside which it differed as physical features and supporting factor of water regime (river status, water level, salinity). The open water as pond, reservoir is static water system and depth water level that find the floating plant, such as *Pistia stratiotes L.*, *Lemna perpusilla Torr.* and *Hydrocharitaceae*. The open water as river, estuary, open coast sea is shallow water level and water flow system up to influence on the tide water level that find the riparian plant, emergent plant, scrub, tree. The vegetation cover develop from the freshwater plant up to salty water plant, such as *Cyperaceae, Typha angustifolia L., Fern, Pithecellobium dulce, Pluchea indica, Mimosa pigra L., Ipomoea aquatica Forsk, Scindapsus pictus, Suaeda maritime, Syzygium gratum, Avicennia marina, Excoecaria agalloch*.

2) Soil characteristic: The soil types differ on the frequency flooding of water. Firstly, the geological characteristic is flood plain that find the clay soil, it had a few organic matter that suitable to build reservoir. Secondarily, the geological characteristic is coast plain that find the silty clay and mud, it had a high organic matter of fossil.Thirdly, the geological characteristic is beach and open coast sea that

find the sand soil, it had a lot of organic matter of shell in the soil. And finally the geological characteristic is coastal flat land often find the permanently inundate, it soil texture had gray. Some highland seasonally inundate, it can see the visual observation of watermark from the mottle color in soil texture. By detective the soil water content, it finds the emergent pant in area that shown in the condition of seasonally waterlogged.

3) Hydrological characteristic: The open water will divide into the water regimes. The open water is close water system has permanently inundate, such as reservoir, pond, well which the water level get from the rainfall. The open water is open water system had seasonally inundate, such as river, estuary, beach and open coast sea which the water level get from the freshwater in the river and sea level rise that effect on the salty of open water sources found in the period of 1-35 ppt.

4.1.2 Farmland wetland

Farmland likely to be the human-made wetlands such as, paddy field, salt farm, and aquaculture pond with the total 23 sampling points, the mostly found in, 9 samples of Muang Phetchaburi District, 6 samples of ThaYang District, 5 samples Ban Lham District, 3 samples Cha-Um District, respectively. Paddy field found in Muang Phetchaburi District and ThaYang District due to flat land. Salt farm and aquatic farming found in Ban Lham District and Cha-Um District due to its boundary connected on the coastlines, it convenient to take the sea water using for farmland. As shown in the table 4.3 by the farmland characteristics as this:

Table 4.3 Farmland wetland in study area

Farmland class	Sample point	Description
Paddy Field	16	in-season rice field, double-crop field
Salt Farm	4	salt flat, empty salt flat
Shrimp Farm	2	shrimp pond
Fish Farm	1	fishery pond

1) Biological characteristic: The vegetation types are differ on the land use. In the part of salt farm and aquaculture pond found the vegetations spreading around only 1-5% that mostly found on salt farm. The vegetation types is a halophyte, such as *Suaeda maritime, Avicennia marina, Rhizophora mucronata, Thespesia populnea(L.)* Farmland wetland is the most important in Phechaburi River as the result of fully with the paddy field area up to the important coastlines as fishery.

2) Soil characteristic: The soil type is clay soil which the suitable for waterlogged. Farmland wetland will find the soil matrix color gray up to dark grayish brown as the result from frequency on flooding water. It can shown in mottle color in soil texture. The organic matter instant mostly found dead plants with post harvesting in the soil about 20-60%.

3) Hydrological characteristic: Hydrological characteristic influence from the land use. The water regime of ThaYa District and Muang District would mostly get the water from reservoir, such as Phetchaburi dam that help them work on paddy field all season in the area of Phetchaburi River. By in-season rice field will do during on June-November and double-crop field will do during on December-May. The coastline boundary is pumping water from the sea because the area is not connected on the coastline that has water through all the year. The aquatic farming area found the salinity water in there.

4.1.3 Forest wetland

Forest wetland found 11 sample points such as, mangrove forest or terrestrial forest located in the riverside of Phetchaburi basin since Ban Lham District up to Cha-Um District. Forest wetland remained on forest's abundant due to working the project of research study and environmental development in LhamPukBea as the Royal Project and Department of Marine and Coastal Resources. This effect on mangrove forest area are keeping protected that found in 7 sample points of Cha-Um District, 2 sample points of Muang Phetchaburi District, 1 sample points of ThaYang District, respectively. Forest wetland has ecological characteristics as shown in the table 4.4 as this:

Table 4.4 Forest wetland in study area

Forest class	Sample point	Description
Mangrove forest	17	halophyte/ mesophyte
Forest	1	terrestrial plants

1) Biological characteristic: The vegetation cover is mangrove forest type that found in Ban Lham District, Cha-Um District, Muang Phetchaburi District, respectively. The spreading vegetations in the study area, one part found the aquatic plant in the general wetland was 10%. Mangrove forest has grow up distributed exactly area due to salt water factor identify their spreading, with coastline to estuary. The halophytes found in the forest wetland, such as *Rhizophora mucronata, Avicennia marina, Syzygium gratum, Xylocarpus obovatus, Excoecaria agallocha, Nipa fruticans Wurmb, Suaeda maritime, Acanthus ebracteatus Vahl, Thespesia populnea(L.).* Freshwater plants found in the forest wetland, such as coconuts, *Limonia, Acacia auriculiformis Cunn. Donation Stats.*and grass.

2) Soil characteristic: The soil type is clay soil as the result of the frequency on flooding of water from sea level rise. The matrix color is gray color to black color, with high the organic matter on the soil surface and soil texture. It appeared the smell of hydrogen sulfide gas obviously that presented on without oxygen within the soil texture which the presented marking used to have water and no water switching.

3) Hydrological characteristic: The coastline boundary got influence from the sea level rise with different on seasonal. It could observation of water mark, drift line or sediment deposit in study area. The low land area got influence from rainfall that has some of flooding in some seasonall.

4.1.4 Scrub wetland

Scrub wetland happened by nature that found shrub with 18 sample points of Cha-Um District, 12 sample points of Ban Lham District, 3 sample points of ThaYang District, 1 sample point of Muang Phetchaburi District , respectively that can divide into scrub and shrub. Scrub wetland has ecological characteristics as shown in the table 4.5 as this:

Table 4.5 Scrub wetland in study area

Scrub class	Sample point	Description
Scrub	14	bush, sedge
Shrub	4	tree shrub

1) Biological characteristic: The small scrub, small perennial plants or creeping plants are spreading by switching with space area, with density less than 50%. Scrub wetland have to similarity of vegetation cover and may be found emergent plant's combination, such as cactus, mimosa, *Pluchea indica Less., Acacia auriculiformis Cunn. Pithecellobium dulce,* and caladium.

2) Soil characteristic : The geological characteristic is coastal low land that it found seasonally waterlogged, especially in the rainy season. As a result of saturated soil's affects, that made the soil texture as silt clay soil and sandy soil. In this area, the soil texture is gray color. Whereas, the dry season, the soil is not saturated soil with grayish brown soil color.

3) Hydrological characteristic: The hydrological condition of scrub wetland receives effect from the seasonal rainfall. The inundation on scrub wetland area differ flooding period which depending on the type of soils. Due to sediment deposit presents in some area, the factor of water regime is not influence too much in the scrub wetland.

4.1.5 Emergent wetland

Emergent wetland is a vegetation type growing up in the low land. There are 28 sample points of marsh growing up by nature, such as 12 sample point of Muang Phetchaburi District, 9 sample points of Cha-Um District, 3 sample points of Ban Lham District, 3 sample points of ThaYang District, respectively. Emergent wetland combination with other wetland types, such as paddy field and scrub. Emergent wetland ecological characteristics as this:

1) Biological characteristic: The mostly, vegetation cover is category of emergent plants, such as *Typa angustifolia* and *Scirpus grossus*. Distribution of emergent plants is highest density in coastal wetlands. In marsh area, that found in the other vegetation types are category of floating plants only because the emergent plant

can adapt itself within the saturated soil condition. By saturated soil condition must have water level not excess 0.50 centimeter.

2) Soil characteristic: The soil type is clay and sandy clay soil, brown to gray color of soil texture. It occurred from flooding water that present highest marking of coastal wetland's types. It showed that once used to be flooded with long time. There was high organic substance on the soil surface from decompose of dead plants during without the water bog > 50%.

3) Hydrological characteristic : the water got influence the water surface and underground presented on water's flooding on the soil's surface and found water in the underground. As the appeared on hydrogen sulfide gas clearly in some area, it showed the soil without oxygen, with some season to be flooded.

4.2 Satellite Image Processing

Satellite data analysis is to find the spectacle statistic in coastal wetland of Landsat 5-TM and SPOT-5 satellite image data that consisted on this detailed study as:

4.2.1 Image Import

Working on layer stacking with gather the file together by using the program of Erdas Imagine 9.2 from Landsat 5-TM satellite image data with 7 band SPOT-5 satellite image data with 3 band. The image is collected in gray scale format with the digital number in between 0-255 of each band (table 4.1). The image data statistic has benefit on band selection as the potential benefit on spectral characteristic and data improvement on mixing color technique (figure 4.1 and figure 4.2), to identify the image data by the image data statistic. It presents the spreading of each band's brightness that means on spreading of data according to the objects' different is related on Mean and S.D.

Table 4.6 Presenting on statistic of satellite image data

Landsat 5-TM (Band)	**Statistics Information**			
	Min	**Max**	**Mean**	**S.D.**
1	0.00	244.00	41.65	48.31
2	0.00	127.00	19.66	23.02
3	0.00	158.00	20.74	25.19
4	0.00	171.00	35.95	42.85
5	0.00	255.00	44.39	56.39
7	0.00	255.00	20.04	27.11
SPOT-5 (Band)	**Statistics Information**			
	Min	**Max**	**Mean**	**S.D.**
1	0.00	254.00	67.62	82.74
2	0.00	255.00	71.38	89.56
3	0.00	255.00	71.61	88.20

Landsat5-TM satellite image data has 6 bands that divide into 3 groups according to spectral resolution: (1) Visible Light:Band 1(red) - 2(green) – 3(blue) (2) Near Infrared: Band 4 and 7 (3) Short Infrared: Band 5.

SPOT-5 satellite image data has 3 bands that divide into 2 groups according to spectral resolution: (1) Visible Light: Band 1(green) – 2(blue) (2) Near Infrared: Band 3.

In conclusion of study if any band is S.D. highly, it presents on the different on objects appeared on the ground. Therefore, technique of band's selection is suited for mixed color to identify the coastal freshwater wetland area characteristic, that consider on the band able to distill the data of all types of freshwater wetland ecological characteristic with the suitably mixing the image color creation.

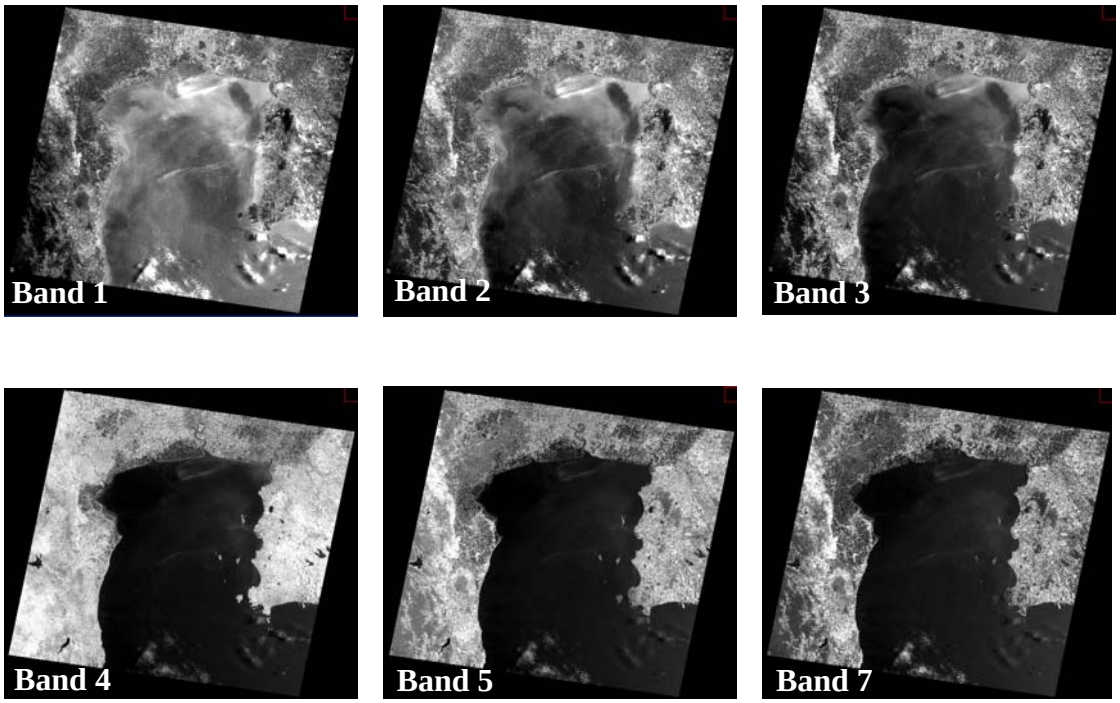

Figure 4.1 Landsat 5-TM imagery in six bands

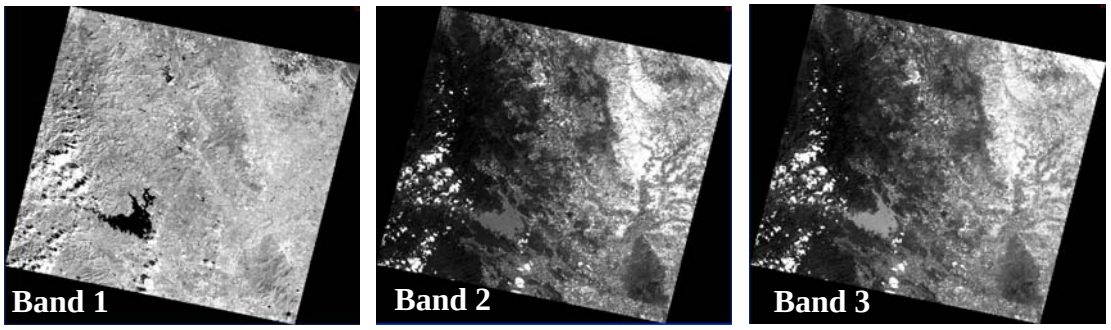

Figure 4.2 SPOT-5 imagery in three bands

4.2.2 Geometric correction

Geometric correction satellite image data into geo-referenced data by use the data of transportation route in system of WGS84 as reference data. It uses the program of Arc GIS 9.2 on method of image to map correction to select G.C.P. to find the coordinated of satellite image data. The error of correction criteria accepts not excess 1 pixel of Landsat 5-TM and SPOT-5 satellite image data. The geometric correction on polynomial function presents the details on table 4.7 as:

Table 4.7 Presenting the RMS_{error} on geometric correction by satellite image data

Satellite Imagery	Path/Row	Transformation (Order Polynomial)	Reference Points	RMS_{error}
Landsat 5-TM	129/051,130/051	1^{st}	9	9.06079
	K-J 261_323	1^{st}	23	0.87042
SPOT5	K-J 261_324	1^{st}	20	0.90829
Panchromatic	K-J 262_324	1^{st}	21	0.88166
	K-J 262_325	1^{st}	17	0.88825

The RMS_{error} of Landsat 5-TM imagery has excess 1 pixel due to position error of image, so the RMS_{error} is high. When accuracy overlay lot of maps, the value of error is in the criteria acceptation.

4.2.3 Image mosaicking and subsetting

Geometric correction image data will occur the swirl on the right picture due to image data of water absorb more energy. Therefore, it takes image mosaicking and subsetting to get especially image data in the needs of study area: coastal wetland area, Phetchaburi basin that cover the governor area 4 Districts of Phetchaburi Province, such us Ban Lham District, Muang Phetchaburi District, ThaYang District, and Cha-Um District. By using the program of Erdas Imagine 9.2 with total area studying 1,872.53 square kilometer (1,170,330 rai) as shown in figure 4.3.

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4.2.4 Image enhancement

Emphasis on the satellite Image enhancement is clearing of spectral enhancement data in the study area. By using the program of Erdas Imagine 9.2 help in separate each other objects clearly and convenient for visual interpretation selecting the training area. For supervise classification uses the technique of false color composite with spectral characteristics represented using red-green-blue color as the represent of characteristic on plant-soil-water of coastal wetland area. The Landsat5-TM satellite image selecting the appropriate bands combination 4-5-3 of color composite due to potential beneficial on wave of green, red, near-Infrared as represent of plants, forest, water, geography, soil that separate the part of water and non water as shown in the figure 4.3.

4.2.5 Image Classification

The satellite image processing for supervise classification by using the program of Erdas Imagine 9.2, after passing all processes above, it get the quality data to analysis the result as the characteristic of land cover class of coastal wetlands. As the sampling point data from field survey is training samples consist of this detail as:

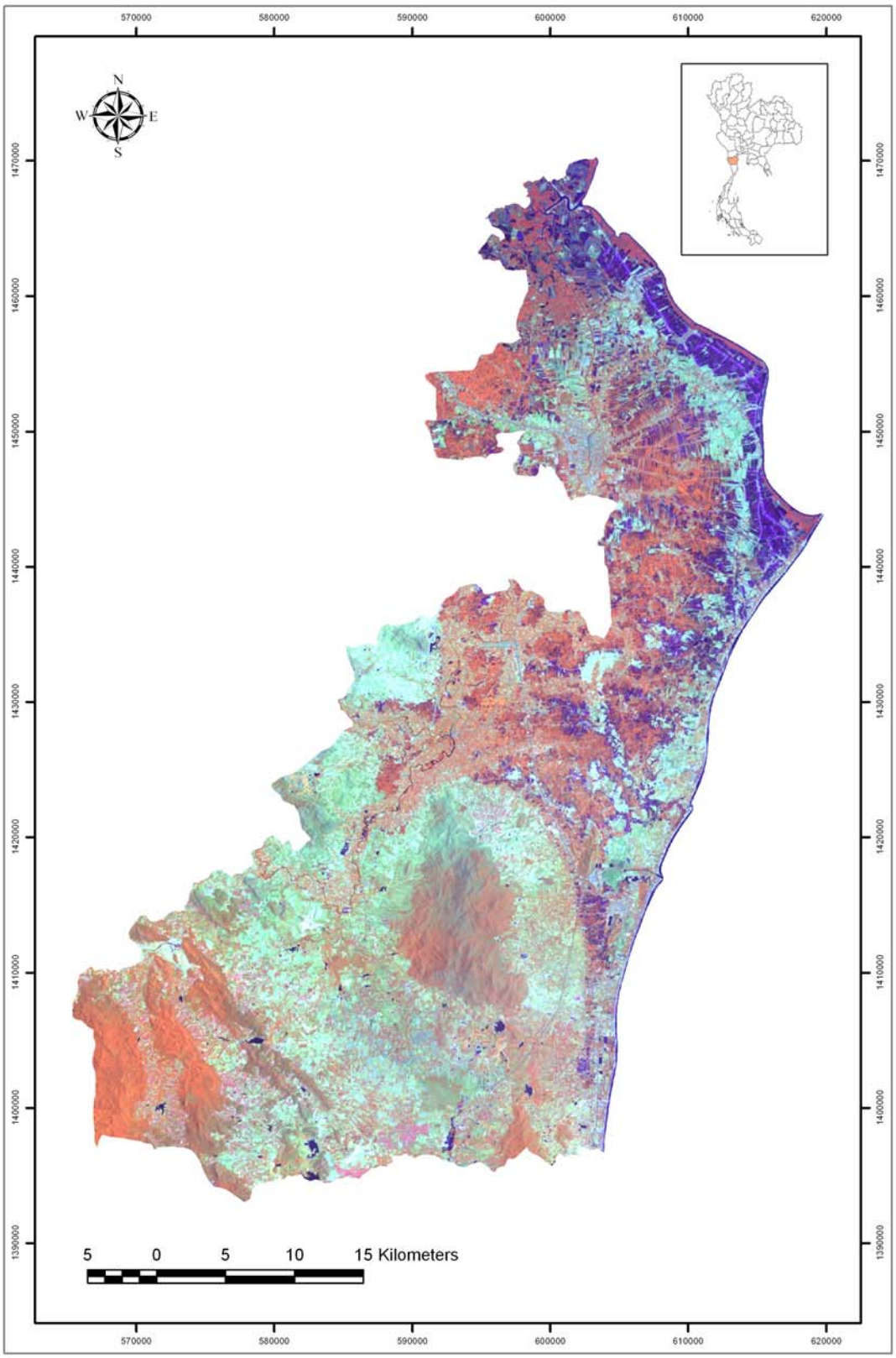


Figure 4.3 False color composite of Landsat 5-TM imagery

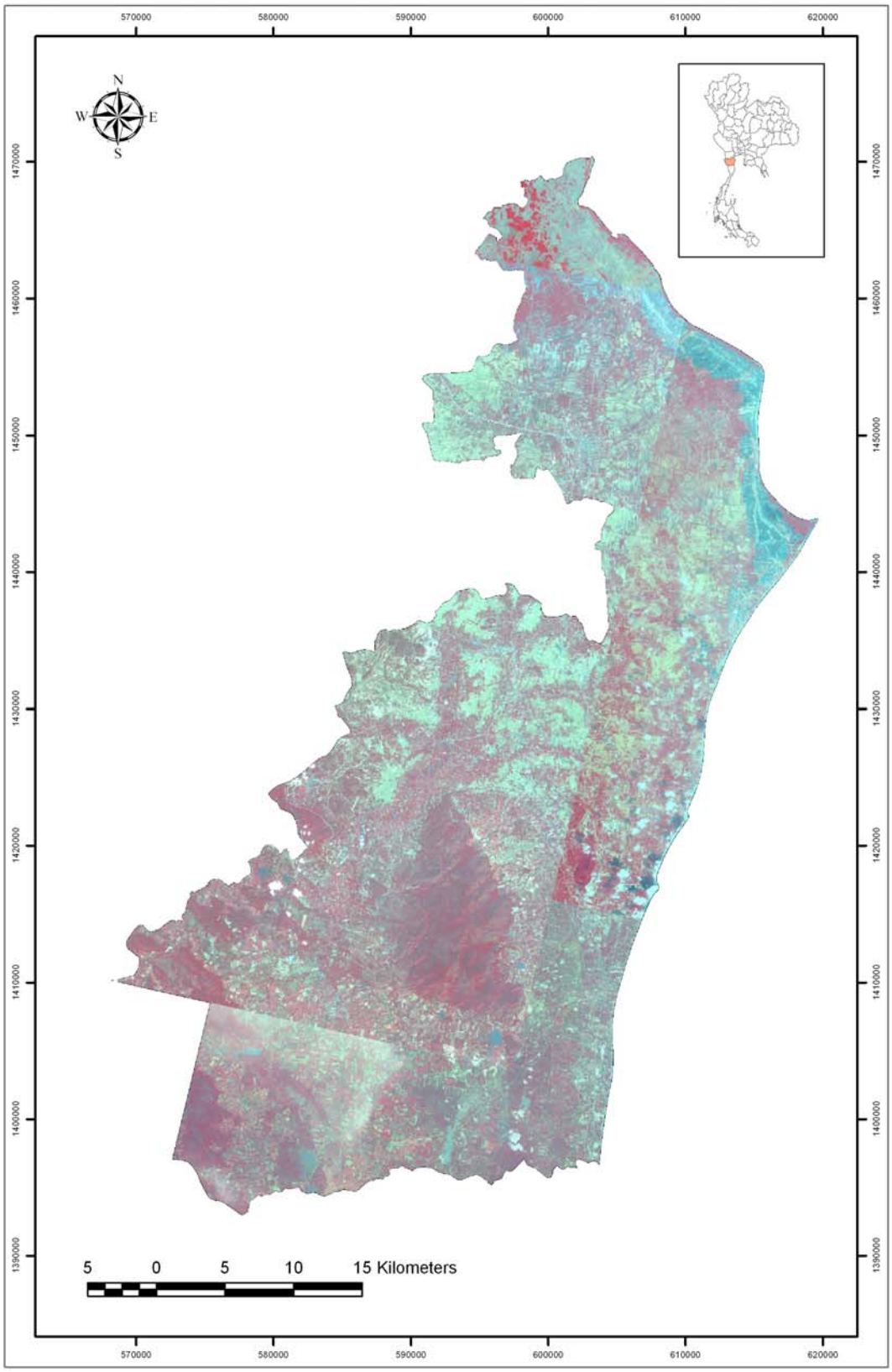


Figure 4.4 False color composite of SPOT-5 imagery

1) Define of classification classes

Identify the training sites into two groups: Coastal wetlands and Nonwetland by training site from GPS. The relation of spectral reflectance and coastal wetland characteristic which indicate any area is to be wetland detection or wetland identification will identify the training site as the spectacle image that it is the represent for analyze the result of satellite data on supervise classification. It is divided the training site of coastal wetland in to six types: Open water , Farmland, Forest, Paddy Field, Scrub, and Emergent. And four types of Nonwetland as land cover class: Deciduous, Agriculture, Grass and Urban (figure 4.4)

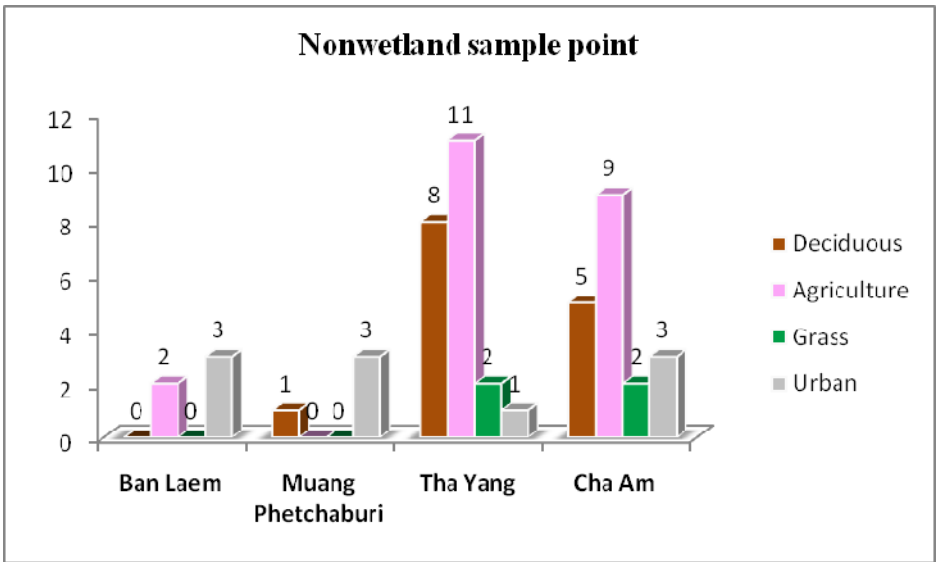
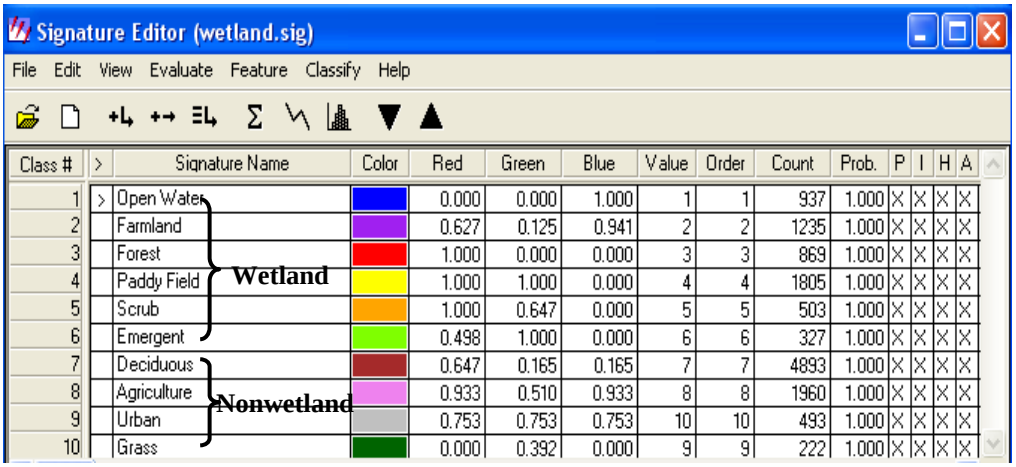


Figure 4.5 Nonwetland sample points

Identify the training area of coastal wetland group from 95 sampling points, it brings 63 sampling points using (32 samples left use for accuracy correction of classification), and 50 sample points of Nonwetland.

By selecting the training area in each of data type > 30 pixel and try to select image data color that present the homogeneous spectacle objects as shown in the figure 4.5. For selecting of training area is statistic data that analysis on identification to the class of land cover.



Class #	Signature Name	Color	Red	Green	Blue	Value	Order	Count	Prob.	P	I	H	A
1	Open Water		0.000	0.000	1.000	1	1	937	1.000	X	X	X	X
2	Farmland		0.627	0.125	0.941	2	2	1235	1.000	X	X	X	X
3	Forest		1.000	0.000	0.000	3	3	869	1.000	X	X	X	X
4	Paddy Field		1.000	1.000	0.000	4	4	1805	1.000	X	X	X	X
5	Scrub		1.000	0.647	0.000	5	5	503	1.000	X	X	X	X
6	Emergent		0.498	1.000	0.000	6	6	327	1.000	X	X	X	X
7	Deciduous		0.647	0.165	0.165	7	7	4893	1.000	X	X	X	X
8	Agriculture		0.933	0.510	0.933	8	8	1960	1.000	X	X	X	X
9	Urban		0.753	0.753	0.753	10	10	493	1.000	X	X	X	X
10	Grass		0.000	0.392	0.000	9	9	222	1.000	X	X	X	X

Figure 4.6 Signature of Training area

2) Image statistic evaluation

Training area choose to study the fundamental statistic on training area's analysis with liability and good representative in each wave range and choose the band appropriate for image classification, the result of study can present as this detailed:

2.1 Open water wetland

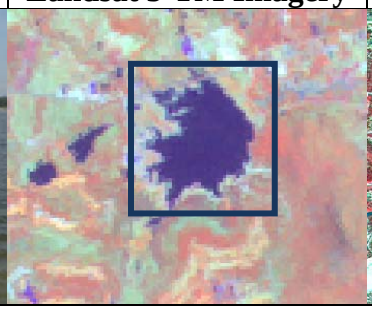
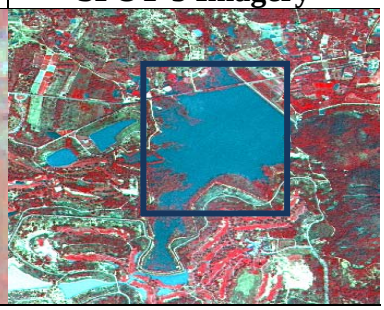
Field Survey	Landsat 5-TM Imagery	SPOT-5 Imagery
		

Figure 4.7 Presents the open water wetland characteristic by photo and satellite imageries

Table 4.8 Landsat 5- TM statistics information of open water wetland

Open Water						
Band (μm)	1 (0.45-0.52)	2 (0.52-0.60)	3 (0.63-0.69)	4 (0.76-0.90)	5 (1.55-1.75)	7 (2.08-2.35)
Univariable statistics						
Mean	92.943	40.868	38.498	34.899	34.398	16.178
S.D.	9.529	5.798	7.932	9.069	12.832	5.536
Variance	90.797	33.617	62.913	82.251	164.669	-2.820
Minimum	78.000	32.000	28.000	21.000	12.000	6.000
Maximum	122.000	59.000	67.000	89.000	105.000	56.000

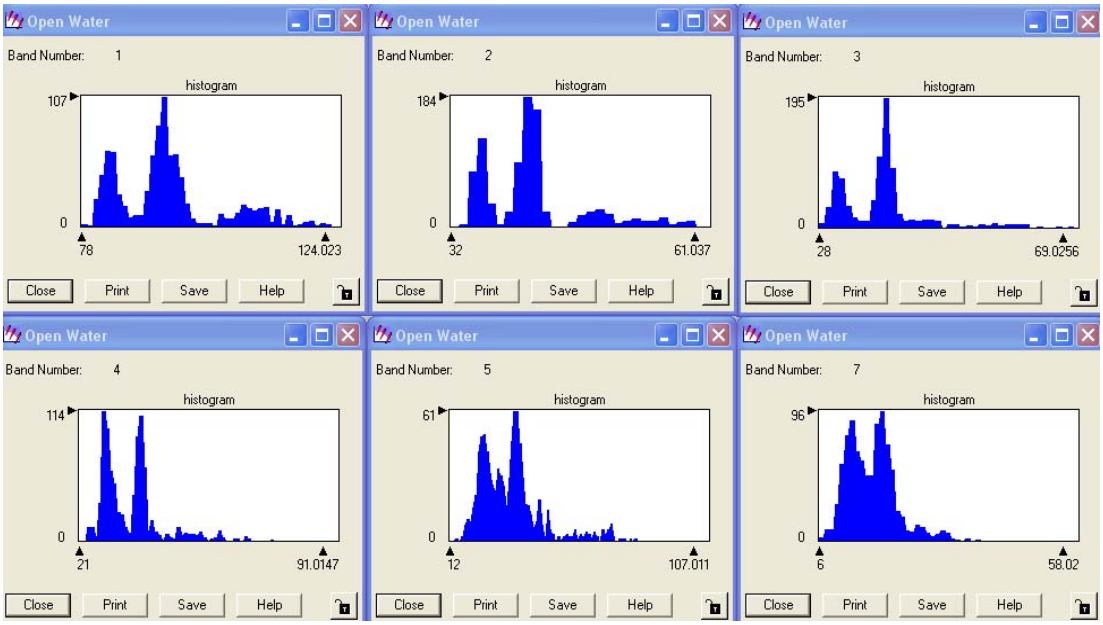


Figure 4.8 Histogram of open water wetland in Landsat 5-TM imagery

The spectral reflectance on open water wetland of Landsat 5-TM satellite image data (table 4.8) found its highest mean was band 1, and spectral reflectance of another band reduced because of the composition of main open water wetland's was water. Water has quality to absorb electromagnetic radiation. Therefore, mean of spectral reflectance has low closely to 0, when consideration of S.D. found that less S.D. presented that the water is clear. The spectral reflectance of open water would variable on water's contamination, consensus on the resulted study of field survey's data, it found the plants covered the water surface. When considering a histogram (figure 4.7) of open water at band 1 found the spreading most of spectral reflectance

on normal curve, means that the means of training area as good average representative. Therefore, band 1 was suited for mostly study about the open water wetland.

Table 4.9 SPOT-5 statistics information of open water wetland

Open Water			
Band (μm)	1 (0.50-0.59)	2 (0.61-0.68)	3 (0.79-0.89)
Univariable statistics			
Mean	123.866	183.922	194.032
S.D.	43.525	39.162	30.396
Variance	1894.402	1533.698	923.888
Minimum	44.000	111.000	136.000
Maximum	217.000	255.000	255.000

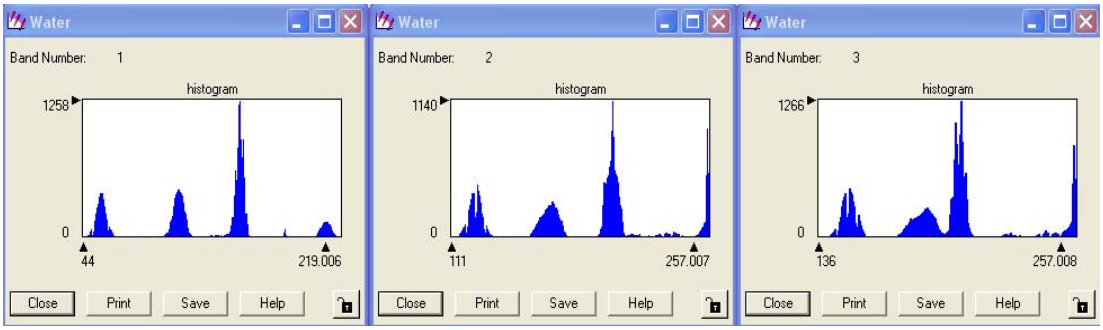


Figure 4.9 Histogram of open water wetland in SPOT-5 imagery

The value of spectral reflectance on open water wetland from SPOT-5 satellite image data (table 4.9) found its mean's similar was band 2-3, and with a lowest of Band 1, by the resulted study differently at Landsat 5-TM satellite image data. Due to high spectral reflectance of open water wetland, spectral reflectance closed to 225 means that the open water wetland has high spectral reflectance, in contrast to the resulted study about the value should be closed to 0; more absorb increasingly. By analysis on high spatial resolution of SPOT-5 satellite imagery data that perhaps effect on training area with high water's contamination, consensus on a field survey data that found on the plants covered the water surface. When considered the histogram found that the training area of open water has spread spectral reflectance in normal curve at band 1, that presented the average of training area was a good representative for study about open water wetland.

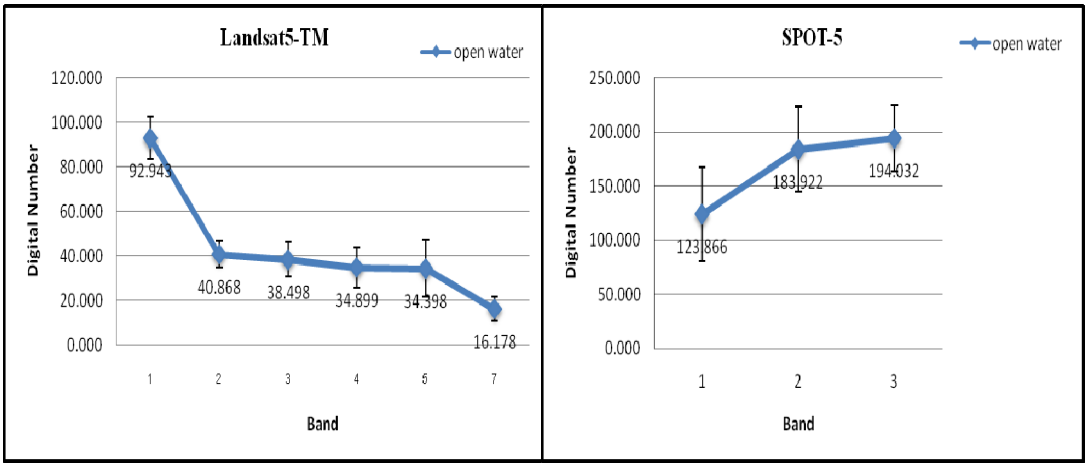


Figure 4.10 Open water signature mean plot

Studying of spectral signature (figure 4-9) found that open water wetland has high homogeneous presented on a stable graph line because the water has qualification of absorbing. The spectral reflectance would different on water's turbidity, deep water, and quality of plants. Therefore, suitably band to identify the open water from the other types of coastal wetland was the good band could reflect the plants (Landsat 5-TM=band 1, SPOT-5=band 1).

2.2 Farmland wetland

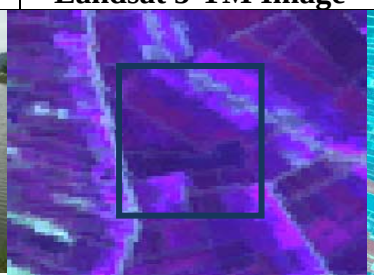
Field Survey	Landsat 5-TM Image	SPOT-5 Image
		

Figure 4.11 Present the farmland wetland characteristic by photo and satellite imageries

Table 4.10 Landsat 5- TM statistics information of farmland wetland

Farmland						
Band (μm)	1 (0.45-0.52)	2 (0.52-0.60)	3 (0.63-0.69)	4 (0.76-0.90)	5 (1.55-1.75)	7 (2.08-2.35)
Univariable statistics						
Mean	101.437	47.918	50.961	44.329	35.403	17.825
S.D.	8.992	7.842	12.751	10.303	15.237	8.050
Variance	80.856	61.498	162.597	106.158	232.181	64.809
Minimum	88.000	35.000	32.000	24.000	14.000	7.000
Maximum	135.000	82.000	103.000	81.000	96.000	56.000

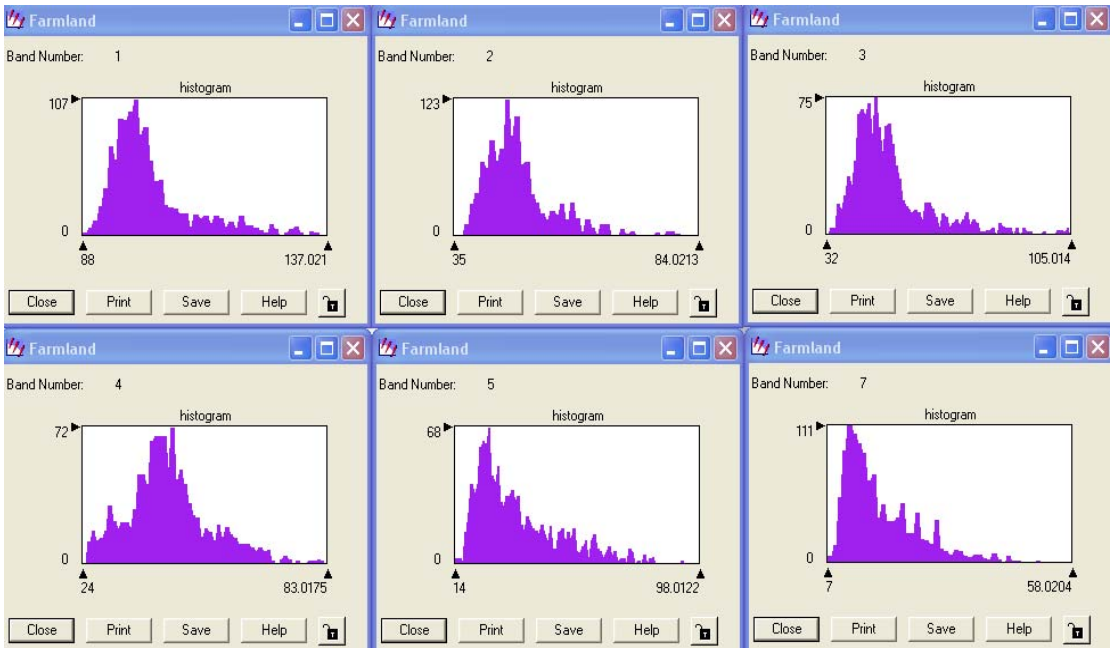


Figure 4.12 Histogram of farmland wetland in Landsat 5-TM imagery

The spectral reflectance on farmland wetland of Landsat 5-TM satellite image data (table 4.10) found its highest mean was band 1, and another band of spectral reflectance reduced because of the main farmland wetland's composition was water as same as characteristic of open water wetland. Due to physical characteristic of training area similar to water, but spectral reflectance got more higher because of higher water's contamination, such as salt farming and shrimp farming. The contamination would high reflect qualification. When considering a histogram (figure 4.11), it found a reflectance's asymmetrical that leaning on right side, the water has less homogeneous depending on the contaminated water differently. By consideration

of S.D. found that Band 1, 2, and 7 has less S.D. that the average of training was the good representative for study about farmland wetland.

Table 4.11 SPOT-5 statistics information of farmland wetland

Farmland			
Band (μm)	1 (0.50-0.59)	2 (0.61-0.68)	3 (0.79-0.89)
Univariable statistics			
Mean	131.311	208.648	215.666
S.D.	29.889	33.996	27.737
Variance	893.977	1155.714	769.360
Minimum	81.000	158.000	172.000
Maximum	187.000	254.000	254.000

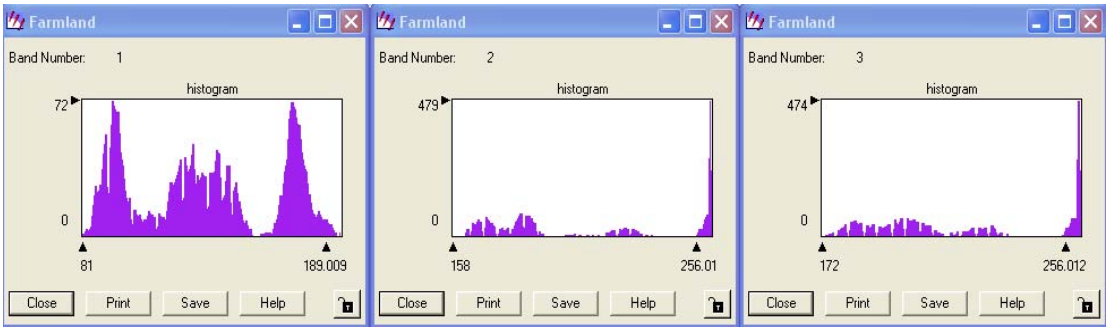


Figure 4.13 Histogram of farmland wetland in SPOT-5 imagery

The spectral reflectance on farmland wetland of SPOT-5 satellite image data (table 4.11) found its mean's similar was band 2-3, and with a lowest of band 1. By the resulted study of spectral reflectance closed to 225 presented at high spectral reflectance because the recorded date of satellite was a period of salt's crystallization. When considering a histogram (figure 4.12), it found the farmland would spread on spectral reflectance's on normal curve at most of band 1, with consensus on least of S.D. mean that the average of training was the good representative.

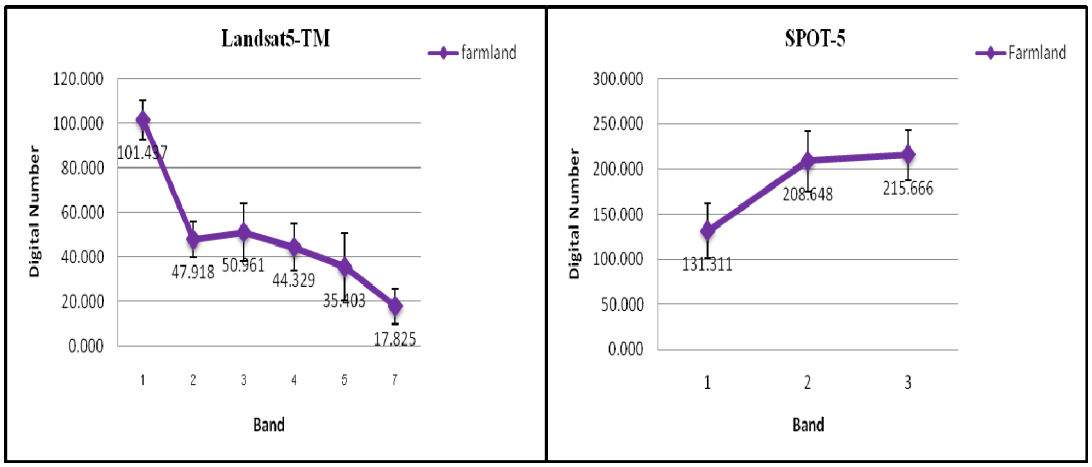


Figure 4.14 Farmland signature mean plot

Studying of spectral signature (figure 4.13) found that farmland has high homogeneous because of the main of water's composition, which has qualification of absorbing electromagnetic radiation. However, the spectral reflectance would different on water's contamination, that different on open water wetland gained influence on the plants' quality. Nevertheless, farmland wetland would variable on the crystallized salt. Therefore, suitably band to identify the farmland from the other types of coastal wetland that was the best band's reflection and separated farmland from the open water wetland because of high spectral reflectance (Landsat 5-TM=band 1, SPOT-5=band 1).

2.3 Forest wetland

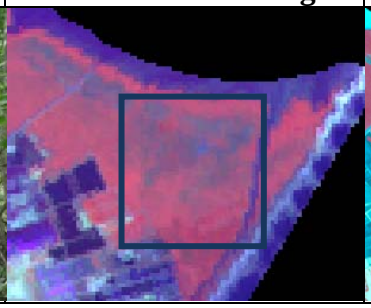
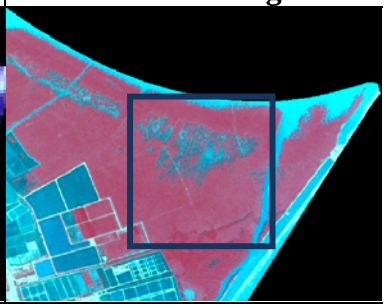
Field Survey	Landsat 5-TM Image	SPOT-5 Image
		

Figure 4.15 Presents the forest wetland characteristic by photo and satellite imageries

Table 4.12 Landsat 5- TM statistics information of forest wetland

Forest						
Band (μm)	1 (0.45-0.52)	2 (0.52-0.60)	3 (0.63-0.69)	4 (0.76-0.90)	5 (1.55-1.75)	7 (2.08-2.35)
Univariable statistics						
Mean	92.351	42.133	37.207	85.024	57.123	18.848
S.D.	23.400	1.496	1.816	7.359	4.131	2.759
Variance	5.475	2.238	3.298	54.148	17.067	7.613
Minimum	87.000	38.000	34.000	60.000	49.000	13.000
Maximum	111.000	53.000	54.000	105.000	84.000	41.000

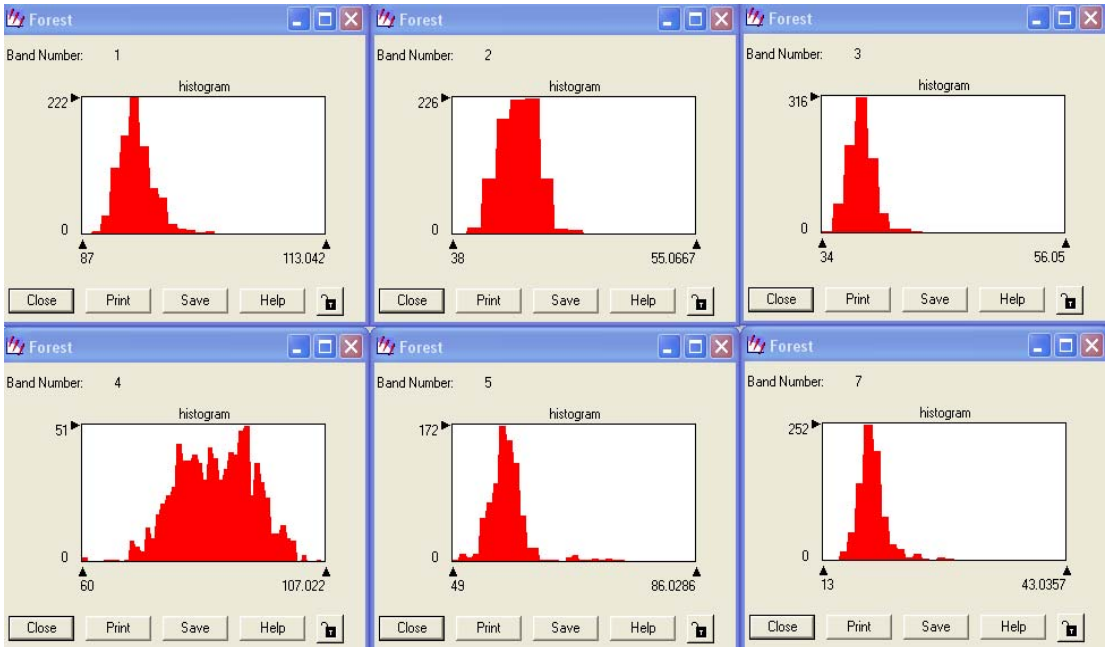


Figure 4.16 Histogram of forest wetland in Landsat 5-TM imagery

The spectral reflectance on forest wetland of Landsat 5-TM satellite image data (table 4.12) found its highest mean was band 1 and 4, but there were similar on band 2, 3, 5, and 7. By spectral reflectance of mangrove forest influenced on waterlogging and quality of plant's humidity, in contrast, the value of spectral reflectance diminish because of absorbing quality of electromagnetic radiation on water. The value of S.D. found that band 1 and 4 was high with consensus on above factors. When considering a histogram (figure 4.15), it found the forest wetland would spread on spectral reflectance's on normal curve at most of band 4 as near-Infrared

band that used for separating the type of plants. Therefore, band 4 was suited for identification of forest wetland apart from the other types of coastal wetland.

Table 4.13 SPOT-5 statistics information of forest wetland

Forest			
Band (μm)	1 (0.50-0.59)	2 (0.61-0.68)	3 (0.79-0.89)
Univariable statistics			
Mean	179.236	143.632	165.437
S.D.	9.836	14.416	10.516
Variance	96.752	207.809	110.579
Minimum	108.000	115.000	132.000
Maximum	225.000	254.000	254.000

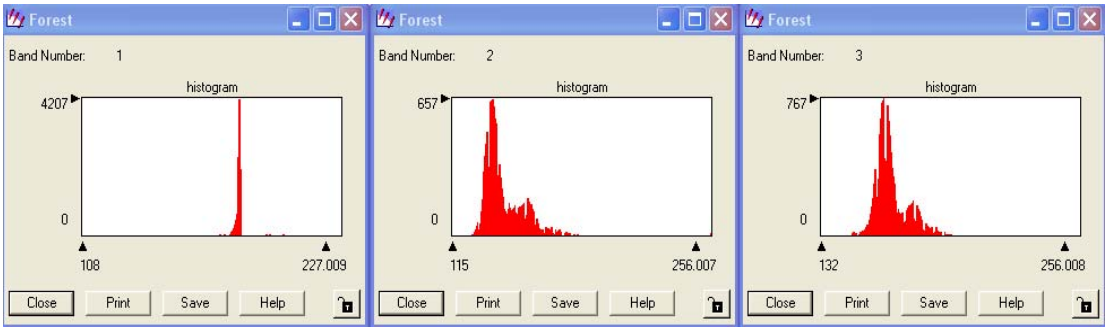


Figure 4.17 Histogram of forest wetland in SPOT-5 imagery

The spectral reflectance on forest wetland of SPOT-5 satellite image data (table 4.13) found its highest mean was band 1, 3, and 2 respectively. Due to band 1 as green band that used for study about plant's types, and band 3 as near-Infrared band that used for identify the plant's types. Meanwhile, band 2 would have the most of S.D.'s variance because the red band indicated the abundance of plants, with consensus on field survey about biodiversity of mangrove forest types that consisted of a natural mangrove forest and plantation of various projects. When considering a histogram, it found the training area would spread on spectral reflectance's on normal curve at most of band 3 that a good average representative for forest wetland identification away from the other types of coastal wetland.

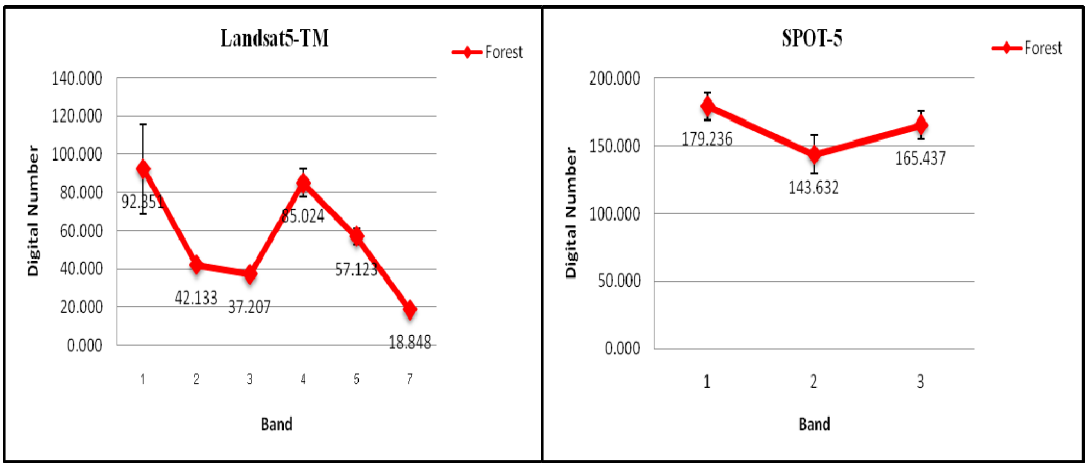


Figure 4.18 Forest signature mean plot

Studying of spectral signature (figure 4.17) found that the forest wetland has high spectral reflectance at near-Infrared band because it was good for study on spectral reflectance of plants. Therefore, suitably band to identify the forest wetland from the other types of coastal wetland was the good band could reflect the plants (Landsat 5-TM=band 4, SPOT-5=band 3).

2.4 Paddy field wetland

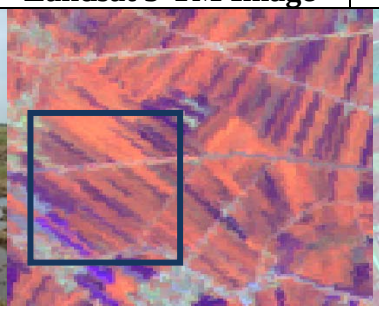
Field Survey	Landsat 5-TM Image	SPOT-5 Image
		

Figure 4-19 Present the paddy field wetland characteristic by photo and satellite imageries

Table 4.14 Landsat 5- TM statistics information of paddy field wetland

Paddy Field						
Band (μm)	1 (0.45-0.52)	2 (0.52-0.60)	3 (0.63-0.69)	4 (0.76-0.90)	5 (1.55-1.75)	7 (2.08-2.35)
Univariable statistics						
Mean	90.251	40.852	37.099	81.812	68.565	26.025
S.D.	6.746	4.183	7.412	19.150	23.892	11.971
Variance	45.508	17.494	54.937	366.741	570.809	143.296
Minimum	82.000	35.000	30.000	37.000	19.000	9.000
Maximum	117.000	60.000	74.000	129.000	168.000	83.000

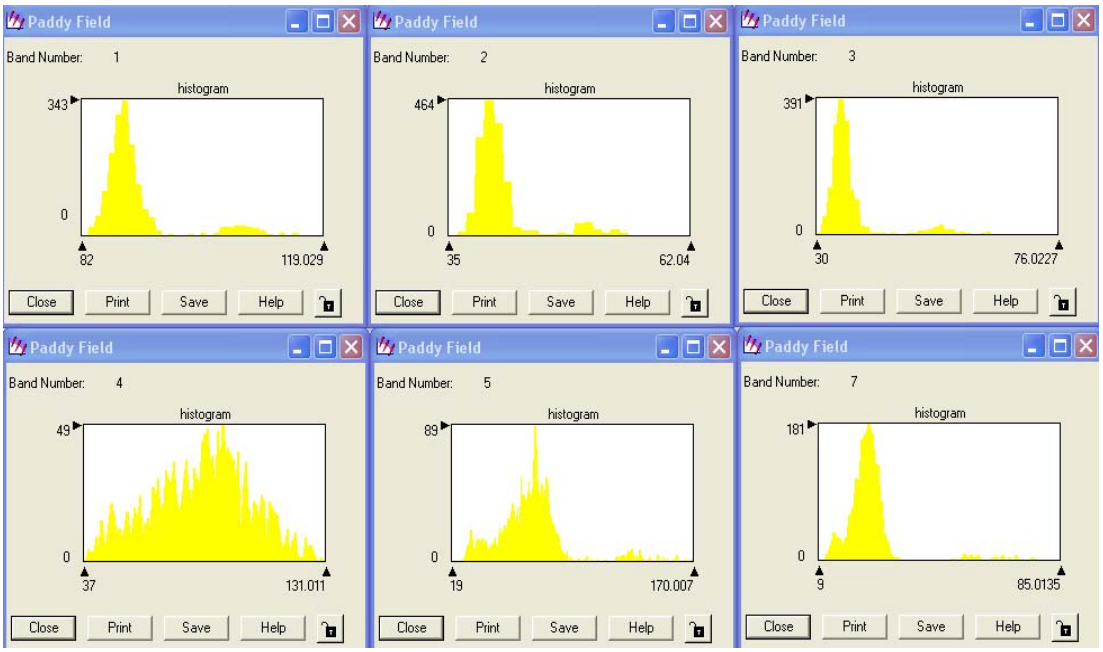


Figure 4.20 Histogram of paddy field wetland in Landsat 5-TM imagery

The spectral reflectance on paddy field wetland of Landsat 5-TM satellite image data (table 4.14) found its highest mean was band 1, 4, but the others were similar. The value of S.D. found in study area with high variance that has 2 types of paddy field: in-season rice field and double-crop field effected on different highly spectral reflectance. When considering a histogram (figure 4.19), it found the training area would spread on spectral reflectance's normal curve at most of Band 4 as a good average representative for paddy field wetland's identification apart from other types of coastal wetland.

Table 4.15 SPOT-5 statistics information of paddy field wetland

Paddy Field			
Band (μm)	1 (0.50-0.59)	2 (0.61-0.68)	3 (0.79-0.89)
Univariable statistics			
Mean	173.943	225.494	202.435
S.D.	9.895	33.380	18.208
Variance	97.906	1114.210	331.520
Minimum	124.000	128.000	137.000
Maximum	209.000	255.000	254.000

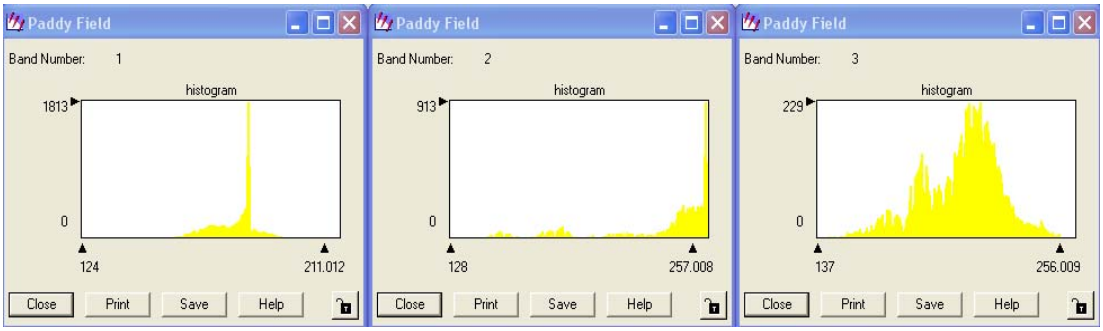


Figure 4.21 Histogram of paddy field wetland in SPOT-5 imagery

The spectral reflectance on paddy field wetland of SPOT-5 satellite image data (table 4.15) found its highest mean was band 2, 3, and 1 respectively. Due to satellite imagery's recorded time was harvesting production of double-crop field; the paddy field has less chlorophyll's quality. Therefore, high spectral reflectance at band 2 (red band) more than band 3 (near-Infrared band) that consensus on S.D.'s variance. When considering a histogram (figure 4.20), it found the training area would spread on spectral reflectance on normal curve at most of band 3 as a good average representative for paddy field wetland's identification apart from other types of coastal wetland.

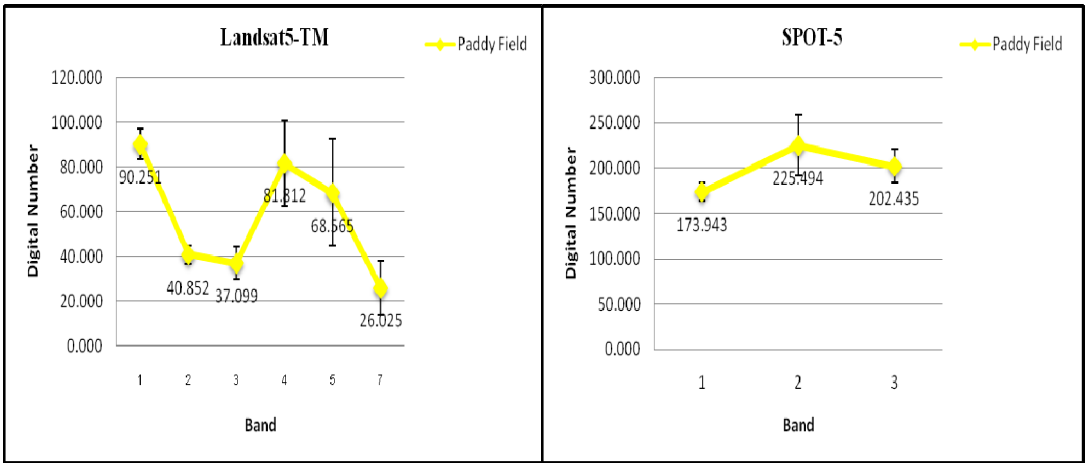


Figure 4.22 Paddy field signature mean plot

Studying of spectral signature (figure 4.21) found that the paddy field wetland has different between Landsat 5-TM and SPOT-5 satellite imagery because making a double-crop field during on January to May and making a in-season rice field during on June to December. Therefore, suitably band to identify the paddy field wetland from the other types of coastal wetland was the good band could reflect the plants (Landsat 5-TM=band 4, SPOT-5=band 3).

2.5 Scrub wetland

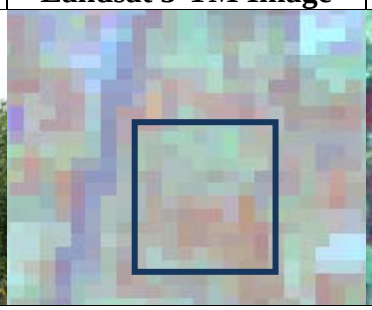
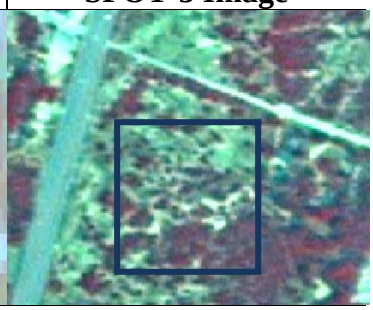
Field Survey	Landsat 5-TM Image	SPOT-5 Image
		

Figure 4.23 Represent the scrub wetland characteristic by photo and satellite imageries

Table 4.16 Landsat 5- TM statistics information of scrub wetland

Scrub						
Band (μm)	1 (0.45-0.52)	2 (0.52-0.60)	3 (0.63-0.69)	4 (0.76-0.90)	5 (1.55-1.75)	7 (2.08-2.35)
Univariable statistics						
Mean	102.604	48.076	49.668	86.083	106.849	47.547
S.D.	5.603	4.092	6.964	6.603	16.230	10.426
Variance	31.391	16.747	48.493	43.603	263.427	108.710
Minimum	92.000	39.000	37.000	52.000	42.000	19.000
Maximum	128.000	68.000	80.000	105.000	153.000	82.000

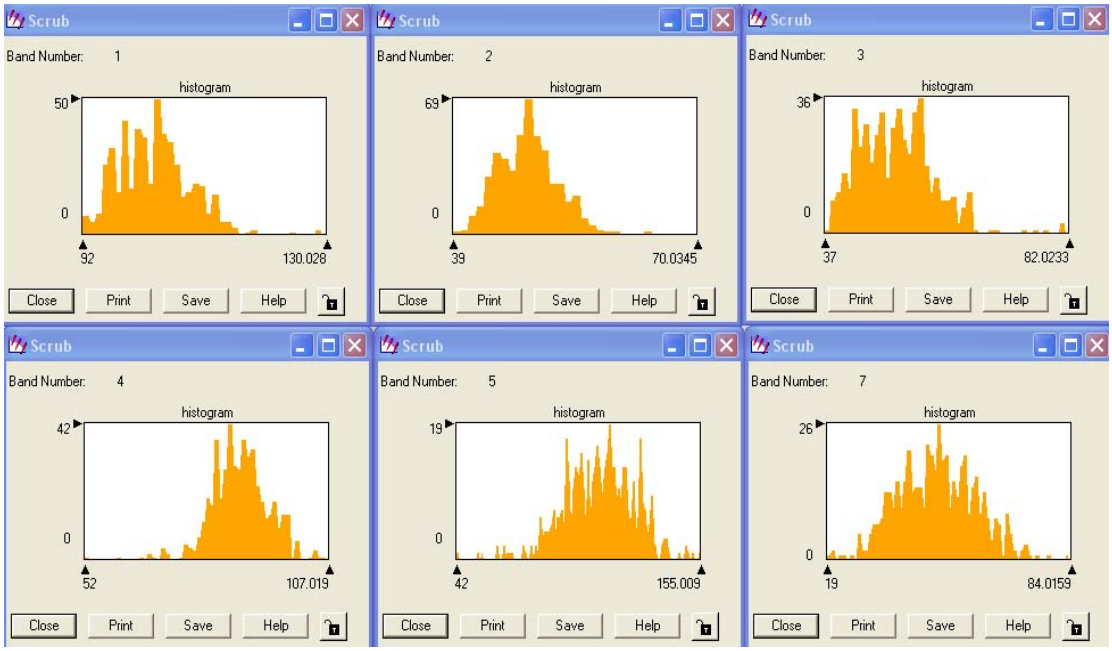


Figure 4.24 Histogram of scrub wetland in Landsat 5-TM imagery

The spectral reflectance on Scrub wetland of SPOT-5 satellite image data (table 4.16) found its highest mean was band 5, 1, and 4 respectively, but the other bands were similar. The most of spectral reflectance quites low because the scrub wetland is a kind of small plant, less chlorophyll quality. Less S.D.'s variance at each band as the result of less diversity of vegetation cover, however, the spectral reflectance of scrub wetland was high at band 5 and 1 as the influence on soil by field survey in scrub wetland, appeared on bare soil. When considering a histogram (Figure 4-23), it found the training area would spread on spectral reflectance on normal curve at most of band 7 that mid-Infrared band used for study of plants' humidity, as a good

average representative for scrub wetland identification apart from the other types of coastal wetland.

Table 4.17 SPOT-5 statistics information of scrub wetland

Scrub			
Band (μm)	1 (0.50-0.59)	2 (0.61-0.68)	3 (0.79-0.89)
Univariable statistics			
Mean	118.000	117.000	127.000
S.D.	14.798	32.545	24.025
Variance	218.922	1059.145	577.206
Minimum	118.000	117.000	127.000
Maximum	201.000	255.000	255.000

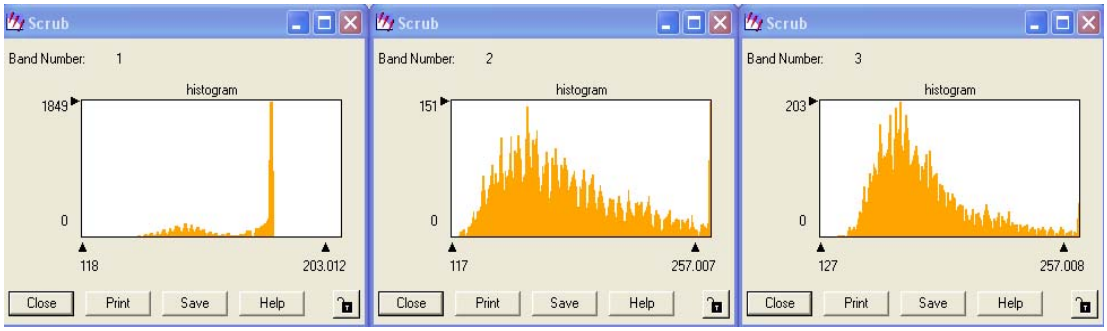


Figure 4.25 Histogram of scrub wetland in SPOT-5 imagery

The spectral reflectance on scrub wetland of SPOT-5 satellite image data (table 4.17) found its highest mean was band 3, and similar on band 1 and 2. But the value of S.D. would have most at band 2 due to being as red band that used for study of plants' abundant, with consensus on scrub wetland by field survey that found the low chlorophyll of plants. When considering a histogram (figure 4.24), it found the scrub wetland would spread on spectral reflectance on normal curve of training area at band 2 and 3 that a good average of training area as representative for scrub wetland's identification apart from other types of coastal wetland. However, band 3 was the most suited as near-Infrared band that used for a good study about plant.

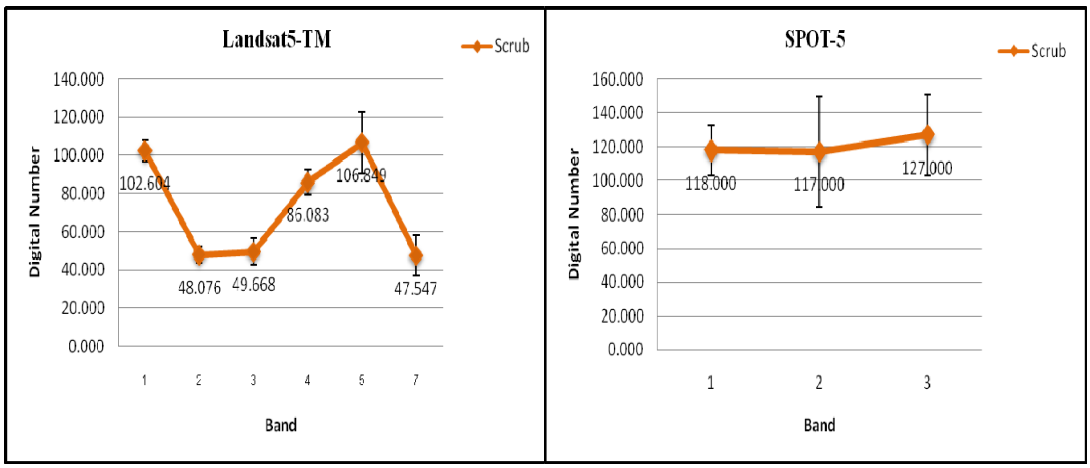


Figure 4.26 Scrub signature mean plot

Studying of spectral signature (figure 4.25) found that the scrub wetland has good reflected in infrared band that related on physical characteristic of plant. The scrub wetland is a kind of humid plant influenced on waterlogging in some season that effected on landed plants differently, and less diversity of vegetation cover. Therefore, suitably band to identify the scrub wetland from the other types of coastal wetland that was the good band could reflect the plants (Landsat 5-TM=band 7, SPOT-5=band 3).

2.6 Emergent wetland

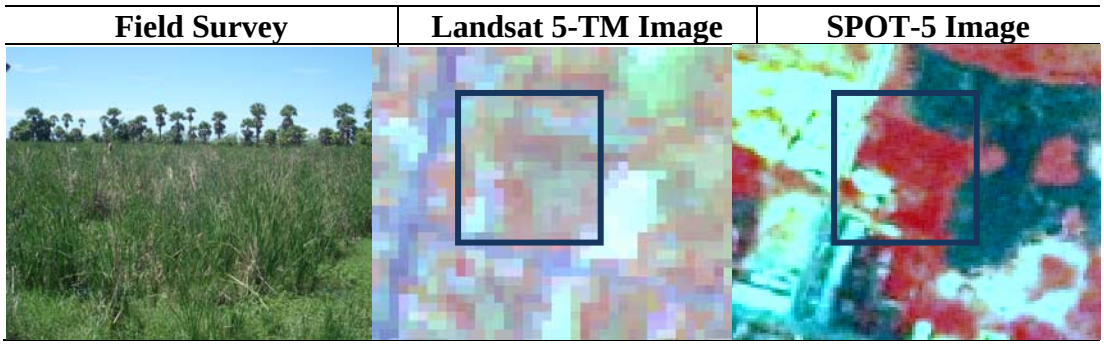


Figure 4.27 Represent the emergent wetland characteristic by photo and satellite imageries

Table 4.18 Landsat 5-TM statistics information of emergent wetland

Emergent						
Band (μm)	1 (0.45-0.52)	2 (0.52-0.60)	3 (0.63-0.69)	4 (0.76-0.90)	5 (1.55-1.75)	7 (2.08-2.35)
Univariable statistics						
Mean	101.823	48.052	51.633	84.260	114.954	53.887
S.D.	7.291	4.881	9.003	8.759	26.326	15.813
Variance	53.152	23.822	81.061	76.714	693.068	250.039
Minimum	89.000	40.000	37.000	60.000	68.000	25.000
Maximum	126.000	68.000	83.000	105.000	192.000	101.000

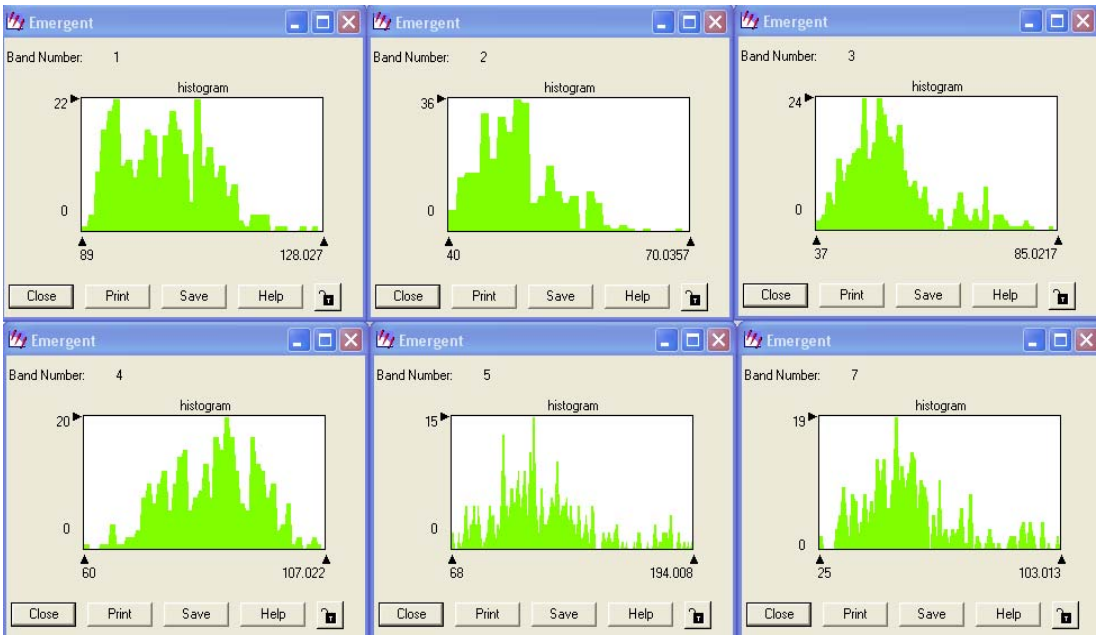


Figure 4.28 Histogram of emergent wetland in Landsat 5-TM imagery

The spectral reflectance on emergent wetland of Landsat 5-TM satellite image data (Table 4-17) found its highest mean was band 5, 1, and 4 respectively, but the others were similar. The value of S.D. found on high variance at band 5 due to different on plant's humidity. As the resulted study found that the totally spectral reflectance of emergent wetland was high due to plants' full-grown. When considering a histogram (figure 4.27), it found the training area would spread on spectral reflectance on normal curve at band 4, 5 and 7, but considering of S.D. found the Band 4 has less fluctuated that indicated on homogeneous of training area as a good average

representative for emergent wetland's identification apart from other types of coastal wetland.

Table 4.19 SPOT-5 statistics information of open water wetland

Emergent			
Band (μm)	1 (0.50-0.59)	2 (0.61-0.68)	3 (0.79-0.89)
Univariable statistics			
Mean	167.803	158.976	167.284
S.D.	13.044	22.130	14.760
Variance	170.146	489.746	217.869
Minimum	130.000	96.000	115.000
Maximum	224.000	218.000	211.000

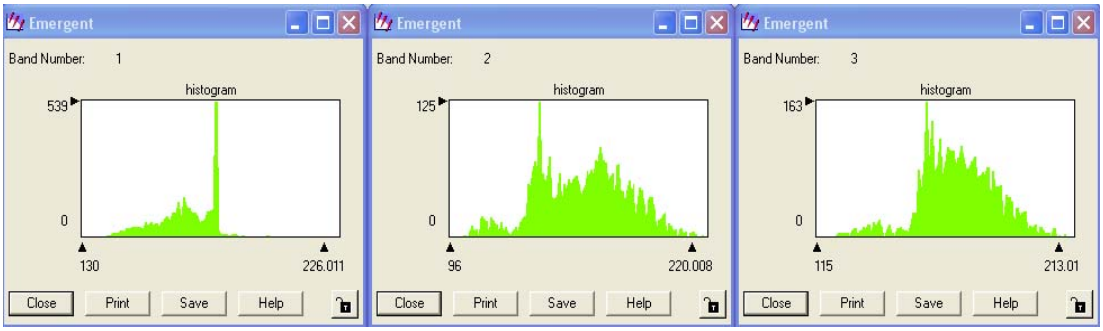


Figure 4.29 Histogram of emergent wetland in SPOT-5 imagery

The value of spectral reflectance on emergent wetland of SPOT-5 satellite image data (table 4.18) found its high mean was band 1, 3, and 2 respectively, but S.D. was more variance at band 2 due to time recording on January. The period of plant started to deteriorate in some area that effected on reflect at green band diminish, and more reflect at red band. When considering a histogram, it found the emergent wetland would spread on spectral reflectance on normal curve of training area at band 2 and 3, but less fluctuate at band 3 that indicated on homogeneous of training area with a good average of training area as representative for emergent wetland's identification apart from other types of coastal wetland.

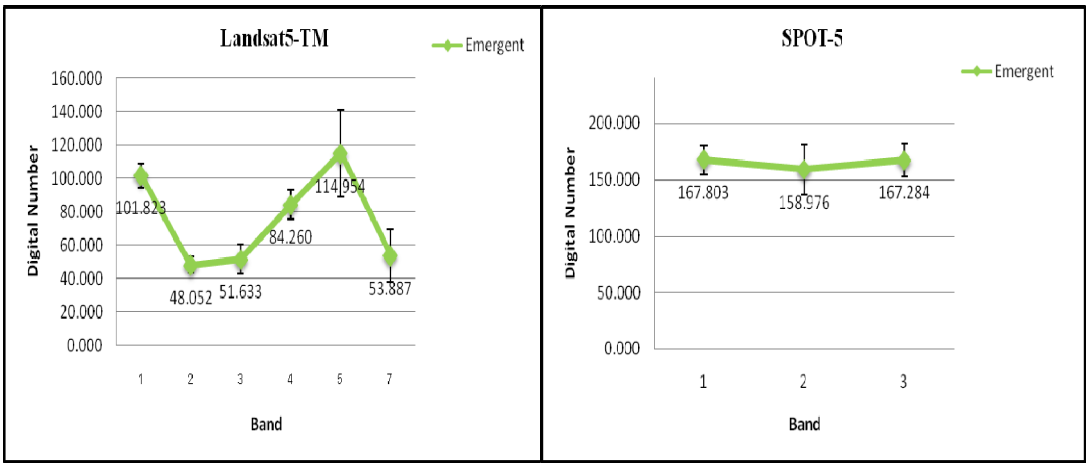


Figure 4.30 Emergent signature mean plot

Studying of spectral signature (figure 4.29) found that the emergent wetland has high reflected in infrared band because of potential on study about plant's humidity. In contrast, beginning of deteriorated plants, spectral reflectance of emergent wetland would have high fluctuate of training area. Therefore, studying of emergent wetland during on period of growing plants as near-Infrared band (Landsat 5-TM=band 4, SPOT-5=band 3) suited for identification, but it could identify the seasoning of deteriorated plants in red band (Landsat5-TM=band 3, SPOT-5=band 2).

In the studying in all types of coastal wetlands conclude that spectral reflectance in Landsat 5-TM and SPOT-5 satellite imageries is differed both of wave and time due to potential on different of spectral reflectance (figure 4.30). Therefore, the appropriate bands to use for coastal wetland classification must to training area in every types of normal curve spreading that it is good to choose the representative and appropriate to classify and consider the potential of band in training area. For this process, selecting the band 3-4-5 for Landsat 5-TM satellite imagery and band 1-2-3 for SPOT-5 satellite imageries. Landsat 5-TM satellite imagery is open water wetland and farmland that absorb on Infrared band with different on reflected vegetations in this band. Vegetation cover: forest wetland and paddy field wetland will reflect on band 4. Scrub wetland and emergent wetland will reflect on band 4 and 5 but the reflection of forest wetland and paddy field wetland is higher than scrub wetland and emergent wetland. SPOT satellite imagery, open water imageries and farmland wetland that absorb on band 1 that the vegetations reflect in band 1 and scrub wetland

and emergent wetland will reflect on band 2. SPOT-5 satellite imagery, open water wetland and farmland wetland absorb in band 1 that reflected vegetations in band 1, and scrub forest and emergent wetland absorb in band 2, but paddy field wetland and scrub wetland absorb in band 2

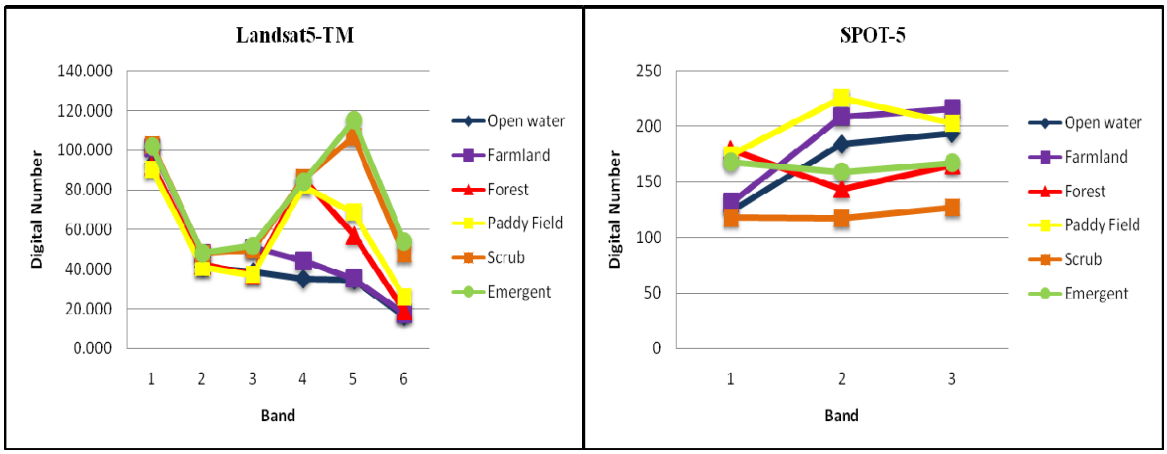


Figure 4.31 Coastal wetland signature mean plot

4.2.6 Supervise classification

Supervise classification method uses the statistic on decision rule on maximum likelihood by using the program of Erdas Imagine 9.2 with the value of spectral reflectance is the index to consider the data type classification as the result shown in Figure 4-31 and Figure 4-32.

4.2.7 Post Classification

Image Reclassification after supervise classification by using the method of image filtering to improve the data get more smoothing by get rid of the isolated pixel. By majority criteria is any small data types dropping in the big group, frame of image filter uses size 3x3 to conserve the data's quality as long as (figure 4.31 and figure 4.32 present image pass on the filter).

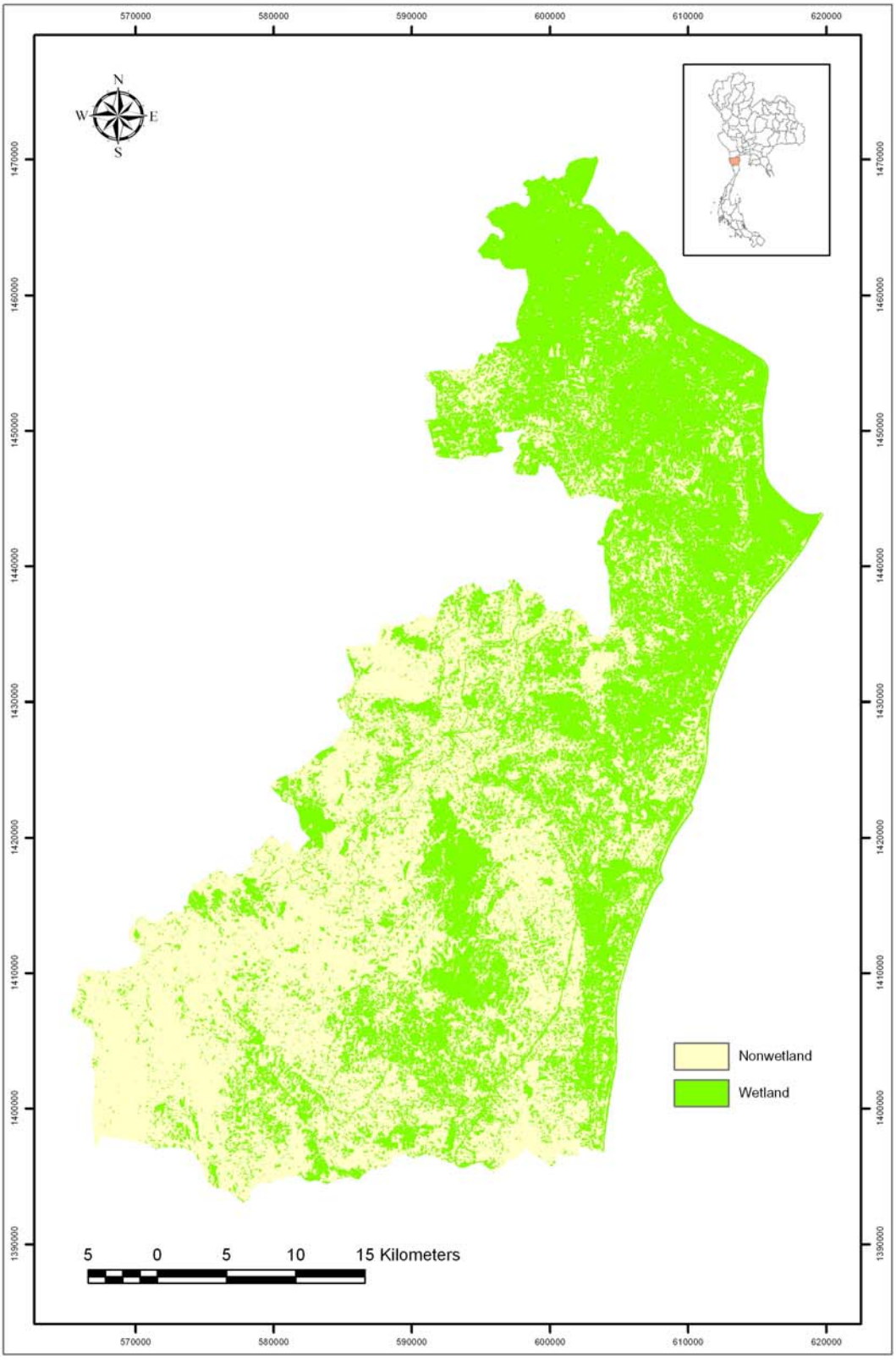


Figure 4.32 Coastal wetland detection of Landsat 5-TM imagery after applying Maximum likelihood classification

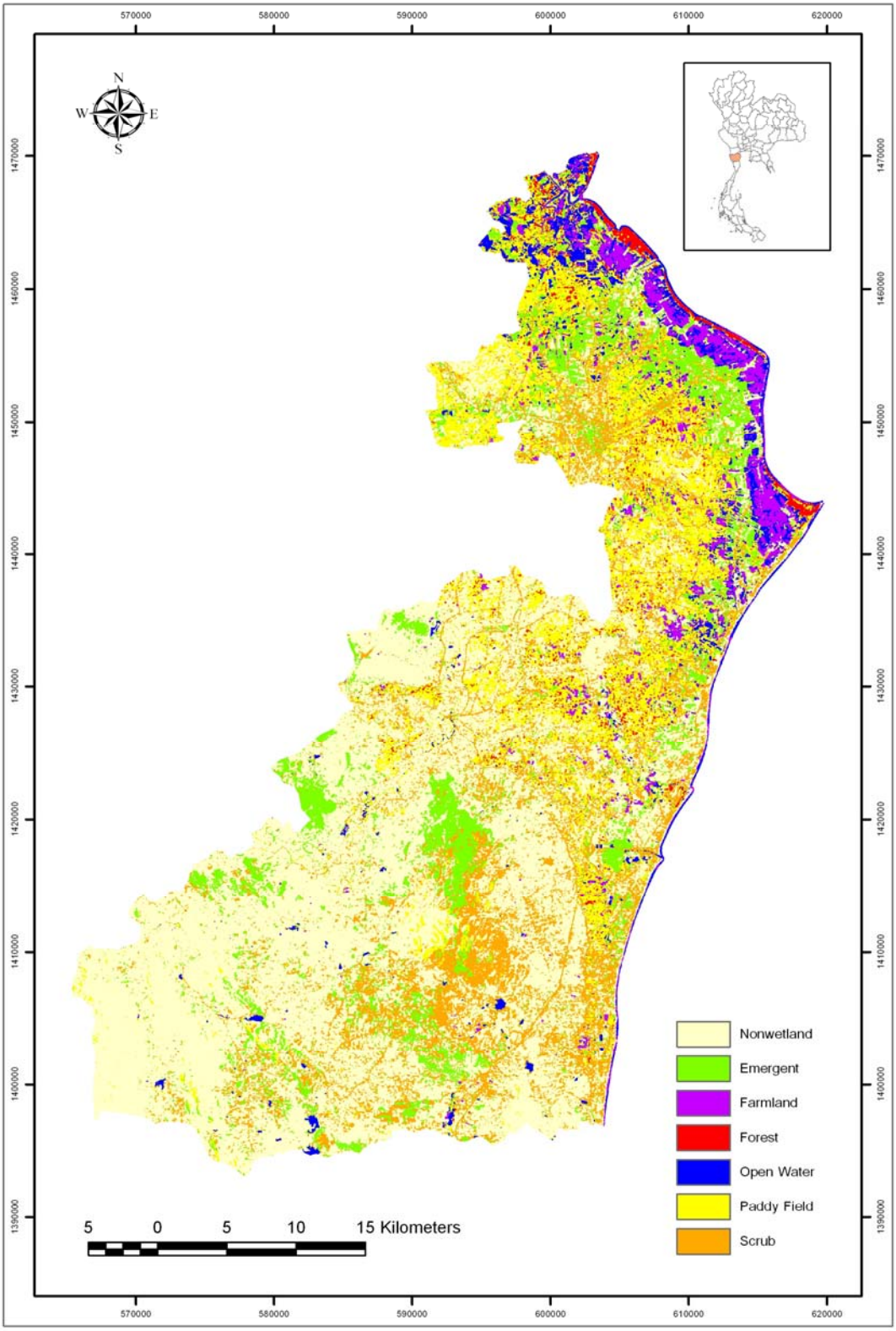


Figure 4.33 Coastal wetland identification of Landsat 5-TM imagery after applying Maximum likelihood classification

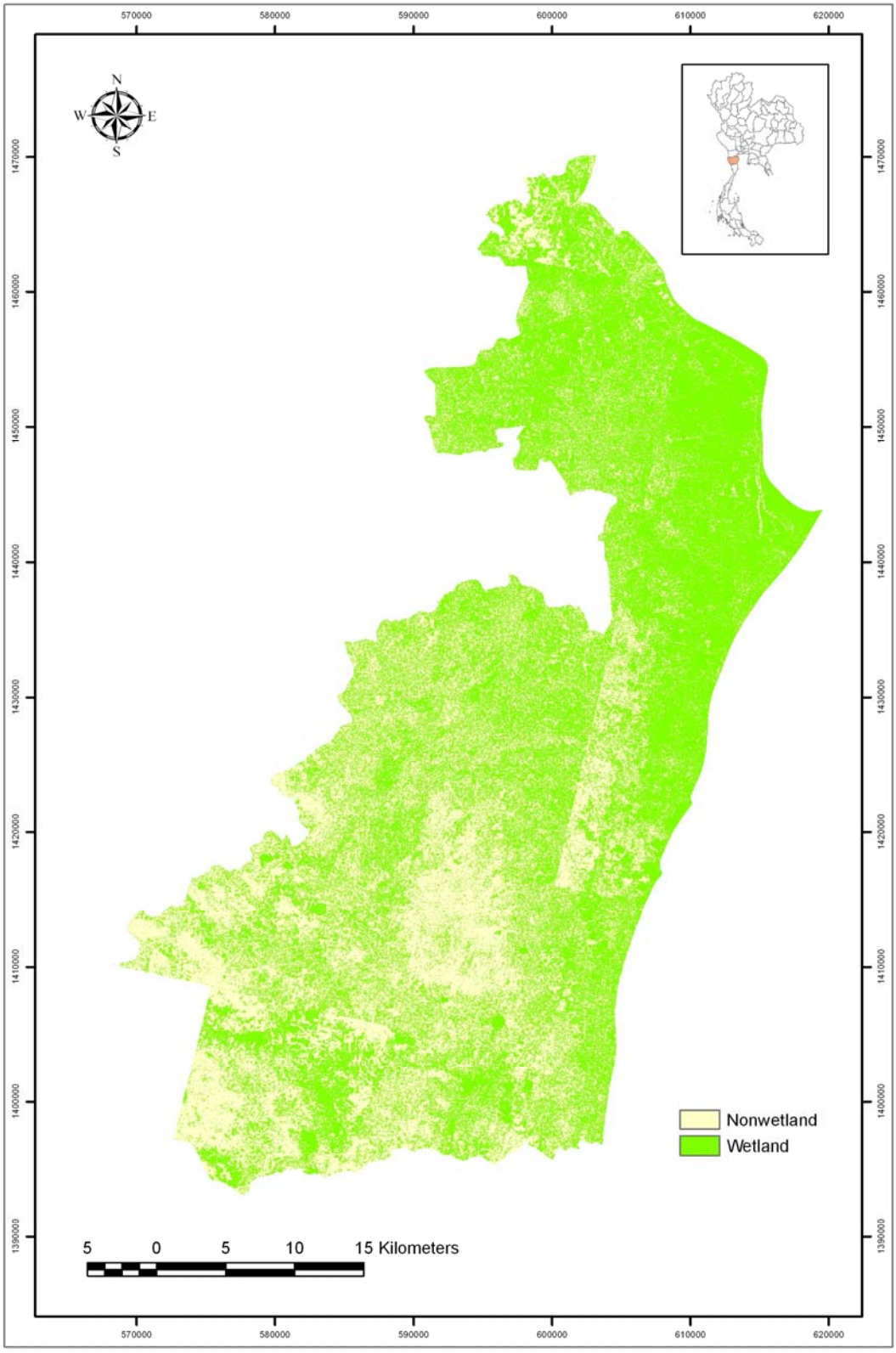


Figure 4.34 Coastal wetland detection of SPOT-5 imagery after applying Maximum likelihood classification

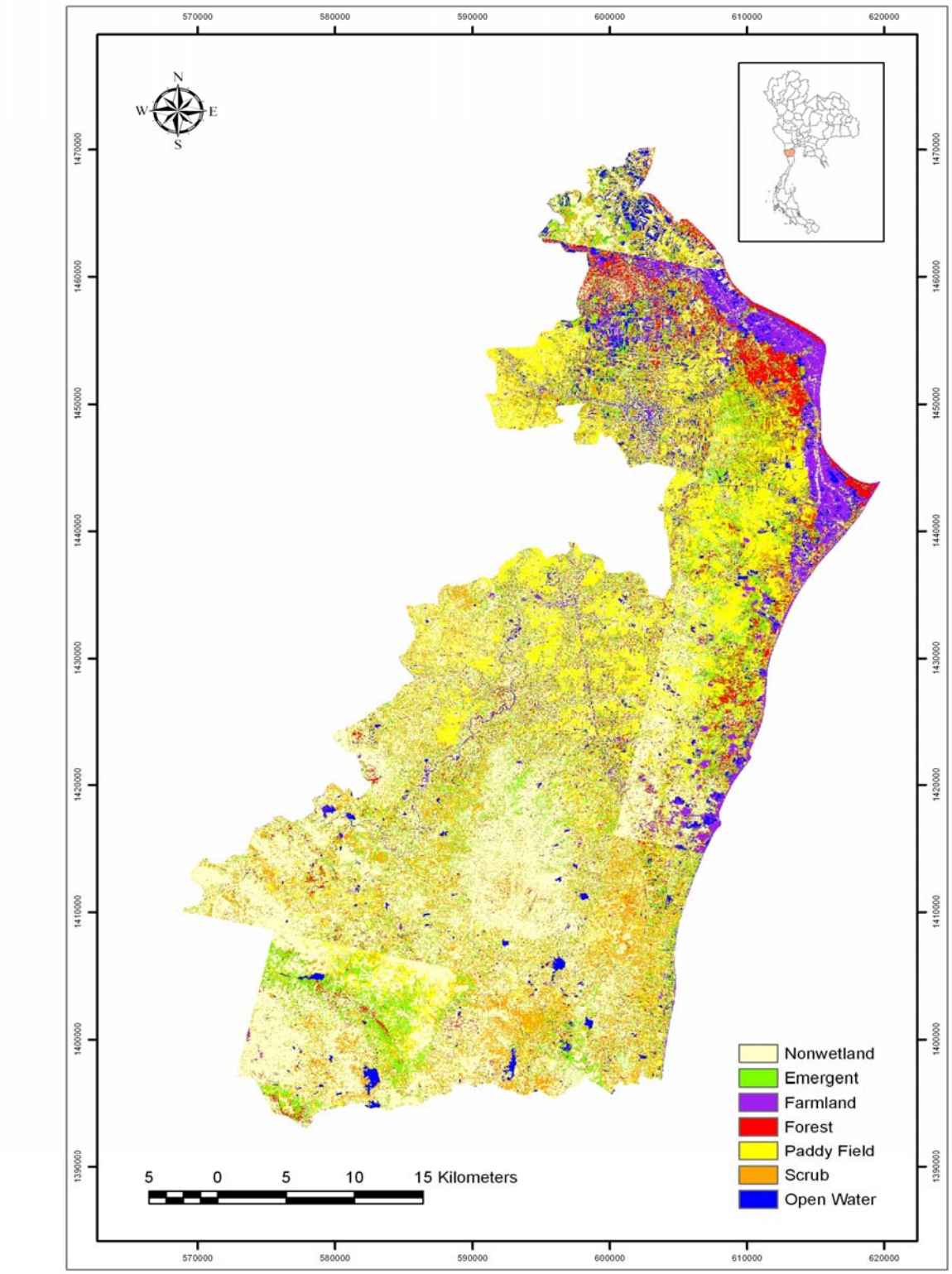


Figure 4.35 Coastal wetland identification of SPOT-5 imagery after applying Maximum likelihood classification

4.3 Validation of Classification Result

Discrete multivariate techniques by using the statistic accuracy assessment on satellite image data, with the program of Erdas Imagine 9.2 and 32 sample points covering overall data types and study area that consist of open water 6 sample points, farmland 2 sample points, forest 4 sample points, paddy field 6 sample points, scrub 6 sample points and emergent 8 sample points. By applying the technique of Error Matrix and Kappa coefficient presents two types of accuracy assessment: wetland detection and wetland identification of Landsat 5-TM and SPOT-5 satellite image data.

Accuracy assessment on Landsat 5-TM satellite image data with overall accuracy assessment on coastal wetland detection is 90.63% (table 4.20), and overall accuracy assessment on coastal wetland identification 81.25% (table 4.22) that the value of K_{HAT} coefficient agreement is 0.7722 (equation 1), respectively.

Table 4.20 Accuracy assessment of Landsat 5-TM satellite image classification for coastal wetland detection

Class Name	**Reference**		**Classified total**
	Wetland	Nonwetland	
Wetland	29	0	29
Nonwetland	3	0	3
Reference total	32	0	32
Overall Accuracy = (29+0)/32 = 90.63%			

Producer's Accuracy (Omission error)

Wetland = 29/32 = 90.63%

Nonwetland = 0/0 = 0%

Ucer's Accuracy (Omission error)

Wetland = 29/29 = 100%

Nonwetland = 0/3 = 0%

The result of accuracy assessment on SPOT-5 satellite image data of overall accuracy assessment with coastal wetland detection is 78.13% (table 4.21) and overall accuracy assessment with coastal wetland identification is 65.63% (table 4.23) that the value of K_{HAT} coefficient agreement is 0.5926 (equation 2) , respectively.

Table 4.21 Accuracy assessment of SPOT-5 satellite image classification for coastal wetland detection

Class Name	**Reference**		**Classified total**
	Wetland	Nonwetland	
Wetland	25	0	25
Nonwetland	7	0	7
Reference total	32	0	32
Overall Accuracy = (25+0)/32 = 78.13%			

Producer's Accuracy (Omission error)

Wetland = 25/32 = 78.13%

Nonwetland = 0/0 = 0%

Ucer's Accuracy (Omission error)

Wetland = 25/25 = 0%

Nonwetland = 7/7 = 0%

Table 4.22 Accuracy assessment of Landsat 5-TM satellite image classification for coastal wetland identification

Class Name	Reference										Classified total
	Open water	Farmland	Forest	Paddy field	Scrub	Emergent	Decidous	Agriculture	Grass	Urban	
Open water	5	0	0	0	0	0	0	0	0	0	5
Farmland	1	1	0	0	0	0	0	0	0	0	2
Forest	0	0	3	0	0	0	0	0	0	0	3
Paddy field	0	1	0	5	0	2	0	0	0	0	8
Scrub	0	0	0	0	6	0	0	0	0	0	6
Emergent	0	0	0	0	0	6	0	0	0	0	6
Decidous	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0	0	0	1	0	1	0	0	0	0	2
Grass	0	0	0	0	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0	0	0	0	0
Reference total	6	2	3	6	6	9	0	0	0	0	32
Overall Accuracy = (5+1+3+5+6+6+0+0+0+0)/32 = 81.25%											

Producer's Accuracy (Omission error)

Open water	=	5/6 = 83.33%	16.67%	Omission error
	=	½ = 50%	50%	Omission error
Forest	=	3/3 = 100%	0%	Omission error
ddy field	=	5/6 = 83.33%	16.67%	Omission error
Scrub	=	6/6 = 100%	0%	Omission error
Emergent	=	6/9 = 66.67 %	33.33%	Omission error

User's Accuracy (Comission error)

Open water	=	5/5 = 100%	0%	Commission error
Farmland	=	½ = 50%	50%	Commission error
Forest	=	3/3 = 100%	0%	Commission error
Paddy field	=	5/8 = 62.50%	37.50%	Commission error
Scrub	=	6/6 = 100%	0%	Commission error
Emergent	=	6/6 = 100 %	0%	Commission error

Computation of K_{HAT} Coefficient of Agreement from Landsat 5-TM :

$$\hat{K} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k} (x_{i+} \times x_{+1})}{N^2 - \sum_{i=1}^{k} (x_{i+} \times x_{+1})} \quad (1)$$

Where N = 32

$\sum_{i=1}^{k} x_{ii}$ = (5+1+3+5+6+6+0+0+0+0) = 26

$\sum_{i=1}^{k} x_{i+} \times x_{+i}$ = (5x6)+(2x2)+(3x3)+(8x6)+(6x6)+(6x9)+0 = 181

there $\hat{K}$ = $\frac{(32x26) - 181}{32^2 - 181}$ = 0.7722

Table 4.23 Accuracy assessment of SPOT-5 satellite image classification for coastal wetland identification

Class Name	Reference										Classified total
	Open water	Farmland	Forest	Paddy field	Scrub	Emergent	Decidous	Agriculture	Grass	Urban	
Open water	2	0	0	0	0	0	0	0	0	0	2
Farmland	1	1	0	0	0	0	0	0	0	0	2
Forest	0	0	3	0	1	1	0	0	0	0	5
Paddy field	0	0	0	4	0	0	0	0	0	0	4
Scrub	0	0	0	1	3	0	0	0	0	0	4
Emergent	0	1	0	0	0	8	0	0	0	0	9
Decidous	0	0	0	0	2	0	0	0	0	0	2
Agriculture	0	0	0	1	0	0	0	0	0	0	1
Grass	0	0	0	0	0	0	0	0	0	0	0
Urban	3	0	0	0	0	0	0	0	0	0	3
Reference total	6	2	3	6	6	9	0	0	0	0	32

Overall Accuracy = (2+1+3+4+3+8+0+0+0+0)/32 = 65.63%

Producer's Accuracy (Omission error)

Open water	=	2/6 = 33.33%	66.67%	Omission error
Farmland	=	1/2 = 50%	50%	Omission error
Forest	=	3/3 = 100%	0%	Omission error
Paddy field	=	4/6 = 66.67%	33.33%	Omission error
Scrub	=	3/6 = 50%	50%	Omission error
Emergent	=	8/9 = 88.89 %	11.11%	Omission error

User's Accuracy (Comission error)

Open water	=	2/2 = 0%	100%	Commission error
Farmland	=	1/2 = 50%	50%	Commission error
Forest	=	3/5 = 60%	40%	Commission error
Paddy field	=	4/4 = 0%	100%	Commission error
Scrub	=	3/4 = 75%	25%	Commission error
Emergent	=	8/9 = 88.89 %	11.11%	Commission error

Computation of K_{HAT} Coefficient of Agreement from SPOT-5 :

$$\hat{K} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k} (x_{i+} \times x_{+1})}{N^2 - \sum_{i=1}^{k} (x_{i+} \times x_{+1})} \quad (2)$$

Where N = 32

$\sum_{i=1}^{k} x_{ii}$ = (2+1+3+4+3+8+0+0+0+0) = 21

$\sum_{i=1}^{k} x_{i+} \times x_{+i}$ = (2x6)+(2x2)+(5x3)+(4x6)+(4x6)+(9x9)+(2x0)+(1x0)+(3x0)+0 = 160

there $\hat{K}$ = $\frac{(32x21) - 160}{32^2 - 160}$ = 0.5926

4.3 Discussion

This studying presented the discussion about coastal wetland characteristic and relation between spectral reflectance and coastal wetland characteristic. At last, it discussed about the accuracy of satellite image classification.

4.3.1 Coastal wetland characteristics

The coastal wetland ecosystem in Phetchaburi basin is situated in transitional zone between land and water where this ecosystem has an influence on the physical and ecological characteristics of wetland types. The study can be divide coastal wetlands into 6 categories: Open water wetland, Farmland wetland, Forest wetland, Paddy field wetland, Scrub wetland and Emergent wetland which correspond to wetland classification system of Thailand, such as Type, System, Sub-System and Class (20). By the coastal wetland types of forest, scrub, emergent and paddy field are divide from vegetation cover. MDEQ (22) said plants that occupy the wetland area under natural conditions were estimated probability at least 67%. The coastal wetland types of open water and farmland are divide from physical characteristic and land use characteristic because of vegetation cover have follow applying by land use.

From the study result of forest wetland, scrub wetland and emergent wetland have characteristic lowland along the coastline at the areas of Ban Lham District and Cha-Um District, that salinity factor is significant more than waterlogging. Due to the coastal wetlands have salinity value more than 0.5 part per thousand (51). Phanawon ChunsaKul (19) and Kitiya Ninlapat and Yongyut Trisurut (48) said that wetland hydrology influenced on the wetland vegetation and wetland soil. These coastal wetland areas are present on vegetation cover of salt-tolerant tidal plants such as mangrove communities and the plants in brackish water (*Rhizophora mucronata, Avicennia marina, Syzygium gratum, Xylocarpus obovatus, Excoecaria agallocha, Nipa fruticans Wurmb, Suaeda maritime, Acanthus ebracteatus*). While farmland wetland and open water wetland have characteristic lowland along the riverside at the areas of Muang Phetchaburi District and ThaYang District and paddy field found in at the area of Muang Phetchaburi District, ThaYang District and Cha-Um District. Therefore the wetland hydrology has an influence on the water

supply in wetland areas, such as precipitation, surface runoff and irrigation. Because most flood plain areas in Thailand was developed to paddy field, agriculture or aquaculture (52). Due to salinity factor has less than 0.5 part per thousand that it is not significant to wetland vegetation or wetland soil, but water level and period of waterlogging factor is significant. For paddy field found in area of Muang Phetchaburi District, ThaYang District and Cha-Um District, because the area has the suitability for paddy field or reservoir (11). These coastal wetland areas are present on a kind of floating plants (53). In present coastal wetland areas in Phetchaburi basin at the area of Muang Phetchaburi District and ThaYang District were detroied and losing (4, 40). An aquatic farming and salt farm mostly found in Ban Lham District along the coastline which one the problem was mangrove forest degradation from the expansion of aquaculture (54). Due to the modification from the natural wetland is human-made wetland, such as aquatic farming, salt farm that coastal wetland types were an occupation source for people at Ban Lham District, Muang Phetchaburi District, Cha-Um District as a report of 8th regional environmental office (7).

4.3.2 Relationship between spectral reflectance and coastal wetland characterization

Coastal wetland areas in Phetchaburi basin have a dominant characteristic different from the other types of land cover or land use. Because of, the spectral reflectance of coastal wetland has an influence on the characteristics of wetland vegetation, wetland soil and wetland hydrology. Rebelo L. M., Finlayson C. M., Nagabhatla N. (47) said the remote sensor acquires a response is based on many characteristics of the land surface interaction with electromagnetic radiation with to spectral resolution, spatial resolution or temporal resolution, including natural or artificial cover. It can helps to solve a problem the overlap in spectral signatures between wetlands and other classes such as agricultural crops and upland forests (44). Due to coastal wetland ecosystem was related to water quantity, hydric soil, and humidity change in plant types. Firstly, as a result wetland vegetation of mangrove forest, paddy field, scrub and emergent was spectral reflectance differed to the other plant types at mid-Infrared band clearly because it could record the spectral reflectance on humidity of plants well that called water absorption band. Because spectral

reflectance of the other plant types that differed in red and near-Infrared band (32). Secondarily, as a result spectral reflectance of open water and aquatic farming was different from wetland hydrology. Therefore, spectral reflectance of open water and aquatic farming is easiest in wetland identification process. Due to the characteristic of wetland hydrology would related to waterlogging or saturated condition. The spectral reflectance would different from other factors at blue band that the wetland hydrology different both in quality and water contamination (29). In order to separate the open water from aquatic farming of coastal wetland in Phetchaburi basin that it is blue band which aquatic farming has higher spectral reflectance. Finally, the characteristic of hydric soil has related to the quality of organic, soil humidity, soil texture, quality of oxide iron, and rough surface soil that its character aforementioned have a little response to spectral reflectance when compare with wetland vegetation and wetland hydrology of coastal wetland in Phetchaburi basin .

Landsat 5-TM and SPOT-5 satellite imagery are multispectral remote sensors that it can be divided spectral resolution into 3 groups of wave length: visible light, near-Infrared and short-Infrared. Stacy L. O. and Marvin E. B. (44) said the most important Landsat-TM band of wetland identification is infrared band because of its ability to identify wetland vegetation and soil moisture level. And Landsat-TM band of band 3-4-5 for wetland detection. Therefore, SPOT-5 band of 1-2-3 has appropriate for wetlands detection and identification of coastal wetland in Phetchaburi basin.

4.3.3 Accuracy of Satellite Image Classification

The accuracy of image processing are include satellite remote sensor and classification method. First, the relevant selection of satellite imagery using should base on the study's objective. For example, detection of wetalnd in study area of Landsat 5-TM imagery has more benefit than SPOT-5 imagery. Landsat 5 -TM imagery has required on study area in basin scale. However, Landsat 5-TM satellite imagery has spatial resolution less than SPOT-5 satellite imagery. Spatial resolution in some case has more important than spectral resolution for wetland identification. As the result limitation of spatial resolution of Landsat 5–TM imagery, it was difficult to identify a small wetland area (44), such as emergent wetland, consensus with a case study of Rebelo L.M. et al. (47) that found confused problem on identified wetland

types of marsh and shrub patches, and open moist area and shrubs. Thus, for the other studies area should considered about responding of spectral reflectance which base on both spatial and spectral resolution of satellite remote sensors. Secondary, classification method area depend on different spectral reflectance of wetland vegetation types. Due to supervise classification technique used decision making on maximum likelihood algorithm, when overlapping of spectral signature of wetland vegetation types. An accuracy of satellite image classification would related on spectral reflectance of training data and different in each band of satellite remote sensor. However, training area selection was a good representative, combination band and chosen decision rule on statistic that effect on accuracy of satellite image classification (29). Therefore, field survey in ground truth help to increase the overall classification accuracy.

CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1 Summary of major finding

This study was to detect the coastal wetland in Phetchaburi basin with remote sensing, by using a field survey and ancillary data to collect 95 sample points of coastal wetland characteristic, such as boundary of Phetchaburi basin, land use benefits, coastal topographic that explained the ecological characteristic of coastal wetland as wetland vegetation, wetland soil and wetland hydrology. To present the coastal wetland area and to use for coastal wetland identification in Phetchaburi basin that it covered 4 Districts: Ban Lham, Muang Phetchaburi, ThaYang, and Cha-Um with total area 1,872.53 square kilometres (1,170,330 rai). By satellite image processing, it got a result from satellite image classification of Landsat 5-TM and SPOT-5 satellite imageries on supervise classification under decision on maximum likelihood. To indicate coastal wetlands and separate coastal wetland types by use ecological characteristics, being as geography of lowland along the coastline and riverrine that could divide into 5 types of coastal wetland: open water, farmland, forest, scrub and emergent. For process of statistic analysis on spectral reflectance by a selection of training area on spectral signature could classify into 6 types: open water, farmland, forest, paddy field, scrub and emergent. The band combination in this study was band 3-4-5 for Landsat 5-TM satellite imagery and band 1-2-3 for SPOT-5 satellite imagery would get the best representative of training area.

Finally, the resulted study about accuracy of coastal wetland classification both coastal wetland detection and coastal wetland identification, its result of Landsat5-TM satellite imagery has overall accuracy of coastal wetland detection at 90.63% and overall accuracy of coastal wetland identification at 81.25% which accuracy assessment coastal wetland identification with a value of K_{HAT} coefficient agreement at 0.7722. As the results of SPOT-5 imagery has overall accuracy of

coastal wetland detection at 78.13%, and overall accuracy of coastal wetland identification at 65.63%, which accuracy assessment of coastal wetland identification with a value of K_{HAT} coefficient agreement at 0.5926. To considerate overall accuracy of coastal wetland detection found that Landsat5-TM satellite imagery has high accuracy more than SPOT-5 satellite imagery about 12.50%, and value of overall accuracy of coastal wetland identification about 15.62%. From study concluded that Landsat5-TM satellite imagery has high more accuracy than SPOT-5 satellite imagery to detection the coastal wetland in Phetchaburi basin.

The remote sensing technology could apply to survey and design a coastal wetland map that it help to reduce time for field survey in the other study areas and up-to-date data to reliable for consider on wetland management in wise use and sustainability. In present, Thailand tries to conserve and protect the wetland area, but a problem of the wetland management is absence of the information on wetland distribution and wetland boundary. For this reason, advantage of satellite image data in wetland inventory that can fill gap in management wetland.

5.2 Limitation of study

1) Landsat 5-TM and SPOT-5 satellite imagery data had differently recorded and not update. By comparing the satellite imagery data on spectral resolution and spatial resolution, the image must have time closely because it might occur the mistaken on study.

2) Selection of satellite imagery data, such as image recording by without cloudy and clearance due to the spectral reflectance that would be variable to change of covering objects on geography appeared on that real satellite images.

3) The field survey dated was not exact on the time of recording, therefore, training area gained by survey that identified the training area for image processing that made the spectral reflectance of objects similarly and hard to separate any types.

4) Check point of accuracy analysis on satellite imagery data's classification has a few and not covered over all study area, related on SPOT-5 satellite imagery data's accuracy decreasingly because satellite image with high delicated

spatial resolution, the check point must provide a lot that being a good represented statistic's analysis.

5.3 Recommendation for further study

The recommendations for further research are as follows :

1) Studying a characteristic of ecological wetland should focus on a period of plants' growing in the study area, considers plant calendar of agricultural area to set a filed survey plan that uses for training site as a good representative classification, and the value of spectral reflectance consensus with the real geography conditions.

2) Increasing the sampling point as much as specific on training site and accuracy assessment that calculated the population statistic applied for the reference sampling point's using.

3) Selection a date of satellite imagery recording on beneficial applying should consider the wetland characteristic as land cover types of study area that needed to study with spatial and spectral characteristics of satellite remote sensor.

4) Ancillary data: soils information, a digital elevation model, and hydrography data considers to the solve a solution and overlap problem of spectral signature that uses for a pattern of GIS database.

5) A technique to develop the satellite data's qualification is to increase a detailed imagery data or differently level of objects more clearly, to identify the type of wetland classification due to a wetland consists with more than one wetland type together.

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APPENDICES

APPENDIX A

แบบสำรวจข้อมูลภาคสนามพื้นที่ชุ่มน้ำ

วันที่บันทึก_____**เวลา**_____**พอร์ทเลขที่/จุดศึกษาที่**_____

ผู้บันทึก_____ **สถานที่**_____

พิกัดตำแหน่ง N_____**E**_____

ความสูงจากระดับน้ำทะเลปานกลาง_____**ความชัน**_____

ระวางแผนที่_____ **ตำบล**_____**อำเภอ**_____**จังหวัด**_____

1 . พืชพรรณ : Hydrophytic Vegetation

ลำดับ	ชื่อ/ชนิดพืช	%ในพื้นที่	หมายเหตุ	ลำดับ	ชื่อ/ชนิดพืช	%ในพื้นที่	หมายเหตุ
1				9			
2				10			
3				11			
4				12			
5				13			
6				14			
7				15			
8				16			

%ของพืชในพื้นที่ชุ่มน้ำ OBL, FACW และ/หรือ FAC: _____%

ดัชนีชี้วัดอื่นๆ:

*-*มีพืชในพื้นที่ชุ่มน้ำท้องถิ่น (สอบถาม)* ใช่_____ ไม่_____

-มีการปรับตัวทางกายภาพของพืช (ฟองน้ำ , ผนังเซลมีรูพรุน.....) ใช่_____ ไม่_____

*-*เจริญเติบโตได้ในพื้นที่ชุ่มน้ำ* ใช่_____ ไม่_____

*-*สามารถขยายพันธุ์ในพื้นที่ชุ่มน้ำ* ใช่_____ ไม่_____

เป็น Hydrophytic Vegetation: ใช่ ☐ **ไม่** ☐

2 . ดิน : Hydric Soils

- **เจาะดินที่ความลึก 8-16 นิ้วพบน้ำ (ดินอิ่มตัวด้วยน้ำ)**

  ใช่_____ ไม่_____

- **มีจุดประ (สีจุดประ: _____)**

  ใช่_____ ไม่_____

  ค่า Hue_____

  ค่า Value_____

  ค่า Chroma_____

- **พบดินเป็นสีเทา (สีเนื้อดินหลัก: _____)**

  ใช่_____ ไม่_____

  เนื้อดิน: ดินเหนียว ☐ ดินร่วน ☐ ดินทราย ☐ ดิน.....☐

- **มี Organic material**

  ใช่_____ ไม่_____

  น้อยกว่า20% ☐ 20% ☐ 30% ☐ 40% ☐ 50% ☐ 60% ☐ >60% ☐

ดัชนีชี้วัดอื่นๆ:

-7.5 cm. พบเม็ดหินสีดำและน้ำตาลเข้มเส้นผ่าศูนย์กลางมากกว่า 2 mm. *ใช่_____ ไม่_____*

(Iron and Manganese concretions)

-กลิ่นก๊าซไข่เน่า (ซัลเฟอร์) *ใช่_____ ไม่_____*

*-*ชื่อชุดดิน_____อยู่ในรายการกลุ่มดินของพื้นที่ชุ่มน้ำ* *ใช่_____ ไม่_____*

เป็น Hydric Soils: ใช่ ☐ **ไม่** ☐

3 . น้ำ : Hydrology

● **มีน้ำท่วมขัง ใช่____ ไม่____**

น้ำท่วมตลอดปี ☐ น้ำท่วมบางฤดูกาล ☐ น้ำขึ้นน้ำลง ☐

ความลึกของระดับน้ำ: _____ เมตร

ระดับความเค็ม: _____ น้อยกว่า 0.5 S‰ ☐ 0.5 - 30 S‰ ☐ > 30 S‰ ☐

● **ดินอิ่มตัวด้วยน้ำ: ใช่____ ไม่____**

ความลึกของดินอิ่มตัวด้วยน้ำ: ที่ระดับความลึก 8- 16 นิ้ว พบน้ำที่ระดับ_____นิ้ว

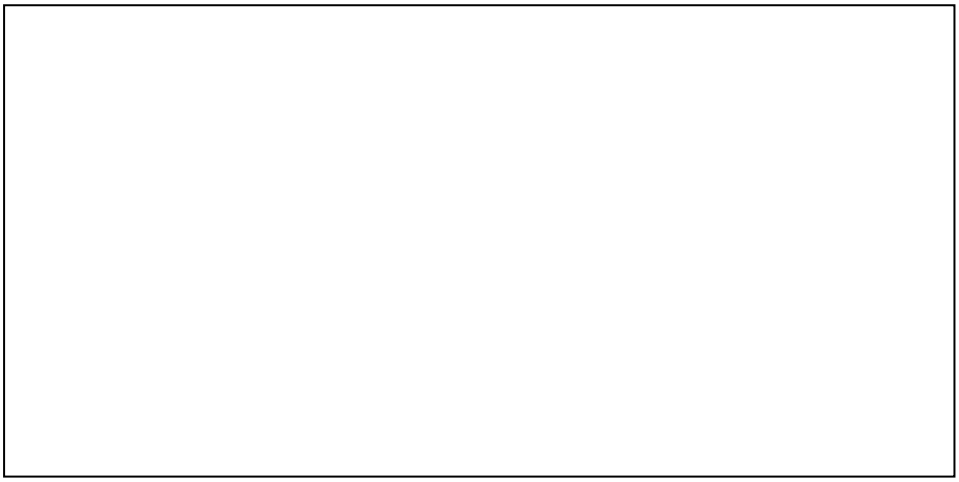
ดัชนีชี้วัดอื่นๆ:

-พบรอยระดับน้ำ (Water Mark) *ใช่____ ไม่____*

-พบแนวกองทราย (Drift line) *ใช่____ ไม่____*

-พบสิ่งที่ตกตะกอน (Sediment deposits) *ใช่____ ไม่____*

-ลักษณะลำน้ำและการไหลของน้ำ (Drainage patterns)



N

ปรากฏลักษณะ Wetland hydrology: ใช่ ☐ ไม่ ☐

การกำหนดพื้นที่ชุ่มน้ำ : เป็นพื้นที่ชุ่มน้ำ ☐ ไม่เป็นพื้นที่ชุ่มน้ำ ☐

เป็นพื้นที่ชุ่มน้ำประเภท

☐ 1) แหล่งน้ำ ☐ 2) พืชน้ำ ☐ 3) ไม้พุ่ม

☐ 4) ป่าในพื้นที่ชุ่มน้ำ ☐ 5) ฟาร์มในพื้นที่ชุ่มน้ำ ☐ 6) อื่นๆ

บันทึกและคำแนะนำ_____

_____

กำหนดโดย _____

APPENDIX B

COASTAL WETLAND CHARACTERRISTIC

Open Water

Amphoe	X	Y	Ses level	Slope		Dominant	Vegetation	Depth to	Soil color		Soil type	Organic	Iron	Sulfer	Hydrology	Depth of	S°%	Water	Drift	Sediment
				degree	%	Vegetation	cover (%)	Suturate Soil(c.m.)	Matrix color	Motlle color		%			condition	Standing Water(m.)		Remark	Line	Deposit
บ้านแหลม	604557	1402650	1	14	26	ขู่,ตาตุ่มทะเล,เฟิร์น,แสม,เสม็ด,ชะคราม	60	0.15	greenish gray	-	ดินเหนียว	50	No	Yes	น้ำท่วมตลอดปี	3	22	Yes	No	Yes
บ้านแหลม	606382	1416878	5	4	6	-	-	0.10	yellowish brown	-	ดินทราย	20	No	No	น้ำท่วมตลอดปี	6	32	Yes	Yes	Yes
เมืองเพชรบุรี	592020	1434677	17	9	15	ไมยราบ,ผักบุ้งทะเล	-	0.50	light olive brown	-	ดินทราย	30	No	No	น้ำท่วมตลอดปี	6	32	Yes	Yes	Yes
ท่ายาง	596306	1406371	48	29	55	-	-	0.20	greenish gray	olive yellow	ดินเหนียวปนทราย	50	Yes	Yes	น้ำท่วมตลอดปี	7	0	Yes	Yes	Yes
ท่ายาง	592367	1407420	114	55	100	-	-	0.3	dark greenish gray	reddish brown	ดินเหนียวปนทราย	40	Yes	No	น้ำท่วมตลอดปี	11	0	Yes	Yes	Yes
ท่ายาง	586534	1408958	55	67	10	ต้นตุ้กแก,หญ้า,ธูปฤาษี	30	0.20	dark greenish gray	-	ดินเหนียวปนทราย	40	No	No	น้ำท่วมตลอดปี	2	0	Yes	Yes	No
ท่ายาง	591713	1433908	15	0	0	ธูปฤาษี,กก	10	0.00	gray	-	ดินเหนียว	30	No	No	น้ำท่วมตลอดปี	8	0	Yes	No	Yes
ท่ายาง	587624	1432353	32	18	35	-	-	0.15	light olive brown	-	ดินทราย	30	No	No	น้ำท่วมตลอดปี	6	20	Yes	Yes	No
ชะอำ	611595	1429715	0	8	14	ธูปฤาษี	5	0.00	dark greenish gray		ดินเหนียว	> 60	No	No	น้ำท่วมตลอดปี	8	0	Yes	Yes	Yes
ชะอำ	615278	1448212	0	0	0	ต้นมะขามเทศน์	-	0.05	dark greenish gray		ดินทราย	20	No	No	น้ำท่วมตลอดปี	1	31	Yes	Yes	No
ชะอำ	601077	1461223	-4	31.5	64	ปรง,ธูปฤาษี,ไมยราบยักษ์,กก,ขลู่	30	0.10	bluish gray	-	ดินเหนียว	60	No	No	น้ำท่วมตลอดปี	8	6	Yes	Yes	Yes
ชะอำ	603657	1404960	4	0	0	-	-	0.05	dark greenish gray	-	ดินเหนียว	30	No	No	น้ำท่วมตลอดปี	0	0	Yes	Yes	No
ชะอำ	579179	1405107	87	34	67	-	-	0.00	dark greenish gray	-	ดินเหนียว	20	No	No	น้ำท่วมตลอดปี	8	0	Yes	Yes	Yes
ชะอำ	617801	1440675	2	11	19	-	-	0.00	bluish gray	-	ดินทราย	50	No	Yes	น้ำท่วมตลอดปี	8	0	Yes	Yes	Yes
ชะอำ	615820	1438250	-5	3	6	สาหร่ายหางกระรอก	10	0.15	dark gray	-	ดินทราย	50	No	Yes	น้ำท่วมตลอดปี	13.5	0	Yes	Yes	Yes

Farmland																				
Amphoe	X	Y	Ses level	Slope		Dominant	Vegetation	Depth to	Soil color		Soil type	OM	Iron	Sulfer	Hydrology	Depth of	S*%	Water	Drift	Sediment
				degree	%	Vegetation	cover (%)	Suturate Soil(c.m.)	Matrix color	Motfle color		%			condition	Standing Water(c.m.)		Remark	Line	Deposit
บ้านแหลม	614615	1449152	14	6	11	ชะคราม	100	0.00	olive	-	ดินเหนียว	20	No	No	น้ำท่วมบางฤดูกาล	0	0	Yes	No	No
บ้านแหลม	608901	1457281	6	16	29	ขู่,ชะคราม,แสม,โคงคาง,โพธิ์ทะเล	0	0.00	dark greenish gray	-	ดินเหนียว	10	No	No	น้ำท่วมบางฤดูกาล	0.3	0	Yes	Yes	Yes
บ้านแหลม	601881	1460857	4	31	60	ชะคราม,แสม	95/5	0.05	dark greenish gray	-	ดินเหนียว	40	No	Yes	น้ำท่วมตลอดปี	5	46	Yes	Yes	Yes
บ้านแหลม	608341	1458189	-2	22	51	ชะคราม,หญ้า,แสม	99/1	0	dark greenish gray	-	ดินเหนียว	50	Yes	No	น้ำท่วมบางฤดูกาล	0.3	0	Yes	Yes	Yes
บ้านแหลม	615968	1440131	2	5	9	ต้นขู่,ไมยราบ,ผักบุ้ง,จอก,แหน	1	0	olive brown	dark greenish gray	ดินเหนียว	10	No	No	น้ำท่วมบางฤดูกาล	0.25	0	Yes	Yes	Yes
เมืองเพชรบุรี	608201	1440723	2	10	14	ข้าว	100	0.00	bluish gray	dark red	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.25	0	Yes	No	Yes
เมืองเพชรบุรี	604997	1445518	0	27	41	ข้าว	100	0	dark bluish gray	-	ดินเหนียว	50	No	No	น้ำท่วมบางฤดูกาล	0.2	0	Yes	Yes	Yes
เมืองเพชรบุรี	600283	1453035	4	28	53	ข้าว	99/1	0.15	greenish gray	yellowish red	ดินเหนียว	40	No	Yes	น้ำท่วมบางฤดูกาล	0.15	0	Yes	Yes	Yes
เมืองเพชรบุรี	606107	1443001	0	20	36	ข้าว	100	0	dark bluish gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.15	0	Yes	No	Yes
เมืองเพชรบุรี	607371	1443370	0	4	12	ข้าว	100	0.00	very dark bluish gray	-	ดินเหนียว	60	No	Yes	น้ำท่วมตลอดปี	0.3	0	Yes	No	Yes
เมืองเพชรบุรี	610782	1440445	1	0	0	ข้าว	100	0.00	dark bluish gray	-	ดินเหนียว	20	No	No	น้ำท่วมบางฤดูกาล	0	0	Yes	No	No
เมืองเพชรบุรี	610340	1440678	4	13	24	ข้าว	100	0.20	dark bluish gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.3	0	Yes	No	Yes
เมืองเพชรบุรี	604100	1452000	0	11	29	ข้าว	100	0.20	dark gray	-	ดินเหนียว	50	No	No	น้ำท่วมบางฤดูกาล	0.2	0	Yes	Yes	Yes
เมืองเพชรบุรี	603655	1451031	16	15	16	ข้าว	100	0	dark greenish gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.15	0	Yes	Yes	Yes
ท่ายาง	593182	1430056	12	12	21	ข้าว	100	0.30	dark bluish gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.2	0	Yes	No	Yes
ท่ายาง	599056	1433547	5	22	40	ข้าว	100	0.00	dark bluish gray	dark red	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.25	3	Yes	No	Yes
ท่ายาง	598797	1433745	11	25	47	ข้าว	100	0.00	dark bluish gray	dark red	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.2	2	Yes	No	Yes
ท่ายาง	593319	1437736	16	11	19	ข้าว	100	0.00	reddish brown	-	ดินเหนียวปนดินร่วน	40	No	No	น้ำท่วมบางฤดูกาล	0.3	0	Yes	No	Yes
ท่ายาง	612113	1432875	7	8	15	-	0	0.00	dark grayish brown	-	ดินเหนียว	<20	No	No	น้ำท่วมบางฤดูกาล	2	26	Yes	Yes	No
ท่ายาง	595308	1435635	14	12	22	ข้าว	100	0.00	dark bluish gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.25	0	Yes	Yes	Yes
ชะอำ	607736	1421800	3	4	7	-	0	0.00	brown	red	ดินเหนียว	30	No	No	น้ำท่วมบางฤดูกาล	1.2	3	Yes	No	No
ชะอำ	611352	1430746	2	7	12	ข้าว	100	0.00	greenish gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.1	0	Yes	No	Yes
ชะอำ	610481	1427760	6	11	20	ข้าว	100	0.00	bluish gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.1	0	Yes	No	Yes

Forest

Amphoe	X	Y	Ses level	Slope		Dominant	Vegetation	Depth to	Soil color		Soil type	OM	Iron	Sulfer	Hydrology	Depth of	S°%	Water	Drift	Sediment
				degree	%	Vetgetation	cover (%)	Suturate Soil(c.m.)	Matrix color	Mottle color		%			condition	Standing Water(c.m.)		Remark	Line	Deposit
บ้านแหลม	610620	1457488	1	4	5	แสม,โกงกาง	100	0.30	dark greenish gray	-	ดินเหนียว	40	No	Yes	น้ำขึ้นน้ำลง	1.2	35	Yes	No	Yes
บ้านแหลม	600544	1460975	7	28	55	มะพร้าว,จาก,แสม,เหงือกปลาหมอ,กระถิน	10	0.15	greenish gray	-	ดินเหนียว	>60	No	Yes	น้ำท่วมตลอดปี	3	14	Yes	No	Yes
บ้านแหลม	602785	1466384	17	5	9	โกงกาง	100	0.15	dark greenish gray	-	ดินเหนียว	0	No	No	น้ำขึ้นน้ำลง	0.4	5	Yes	Yes	Yes
บ้านแหลม	615076	1455099	-1	8	13	โกงกาง,แสม	60/40	0.1	dark greenish gray	-	ดินเหนียว	30	No	Yes	น้ำท่วมตลอดปี	0.5	34	Yes	No	Yes
บ้านแหลม	605668	1459864	2	11	20	ป่าจาก,ตะบูน,โพธิ์ทะเล	95/5	-	very dark grayish br	-	ดินเหนียว	50	No	No	น้ำขึ้นน้ำลง	0.3	18	Yes	Yes	Yes
บ้านแหลม	616963	1440142	3	5	11	แสม,โพธิ์ทะเล,โกงกาง,ชะคราม	95/5	40	dark greenish gray	dark greenish gray	ดินเหนียว	50	No	No	น้ำท่วมบางฤดูกาล	1.5	34	Yes	No	Yes
บ้านแหลม	618112	1442897	13	7	12	แสม,โกงกาง	100	0.10	dark greenish gray	-	ดินร่วน	50	No	No	น้ำขึ้นน้ำลง	0.6	30	Yes	No	Yes
เมืองเพชรบุรี	614963	1438293	-1	4	8	แสมขาว,แสมดำ,ตาตุ่มทะเล,ตะบองเพ็ด,ขู่,โพธิ์ทะเล,ชะคราม	*	0.00	dark yellowish brow	-	ดินทราย	>60	No	No	น้ำท่วมบางฤดูกาล	0.3	12	Yes	Yes	Yes
ท่ายาง	591957	1433882	10	25	48	มะขวิด,กระถิน,หญ้า,ตะขบ	100	0	dark grayish brown	yellowish brown	ดินเหนียว	60	No	No	น้ำท่วมตลอดปี	10	2	Yes	Yes	Yes
ชะอำ	604496	1402687	18	4	7	โกงกาง,แสมจาก,โพธิ์ทะเล,	80/20	0.30	dark greenish gray	-	ดินทราย(ปนเลน)	50	No	Yes	น้ำท่วมตลอดปี	4	34	Yes	Yes	Yes
ชะอำ	607195	1418617	5	9	16	แสม	100	0.15	brown	-	ดินทราย	30	No	No	น้ำท่วมตลอดปี	3	27	Yes	Yes	Yes

Scrub

Amphoe	X	Y	Ses level	Slope		Dominant	Vegetation	Depth to	Soil color		Soil type	OM	Iron	Sulfer	Hydrology	Depth of	S*%	Water	Drift	Sediment
				degree	%	Vegetation	cover (%)	Suturate Soil(c.m.)	Matrix color	Motile color		%			condition	Standing Water(c.m.)		Remark	Line	Deposit
บ้านแหลม	615904	1440170	1	0	0	ไมยราบ	100	0	dark reddish gray	-	ดินเหนียว	10	No	No	น้ำท่วมบางฤดูกาล	0	0	No	Yes	Yes
บ้านแหลม	616863	1440076	1	0	0	ต้นขู่,กระบองเพ็ด	100	0	dark reddish gray	-		40	No	No	น้ำท่วมบางฤดูกาล	0.15	0	Yes	No	Yes
เมืองเพชรบุรี	613591	1435272	2	12	21	ธูปฤาษี,กก,ขู่,ไมยราบยักษ์	100	0	dark greenish gray	-	ดินเหนียว	30	No	No	น้ำท่วมบางฤดูกาล	0	0	Yes	Yes	No
ท่ายาง	611658	1432266	5	9	15	บอระเพ็ด,ขู่,หญ้า	100	0	dark brown	-	ดินเหนียวปนร่วน	30	No	No	น้ำท่วมบางฤดูกาล	0	0	No	Yes	No
ท่ายาง	585826	1430623	38	14	26	ข่อย,หญ้า	100	0	bluish gray	-	ดินเหนียว	<20	No	No	น้ำท่วมบางฤดูกาล	0.1	0	Yes	Yes	Yes
ท่ายาง	612863	1434245	4	7	12	มะขามเทศ,ขู่ ชะคราม,ไมยราบยักษ์,หญ้า	100	0	dark greenish gray	-	ดินเหนียว	30	No	No	น้ำท่วมบางฤดูกาล	0.2	0	Yes	Yes	No
ชะอำ	604229	1408905	7	8	14	ไมยราบ,ธูปฤาษี,บอน	100	0	weak red		ดินทราย(ปนดินร่วน)	40	No	No	น้ำท่วมบางฤดูกาล	0.2	0	Yes	Yes	Yes
ชะอำ	604303	1408965	11	7	13	ไมยราบ	100	0	weak red		ดินทราย(ปนดินร่วน)	30	No	No	น้ำท่วมบางฤดูกาล	0	0	No	No	No
ชะอำ	603800	1406645	2	9	15	กก,ไมยราบ,ปราบ	100	0	grayish green		ดินเหนียว	50	No	No	น้ำท่วมบางฤดูกาล	0.3	0	Yes	Yes	Yes
ชะอำ	603659	1405730	7	24	45	ไมยราบ	100	0	grayish green		ดินทราย(ปนดินร่วน)	30	No	No	น้ำท่วมบางฤดูกาล	0	0	No	No	No
ชะอำ	603956	1408153	15	27	50	ไมยราบ,กระบองเพชร	100	0	weak red	-	ดินทราย(ปนดินร่วน)	20	No	No	น้ำท่วมบางฤดูกาล	0	0	No	No	No
ชะอำ	606785	1417828	0	6	11	ขู่,หญ้า	100	0	very dark gray	-	ดินเหนียว	30	No	No	น้ำท่วมบางฤดูกาล	0.2	5	Yes	No	Yes
ชะอำ	610745	1425827	5	10	17	ขู่,ไมยราบ,กระบองเพชร,หญ้า	100	0	dark brown	-	ดินเหนียวปนร่วน	50	No	No	น้ำท่วมบางฤดูกาล	0	0	Yes	No	No
ชะอำ	610272	1425422	3	13	21	กระบองเพชร,ตาตุ่มทะเล,เสม็ด,ขู่,ชะคราม,หญ้า	100	0	greenish gray	red	ดินร่วน	30	No	No	น้ำท่วมบางฤดูกาล	0.15	0	Yes	No	Yes
ชะอำ	610745	1428200	5	8	13	กระบองเพชร,ขู่,หญ้า	100	0	dark brown	-	ดินเหนียวปนร่วน	50	No	No	น้ำท่วมบางฤดูกาล	0.3	0	Yes	No	Yes
ชะอำ	596719	1405672	37	44	95	ไมยราบ,หญ้า,ธูปฤาษี	100	0	dark greenish gray	red	ดินร่วนปนทราย	40	No	No	น้ำท่วมตลอดปี	0.5	1	Yes	Yes	Yes
ชะอำ	596292	1406669	50	43	91	ไมยราบ,ไม้พุ่ม,หญ้า,กระถิน	100	0	dark greenish gray	yellowish red	ดินร่วนปนทราย	40	Yes	No	น้ำท่วมบางฤดูกาล	0.4	0	Yes	Yes	Yes
ชะอำ	596274	1407020	57	43	90	มะขามเทศ,ตำลึง,ขู่,หญ้า,สะเดา,หางนกยูง	100	0	greenish gray	-	ดินร่วนปนทราย	50	Yes	No	น้ำท่วมบางฤดูกาล	1.5	0	Yes	Yes	Yes

Emergent																				
Amphoe	X	Y	Ses level	Slope		Dominant	Vegetation	Depth to	Soil color		Soil type	OM	Iron	Sulfer	Hydrology	Depth of	S*%	Water	Drift	Sediment
				degree	%	Vetgetation	cover (%)	Suturate Soil(c.m.)	Matrix color	Motfle color		%			condition	Standing Water(c.m.)		Remark	Line	Deposit
ชะอำ	604791	1411682	3	4	6	กก,เฟิร์น	80/20	0.10	brown	brownish yellow	ดินเหนียว	60	No	Yes	น้ำท่วมบางฤดูกาล	0.1	0	Yes	No	Yes
ชะอำ	603440	1398595	3	12	23	จูปฤาษี,กก	100	0.00	very dark grayish brown	-	ดินร่วน	40	No	No	น้ำท่วมบางฤดูกาล	0.3	0	Yes	No	Yes
ชะอำ	603374	1400382	7	26	47	จูปฤาษี,แว่นแก้ว,พุทธรักษา,บอน	70/30	0.00	very dark grayish brown	-	ดินร่วน	40	No	No	น้ำท่วมบางฤดูกาล	0	0	Yes	No	Yes
ชะอำ	603482	1405654	9	26	49	จูปฤาษี,'ไมยราบ	95/5	0.10	dark greenish gray	-	ดินเหนียว	50	No	No	น้ำท่วมบางฤดูกาล	0	0	Yes	No	Yes
ชะอำ	604706	1411654	27	13	22	กก,ปรง	95/5	0.15	brown	-	ดินเหนียว	50	No	Yes	น้ำท่วมบางฤดูกาล	0.1	0	Yes	No	Yes
ชะอำ	605727	1415065	5	9	17	จูปฤาษี,'ไมยราบ	60/40	0.00	dark reddish brown	-	ดินทราย	50	No	No	น้ำท่วมตลอดปี	0.7	5	Yes	Yes	Yes
ชะอำ	608082	1420261	3	13	22	จูปฤาษี	100	0.30	strong brown	-	ดินทรายปนดินเหนียว	40	No	No	น้ำท่วมตลอดปี	0.6	4	Yes	Yes	Yes
ชะอำ	607783	1421450	0	3	5	จูปฤาษี,ปรง,ขู่,หญ้า	95/5	0.20	bluish gray	dark red	ดินเหนียว	50	No	No	น้ำท่วมตลอดปี	3	0	Yes	No	Yes
ชะอำ	607882	1422207	3	5	10	จูปฤาษี,กกสามเหลี่ยม,ปรง	98/2	0.20	bluish gray	dark red	ดินเหนียว	50	No	No	น้ำท่วมตลอดปี	3	0	Yes	No	Yes
ท่ายาง	584636	1408058	34	26	49	จูปฤาษี	100	0	dark bluish gray	strong brown	ดินเหนียว	60	Yes	No	น้ำท่วมบางฤดูกาล	0.4	0	Yes	Yes	Yes
ท่ายาง	592135	1434862	14	10	17	จูปฤาษี	100	0.30	reddish brown	-	ดินเหนียว	0	No	No	น้ำท่วมตลอดปี	0.7	0	Yes	Yes	Yes
ท่ายาง	611753	1432047	0	8	14	จูปฤาษี	100	0.15	dark greenish gray	-	ดินเหนียว	>60	No	Yes	น้ำท่วมตลอดปี	0.2	23	Yes	No	Yes
บ้านแหลม	598787	1458130	1	29	56	จูปฤาษี,มะพร้าว,จาก,ขู่,กระถิน	90/10	0.05	bluish black	-	ดินร่วนปนดินเหนียว	>60	No	Yes	น้ำท่วมบางฤดูกาล	0.02	0	Yes	No	Yes
บ้านแหลม	605231	1457590	11	14	24	จูปฤาษี	100	0.20	dark greenish gray	-	ดินเหนียว	60	Yes	No	น้ำท่วมตลอดปี	0.35	3	Yes	Yes	Yes
บ้านแหลม	605101	1457409	1	14	25	จูปฤาษี	100	0.00	dark greenish gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.15	0	Yes	No	Yes
บ้านแหลม	615497	1439551	0	13	24	ป่ากก,แสม,ชะคราม,โพธิ์ทะเล,หญ้า	55/45/5	0.15	dark greenish gray	-	ดินเหนียว	50	Yes	No	น้ำท่วมบางฤดูกาล	0.3	13	Yes	Yes	Yes
เมืองเพชรบุรี	593118	1452688	4	17	20	จูปฤาษี,ปรง	98/2	0.15	very dark brown	-	ดินร่วน	40	No	No	น้ำท่วมตลอดปี	0.4	2	Yes	No	Yes
เมืองเพชรบุรี	592363	1452949	4	6	12	จูปฤาษี	100	0.00	olive gray	-	ดินเหนียว	>60	No	No	น้ำท่วมตลอดปี	1	0	Yes	No	Yes
เมืองเพชรบุรี	604930	1446084	-1	1	2	จูปฤาษี,เฟิร์น,ขู่,มะขาม,มะขามเทศ	80/20	20	olive brown	strong brown	ดินเหนียว	>60	No	No	น้ำท่วมตลอดปี	0.3	0	Yes	No	Yes
เมืองเพชรบุรี	603551	1446997	0	21	39	จูปฤาษี	100	0.30	olive gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0.25	0	Yes	Yes	Yes
เมืองเพชรบุรี	603675	1447084	0	21	39	จูปฤาษี,กก	50/50	0	olive gray	-	ดินเหนียว	30	No	No	น้ำท่วมบางฤดูกาล	0	0	No	No	No
เมืองเพชรบุรี	597626	1453345	9	10	18	กก	100	0.20	dark bluish gray	dark reddish brown	ดินเหนียว	50	No	No	น้ำท่วมตลอดปี	0.35	0	Yes	No	Yes
เมืองเพชรบุรี	600967	1448585	-2	5	8	จูปฤาษี,หญ้า,ต่าลึง,ผักบุ้ง	98/2	0.10	dark gray	strong brown	ดินเหนียว	60	No	Yes	น้ำท่วมบางฤดูกาล	0.3	0	Yes	No	Yes
เมืองเพชรบุรี	606244	1444436	1	0	0	จูปฤาษี	100	0.10	dark gray	-	ดินเหนียว	40	No	No	น้ำท่วมบางฤดูกาล	0	0	No	No	Yes
เมืองเพชรบุรี	597627	1452191	5	12	22	จูปฤาษี,กก,บัว	70/30	0.00	dark greenish gray	-	ดินเหนียว	40	No	No	น้ำท่วมตลอดปี	0.3	0	Yes	No	Yes
เมืองเพชรบุรี	608673	1445650	0	0	0	จูปฤาษี	100	0.10	dark bluish gray	-	ดินเหนียว	>60	No	Yes	น้ำท่วมตลอดปี	0.3	0	Yes	Yes	Yes
เมืองเพชรบุรี	608105	1442142	1	14	26	จูปฤาษี,กระถิน,ขู่,มะขามเทศ,ไผ่,หญ้า	95/5	0.00	dark gray	light olive brown	ดินเหนียว	>60	No	No	น้ำท่วมตลอดปี	1	0	Yes	No	Yes
						,กก,ผักบุ้ง,ต่าลึง,พุทรา,มะพร้าว,เฟิร์น,ผักตบ															
เมืองเพชรบุรี	593276	1452093	6	15	27	กก,จูปฤาษี,ปรง	65	0.50	weak red	-	ดินเหนียว	40	No	No	น้ำท่วมตลอดปี	0.7	0	Yes	Yes	Yes

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