



**MONITORING SHRIMP FARM EXPANSION AND ASSESSING
ITS COMPLIANCE TO LAND USE PLAN ALONG PRASAE AND
PANGRAT RIVER, RAYONG PROVINCE**

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**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE PROGRAMME
(TECHNOLOGY OF INFORMATION SYSTEM MANAGEMENT)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY**

2000

ISBN 974-664-907-8

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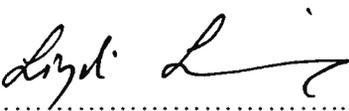
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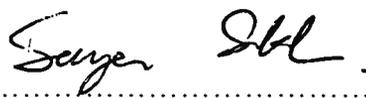
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**MONITORING SHRIMP FARM EXPANSION AND
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was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Technology of Information System Management)

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ACKNOWLEDGEMENT

I would like to thank Dr.Chumlong Arunlertaree, Dr.Phutchapol Suvanachai Mr.Siri Tookwinas and Mr.Niwat Suthemeechaikul for the constructive comments, supervision and encouragement.

Thank are due to Dr.Suwit Ongsomwang, Mr.Boonrak Pattanakanok, Mr.Somporn Patinawin , Mr.Chakchai, Mr. Mulzul and The National research Council of Thailand for supporting imagery data and secondary data.

Thank are also to C&C Education foundation giving the financial support.

Finally, I would like to thank my family, Mr.Saksit Vibolsuk and his fanclub, Lukyee, IM5 alumni and friends for their patience in stressful times and other invaluable assistance. I'm very appreciate and sincere thanks to all.

Jutarat Kittivanich

4036765 ENIM/M : MAJOR: INFORMATION MANAGEMENT ON ENVIRONMENT AND RESOURCES;
M.Sc. (TECHNOLOGY OF INFORMATION SYSTEM MANAGEMENT)

KEY WORD : REMOTE SENSING, GIS, IMAGE PROCESSING, LAND USE CLASSIFICATION, LAND USE COMPLIANCE, MONITORING, LAND USE CHANGE, MANGROVE FOREST, SHRIMP FARM

JUTARAT KITTIWANICH: MONITORING SHRIMP FARM EXPANSION AND ASSESSING ITS COMPLIANCE TO LAND USE PLAN ALONG PRASAE AND PANGRAT RIVER, RAYONG PROVINCE. THESIS ADVISOR : CHUMLONG ARUNLERTAREE, Ph.D., PHUTCHAPOL SUVANACHAI, Ph.D., SIRI TOOKWINAS, M.Sc. 93 P. ISBN 974-664-907-8

Monitoring shrimp farm expansion, including its impact on mangrove forest and land use, is very important for a sustainable management and planning of coastal zones. This study was composed of 3 objectives. The first was to monitor land use for shrimp farms and mangrove forests changing over 22 years (1977 – 1999). The second was to evaluate the spatial relationship of expanding shrimp farms and mangrove forest. The third was to find out the existing shrimp farms which complied with coastal management plan developed by government agencies. Landsat – 4, 5 and JERS-1 satellites were used to process multi – temporal and post classification techniques for detection of shrimp farms and mangrove forest shifts. Shrimp farm maps in 1999 were used to detect land misuse according to land zoning by the government.

The result showed that from 1987 to 1990, about 1,760.15 ha. of mangrove forest were destroyed at the rate of 586.72 ha./yr., whilst shrimp farm expanded by 3,317.03 ha. with a rate of 1,105.69 ha./yr. Both of these had changed dramatically during this period. The shrimp farms were initially located on the area near coastline and then expanded from river mouth to land. Moreover, about 62.34 % (1,097.28 ha.) of total shrimp farms in 1990 were located on the former mangrove areas which were classified in 1987. Also, shrimp farms classified in 1999, were compared with the mangrove zoning areas of Royal Forestry Department and priority crop areas of Land Development Department. It was found that about 1,486.77 ha. or 35.10 % of total shrimp farms in 1999 were located over the preservation and conservation zoning area, while about 977.00 ha. or 23.07 % of total shrimp farms were located over the priority crop area.

4036765 ENIM/M : สาขาวิชาเอก : การจัดการระบบสารสนเทศสิ่งแวดล้อมและทรัพยากร;

วท.ม. (เทคโนโลยีการจัดการระบบสารสนเทศ)

จุฬารัตน์ กิตติวานิช : การติดตามการขยายตัวของพื้นที่เลี้ยงกุ้ง และประเมินความสอดคล้องของพื้นที่กับแผนการใช้ประโยชน์ที่ดินของรัฐ บริเวณแม่น้ำประแสร์และแม่น้ำพังราด จังหวัดระยอง (MONITORING SHRIMP FARM EXPANSION AND ASSESSING ITS COMPLIANCE TO LAND USE PLAN ALONG PRASAE AND PANGRAT RIVER, RAYONG PROVINCE) คณะกรรมการควบคุมวิทยานิพนธ์ : จำลอง อรุณเลิศอารีย์, Ph.D., พุทธพล สุวรรณชัย, Ph.D., สิริ ทุกษ์วินาศ, M.Sc. 93 หน้า ISBN 974-664-907-8

การติดตามการขยายตัวของพื้นที่เลี้ยงกุ้งกุลาดำ รวมทั้งผลของการขยายพื้นที่การเลี้ยงกุ้งกุลาดำที่มีต่อการลดลงของพื้นที่ป่าชายเลนและความไม่สอดคล้องต่อแผนการใช้ประโยชน์ที่ดินของรัฐ เป็นสิ่งที่มีความสำคัญอย่างยิ่งในการนำมาใช้วางแผนและจัดการกิจกรรมการเลี้ยงกุ้งกุลาดำเพื่อให้เกิดความยั่งยืนและไม่มีผลกระทบต่อสิ่งแวดล้อม ดังนั้นในการศึกษาครั้งนี้จึงมีวัตถุประสงค์หลัก 3 ประการด้วยกันคือ 1. เพื่อติดตามการเปลี่ยนแปลงของพื้นที่เลี้ยงกุ้งกุลาดำและป่าชายเลน ตั้งแต่ปี 1977 ถึง 1999, 2. เพื่อทราบความสัมพันธ์ระหว่างการขยายตัวของพื้นที่เลี้ยงกุ้งกุลาดำที่มีต่อพื้นที่ป่าชายเลน ณ ช่วงเวลาเดียวกัน และ 3. เพื่อจำแนกพื้นที่เลี้ยงกุ้งกุลาดำที่ไม่สอดคล้องกับแผนการใช้ประโยชน์ที่ดิน โดยประยุกต์ใช้เทคโนโลยีการสำรวจระยะไกลและระบบสารสนเทศภูมิศาสตร์ และใช้ข้อมูลเชิงดิจิทัลจากดาวเทียม Landsat 4, 5 และ JERS-1 ที่เวลาต่างๆ กัน ใช้เทคนิค multi-temporal และ post classification เพื่อติดตามการเปลี่ยนแปลงของพื้นที่เลี้ยงกุ้งและป่าชายเลนในแต่ละช่วงเวลา และเทคนิคการซ้อนทับข้อมูลเชิงพื้นที่เพื่อจำแนกพื้นที่เลี้ยงกุ้งที่อยู่ในบริเวณที่ไม่สอดคล้องกับแผนที่ กล่าวมาข้างต้น ผลการศึกษาพบว่าในปี 1987 - 1990 เป็นช่วงที่ป่าชายเลนลดลงมากที่สุดและในขณะเดียวกันพื้นที่เลี้ยงกุ้งก็เพิ่มมากที่สุดเช่นกัน โดยป่าชายเลนลดลง 1,750.15 แยกแตร ด้วยอัตราการลดลง 586.72 แยกแตรต่อปี พื้นที่เลี้ยงกุ้งเพิ่มขึ้น 3,317.03 แยกแตร ด้วยอัตราการเพิ่ม 1,105.69 แยกแตรต่อปี โดยบ่อเลี้ยงเริ่มเกิดขึ้นในปี 1987 บริเวณแนวชายฝั่งและขยายพื้นที่จากบริเวณปากแม่น้ำขึ้นไปด้านบน นอกจากนี้ยังพบว่าบ่อเลี้ยงในปี 1990 เกิดขึ้นมาจากพื้นที่เดิมที่เป็นป่าชายเลนในปี 1987 มากที่สุดเช่นกัน ประมาณ 62.34 % ของพื้นที่เลี้ยงกุ้งทั้งหมดคิดเป็นพื้นที่ประมาณ 1,097.28 แยกแตรต่อปี และจากการซ้อนทับพื้นที่เลี้ยงกุ้งปี 1999 กับแผนที่แบ่งเขตการใช้ประโยชน์พื้นที่ป่าชายเลนของกรมป่าไม้และแผนที่ดินที่เหมาะสมสำหรับการปลูกพืชเศรษฐกิจของกรมพัฒนาที่ดิน พบว่าบ่อเลี้ยงอยู่ในพื้นที่ป่าอนุรักษ์และป่าเศรษฐกิจ ก ซึ่งไม่เหมาะสมสำหรับการเลี้ยงกุ้ง 1,486.77 แยกแตร หรือ 35.10 % ของพื้นที่เลี้ยงกุ้งทั้งหมด และอยู่ในบริเวณดินที่เหมาะสมสำหรับการปลูกพืชเศรษฐกิจที่ 977.00 แยกแตรต่อปี หรือ 23.07 % ของพื้นที่เลี้ยงกุ้งทั้งหมด

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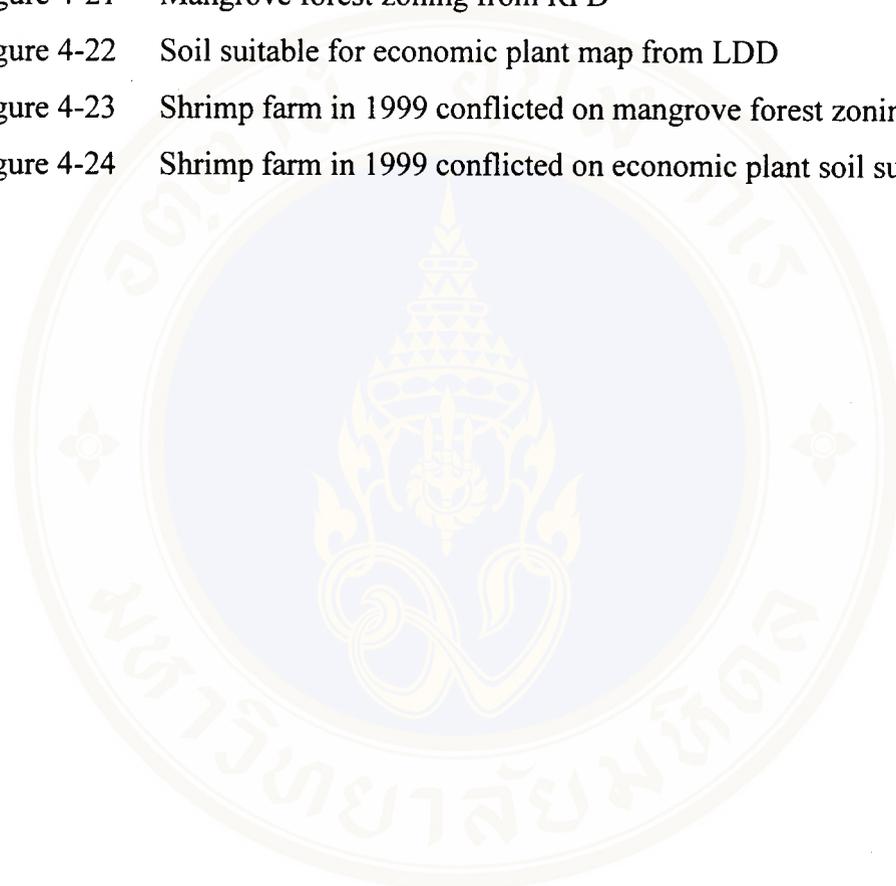
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LIST OF ABBREVIATIONS

AIT	Asian Institute of Technology
DOF	Department of Fisheries
GIS	Geographic Information System
ha	Hectare
LDD	Land Development Department
m	Meter
NRCT	National Research Council of Thailand
OPS	Optical Sensor
RFD	Royal Forestry Department
RS	Remote Sensing
TM	Thematic Mapper

CHAPTER I

INTRODUCTION

Thailand has had the experiences on marine shrimp culture for a long time. However, the intensive marine shrimp farming technique has been developed and expanded along the coastal zone of Thailand since 1986. Its expansion and production has increased very rapidly and continuously. Thailand, therefore, has been the leading country for shrimp export to the world market since 1991. The total area of shrimp farm along the coastline on the Gulf of Thailand and the Andaman Sea is approximately 70,400 ha. This results in the shrimp production is about 234,000 tons with the average income of more than 47,000 million baht a year as being exported (1).

Thailand has been successful in marine shrimp culture, however unplanned and uncontrolled shrimp culture expansion has been leading to several problems. For example, some agricultural areas or mangrove forests were converted into shrimp pond which, in turn, deterioration in coastal natural resources and environment is unavoidable. In Thailand, the mangrove conservation has been carried out by the Royal Forestry Department (RFD) which has allocated mangrove forest into three zones. They are preservation, conservation and development zones as the cabinet resolution in December 15, 1987 (2). In 1996, the survey showed that 62.62% of shrimp farm was located in the conservation and development zones. Due to high density and poor management, shrimp farming has impacted on environment to some

extent such as poor water quality. This degraded environment was not suitable for nearby aquaculture activities. Disease outbreak problem is likely to be appeared. Then, the farmers who got the infected farms will lose or got a little profit. Consequently, some farmers find other the suitable areas for culturing, and leave the previous ponds behind as the inactive and finally abandoned areas. This phenomenon look like shifting cultivation of other agriculture products such as cassava.

The development, distribution, and relationship between shrimp farm and mangrove forest as well as land suitability assessment for shrimp pond development are very important information for planning and management. Therefore, it is necessary surveying and monitoring shrimp pond over time with timely data and effective tools. In turn, we are able of obtaining the indication of reality condition of production, and finding rapid solution immediately or aid in long term planning and formulation of policies as the following examples:

- to prohibit shrimp culture in sensitive area,
- to fix suitability area for shrimp culture,
- to support management technique and infrastructure, and
- to evaluate shrimp production for developing and improving market strategies.

In Thailand, most shrimp farm data collection has been traditionally carried out by government officers interviewing shrimp farmers. This method has several disadvantages which are slow data processing, labor demanding and high costly. The frequency of field survey is also limited to at most once a year, and unfortunately no

one could not visit every farm. In addition to field survey, data can be obtained from farm registration with the Department of Fisheries (DOF) which has been carried out since 1991. However, such data from DOF has still some error and out of date to some extent because farmers ignore informing the officer for data updating when shrimp farmers stop or shift to the other areas. Furthermore, some shrimp farmers do not make a registration because of intention and non – intention ignorance of the regulation. The unregistered farms are located in illegal area such as in the preservation area of mangrove forest.

As mentioned above, it is essential to use an appropriate technology to overcome this problem. Remote sensing (RS) and geographic information system (GIS) are the valuable tools to assist surveying, monitoring and assessing land use change. Satellite RS data have several advantages such as large area coverage, more convenience, more accurate and rapid in compared with the traditional ground survey. GIS is used in spatial operation of thematic map to find out a location where land use change and seeks to find the differences over time. Moreover, land use conflict can be found out by overlaying process.

At present, both tools are applied to various management and research issues including in coastal zone management such as production of coastal habitat maps and the identification of change in habitat cover. The monitoring of mangrove loss and aquaculture development is a particular concern in this study.

Objectives

The main objectives of this study are:

1. To monitor land use changes of shrimp farm and mangrove forests over 22 years (1977 – 1999),
2. To evaluate the spatial relationship of shrimp farm and mangrove forest over 22 years (1977 – 1999), and
3. To find out the existing shrimp farm which are complied with coastal management plan developed by government agencies.

Scope of the study

This study is to apply the use of remote sensing and geographic information system for finding out land use change and evaluate the spatial relationship of shrimp culture area and mangrove forest along Prasae and Pangrat river. A multi-temporal change detection technique using digital satellite imagery is applied to achieve such objectives. In addition, the present shrimp culture area is overlaid with thematic map from the other government agencies such as mangrove land use zones for assessing its compliance to various land use plans.

Research Significant

The appropriate spatial analysis method for classifying and monitoring marine shrimp culture in association with mangrove forest can be obtained. Furthermore, the spatial information can be utilized for a more effective coastal zone management. For instance, the shrimp farm which avoid land use conflict can be identified.

Key words : remote sensing, GIS, image processing, land use classification,
land use compliance, monitoring, land use change, shrimp farm,
mangrove forest



CHAPTER II

LITERATURE REVIEWS

Marine shrimp culture in Thailand

Thailand is the main exporting country of shrimp aquaculture product which can share around 30 percent of the world aquaculture shrimp production (3). The evolution of marine shrimp culture was started on traditional or extensive farming for nearly 70 years. Shrimp fry were accidentally trapped in the salt beds and paddy fields around the estuarine areas. Originally, wild shrimp fry either entering during tidal water exchange or are intentionally gathering from wild and stocked directly in ponds. Production is dependable on seasonal abundance of wild fry which fluctuates widely year by year.

In 1973, Thailand successfully spawned and partially reared larvae of *Penaeus* spp. The DOF initially encouraged for addition seedstock from hatcheries in traditional pond. The supplementary feed was added to the pond which is called semi-intensive shrimp farming system. In the past decade, intensive farming technology for *Penaeus monodon* has been developed and practiced in Thailand and expanded tremendously in coastal areas both side of Gulf of Thailand and Andaman sea. Because shrimp culture gave the good benefit and harvested production in short time. From Table 2-1, shrimp culture expanded along coastline continuous from 1976 to 1998. During 1990 to 1995 number of farm had high expanding rate, then the

expanding rate was slow down in 1996 because of the environment problem lead to outbreak disease in pond and lack of wild broodstock. The shrimp culture area in Rayong province has been started in 1984 and had very high growth rate from 1986 to 1991. The areas were increase from 44.48 ha. to 1,742.24 ha. (1). After that, trend of expansion area has decreased and fluctuated in narrow range. So, shrimp culture data should be collect for monitoring shrimp culture change and planning to support shrimp culture facility for sustainable activity.

At present, shrimp farm data was collected by Fisheries Economic Division to random 10 % of total shrimp farmers. This method has high error and also slowly and accuracy depend on quantity and distribution which the examples could be good to represent the total of shrimp farm. In other way, we got the data from registration which shrimp farmer must be register with Fisheries District Officer, announced by DOF on November 1991, under Fisheries Act 1947. However, DOF has got the cooperation from some part of all farmers and the officer can not update registration data in the distant future. The legislation concerning shrimp culture to control shrimp farm expansion and impact of its on environment.

1. In December 1998. The Deputy Ministry of Agricultural and Cooperatives announced the establishment of registration shrimp farmer. All of shrimp farm to be register at local officer and must be extent every year in the case of farm area more than 8 ha. The register farm must be following the constrain of DOF such as plan of shrimp farm, limit of Biochemical Oxygen Demand in farm effluent, ban on flushing of mud or silt and release of salt water public. If the farmer is not following the

constrain in above mention. The local government officer can withdraw his registration.

2. In July 1998. The cabinet approval to cancel marine shrimp culture in fresh water area.

Table 2-1 Number of farm, area and production of shrimp culture in Thailand since 1976 - 1997 and in Rayong province since 1984 -1997

Year	Thailand			Rayong Province		
	No. of farm	Area (ha.)	Production (metric ton)	No. of farm	Area (ha.)	Production (metric ton)
1976	1,544	12,296	2,533	-	-	-
1977	1,437	12,411	1,590	-	-	-
1978	3,045	24,169	6,395	-	-	-
1979	3,378	24,676	7,064	-	-	-
1980	3,572	26,036	8,063	-	-	-
1981	3,657	27,459	10,728	-	-	-
1982	3,943	30,792	10,091	-	-	-
1983	4,237	35,537	11,550	-	-	-
1984	4,519	36,792	13,007	1	2.56	2.12
1985	4,939	40,769	15,841	4	7.52	1.90
1986	5,534	45,368	17,886	17	44.48	20.77
1987	5,899	44,770	23,566	88	633.28	173.39
1988	10,246	54,778	55,633	127	1,012.16	183.60
1989	12,545	71,166	93,495	127	1,012.16	1,721.25
1990	15,072	64,606	118,227	163	1,733.28	5,417.00
1991	18,998	75,332	162,070	230	1,742.24	8,956.00
1992	19,403	72,796	184,884	183	1,515.52	9,596.33
1993	20,027	71,887	225,514	206	1,624.80	1,2191.64
1994	22,198	73,247	263,446	240	1,489.12	1,7754.27
1995	26,145	74,942	259,541	262	1,383.68	1,1897.85
1996	22,913	69,464	229,000	88	556.00	3,627.50
1997	21,000	69,120	219,000	202	1,366.56	5,921.00

Source: Fisheries Economic Division, 1999.

Land use in Rayong province

Rayong province is located on eastern part of Thailand which has coastal line approximately 100 km. Major agricultural crops are rubber, paddy fields, orchards, dry land cultivation (cassava, pineapple and home garden) and shrimp farming plus other brackish farming. In 1995 Rayong province has total area approximately 352,000 ha. which was classified into 4 classes are: (4)

1. Agriculture area 233,745 ha. 65.18% of total area
2. Forest Forest area 21,927.52 ha. 6.17% of total area
Mangrove forest 154.08 ha. 0.70% of total area
3. Urban, Abandon and other area 10,884.96 ha. 3.06% of total area
4. Unclassified area 88,641.76 ha. 24.46% of total area

The study area is located in Prasae and Pangrat watershed. The land use/cover surveyed from LDD in 1989 on Table 2-2 and the suitable area for each activities on Table 2-3.

Table 2-2 Land use/cover of Prasae and Pangrat watershed in 1989

Land use/cover type	Prasae watershed		Pangrat watershed	
	Area (ha)	%	Area (ha)	%
1. Paddy	6,680	3.23	5,525	11.61
2. Mix field crop	66,335	32.08	7,450	15.65
3. Rubber	86,395	41.78	9,125	19.17
4. Mixed fruit	3,090	1.49	12,725	26.73
5. Shrimp farm	260	0.13	770	1.62
6. Mangrove	1,800	19.17	4,940	10.38
7. Shrub land	2,060	1.00	0	0
8. Low-lying land	510	0.25	4,755	9.99
9. Forest	39,650	19.17	2,310	4.85
Total	206,780	100	47,600	100

Source : Land Development Department, 1989 (5).

Table 2-3 Soil suitable for the activity of Prasae and Pangrat area

Soil Suitable for each activities	Prasae watershed		Pangrat watershed	
	Area (ha.)	%	Area (ha.)	%
1. Paddy	11,700	5.66	10,160	21.35
2. Mix field crop / Mixed fruit	84,820	41.02	590	1.24
3. Reforestation/ march	72,970	35.29	25,020	52.56
4. Forest	33,720	16.31	6,500	13.65
5. Mangrove	3,570	1.72	5,330	11.20
Total	206,780	100	47,600	100

Source : Land Development Department, 1989 (5).

In normally, the coastal area is very important area because it's rich of natural resource and bio-diversity. Hence, it has attracted human settlements, aquaculture, tourism and mining. Several developments have occurred in Rayong coastal area including eastern seaboard project urban and shrimp culture expanding. These development not only have caused significant impacts on natural resource but also the impact on environment deterioration. From the past, rich of mangrove forest along Prasae and Pangrat river. So, The RFD has been declared into conservation zone for the specific purpose of conserving coastal since 1958 which the area about 1,453.92 ha. After that, RFD proposed the definition of three zones of mangrove use, which was approved in 1987. The area of conservation zone, economic A zone and economic B zone were 449 ha., 2,039 ha. and 1,936 ha., respectively. But in reality RFD could not control the utilization of mangrove forest, therefore in 1993 surveying result from Landsat imagery showed the mangrove was cleared for other activities. With the increasing development of coastal area, there will be more pressure on the use of coastal resource especially mangrove forest decreasing. Table 2-4 showed the

mangrove area and activity in mangrove area are interpreted by RFD in 1993.

Mangrove forest and shrimp culture area changed present in Table 2-5.

Table 2-4 The mangrove area and land use activity in mangrove area in 1993

Land use	Conservation zone (ha.)	Economic A zone (ha.)	Economic B zone (ha.)	Total (ha.)
Mangrove	107.28	252.20	350.52	680.00
Shrimp culture	249.44	1,570.80	1,057.08	2,877.32
Urban	12.48	11.72	171.96	196.16
Other	79.80	204.28	886.44	1170.52
Total	449.04	2,039.00	1,936.00	4,424.00

Source: In the 9th National seminar on mangrove Ecosystems, 1997 (5).

As seen in Table 2-4, shrimp culture area is the major impact on mangrove decreasing.

Table 2-5 Change of mangrove forest and shrimp farm area

Year	1975	1979	1986	1989	1991	1993	1996
Mangrove forest area (ha.) ^{1,2}	5,500.00	4,608.00	2,417.92	1,757.92	962.50	680.00	656.48
Shrimp culture area (ha.) ³			44.48	1,012.16	1,742.24	1,624.80	556.00

Source: ¹Havanond (7), ²Jarupat (8), ³DOF (1)

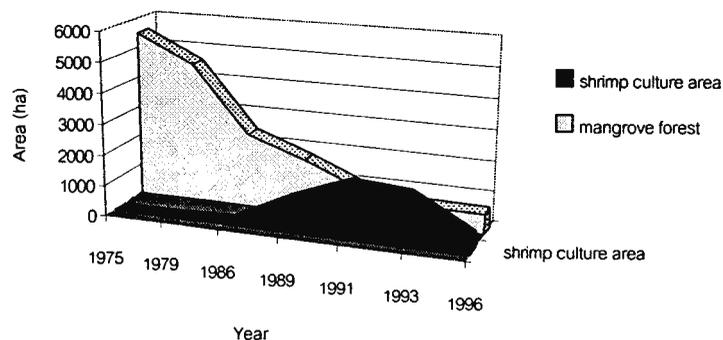


Figure 2-1 Mangrove deforestation and shrimp farms expansion from 1975 – 1996 in of Rayong province

At present, shrimp culture status in Rayong province has high risk in lost because of environment degradation which it is not suitable for rearing and lead to disease outbreak. Moreover, poor management in farm such as high density stocking, overfeeding and no water treatment system which former mention they are cause of fail and some farm stopped running in temporary or permanent status.

Coastal area is sensitive area so many division of government have duty to implement and management in the area which each division has the policy and planning that is responsible for implementations and conservation. The government division in Agricultural and Cooperative Ministry that are relevant for the coastal zone management are broadly summarized below

1. The Department of Fisheries is responsible for fisheries development as well as brackish water fisheries. They register of shrimp farmer.
2. The Royal Forestry Department is in charge of mangrove conservation, reforestation and allocate mangrove area for suitable activities is not impact.
3. The Department of Land Development is responsible for the land use classification plans including coastal zone.
4. The Royal Irrigation Department is responsible for development or creating water sources for agricultural.

From above mention, the promotion of shrimp culture activity is necessary to generate planning and policy carefully for avoiding conflict viewpoints and facilitate a movement towards consensus.



The national mangrove management plan for Thailand

Mangrove forest is the importance natural resource of coastal zone. It is participate coastal ecosystem and very usefulness such as it's source of fry and nursery area for fish and other crustacean, source of dissolved and suspended nutrients which an exported to adjacent area, protection shoreline from wave, wind and storm. From the past, mangrove forest is changed to agriculture area, aquaculture area, urban, port etc. which it impact to rapidly decreasing. The Royal Thai government has several mitigation measure plan for coastal area management for improving mangrove reforestation and relocation the prevent aquaculture area on the propose of minimizing the environmental impacts. The regulation, law and utilization were declared for conservation and control using mangrove forest from the past as follows:

1. In 1958, Ministry of Agricultural and Cooperative declared Prasae and Pangrat mangrove forest to preservation zone.
2. On December 15, 1987 the cabinet decision introduced three zone for mangrove forests based on surveyed data on 1961 in order allocation uses Mangrove forest uses zone are (8)
 - Conservation zone is strongly protected from any impact for its natural environment values.
 - Economic A zone is able to used for forest utilization on sustainable yield basis.
 - Economic B zone is able to be used for other developments natural with consideration given to the impacts on the environment.

3. On July 23, 1991 the cabinet has also issued strictly prohibit to access and use into mangrove forest both of government agency and private sector. Furthermore, asking for cooperate with government and commercial bank to ban a loan for activity in mangrove area (10).
4. On November 19, 1996 the approval to cancel the mangrove concession on over the country. It mean that it would not have any more mangrove economic A zone under the mangrove zonation on December 1987 (9).

Study period

Mangrove forest is a significant coastal habitat, rich in ecologically and economically importance natural resource in coastal zone system. Rayong province has the coast which it composed of large area of mangrove forest along coastal line. It was surveyed since 1975 by the RFD. The result of surveying was separated mangrove forest area changing into 3 periods. First of all in 1975 – 1989, mangrove forest decreasing from 5,500 ha. to 1,757.92 ha., the decreasing rate 267.30 ha/yr. During 1989 – 1991 the decreasing rate more highly to 801.96 ha/yr., the area was still remain 154 ha. After 1991, mangrove forest area is increasing because of reforestation project by RFD followed the accelerative policy of cabinet for management coastal resource (mangrove and coral).

Coastal development have conflicting interest in the use of natural resource especially mangrove forest such as shrimp culture, port and urban were cause of adverse impact on the mangrove forest. From DOF statistic of Rayong province, shrimp culture activity started in 1984 and expanding in high rate from 1986 to 1991,

the area expanded from 44.48 ha. to 1,742.24 ha. and expanding rate 339.56 ha/yr. After 1991, the shrimp culture are hardly increase which it is harmonious with mangrove forest changing.

From Table 2-1 the monitoring should started before shrimp culture activity happening (1984) and during shrimp culture expanding in 1987, 1990, 1994, 1997 and 1999. In study area, shrimp culture area expanding very rapidly so we should monitoring changing in short interval (every 3 years). It will show conversion of mangrove forest to shrimp farm distinctly.

Table 2-6 List of satellite data source

Year	Satellite	Path/Row	Format	Recorded date	Source of data
1977	Landsat 4 (MSS)	128/51	Digital	N.A.	RFD
1987	Landsat 5 (TM)	128/51	Digital	N.A.	AIT
1990	Landsat 5 (TM)	128/51	Digital	22/12/1990	RFD
1994	JERS-1 (OPS)	124/279	Digital	22/01/1994	NASDA
1997	JERS-1 (OPS)	124/279	Digital	24/04/1997	NASDA
1999	Landsat 5 (TM)	128/51	Digital	17/02/1999	NRCT

Remote sensing (RS)

“Remote sensing” is the observation of the earth from distant vantage points, usually by/from satellites or aircraft. Cameras mounted on this platforms captured detailed pictures of the earth that reveal features not apparent to the naked eye. Once captured, the image are passed on to analysts who interpret the data, extract information, and use it to answer question. This information may be used to map

forests, detect pollution, measure elevation, locate a diseased crop, and answer a variety of other questions (11).

Sensor systems (e.g. camera, radiometer or radar) mounted on elevated platforms (e.g. aircraft or satellite) detect and measure electromagnetic energy reflected or emitted by an object. Sensor systems may be active, or passive. Satellite data is recorded in digital form. There are processed through the use of image processing system. The main propose of image processing and analysis is to extract relevant information, which is then represented in thematic maps and interpreted for various propose such as environmental assessment, cartography, meteorology military and management (12). However, satellite data has many wavelength. The user should choose wavelength which suitable for analyzing interested target. More narrow range of DN-value reflectance of object in each band is better for studying. In reality, the reflectance value in each objects are overlap and can not separate distinctly. So, for more accuracy and clearly to classify object from satellite data. Many analysis methods are applied to band operation such as image rational, image subtraction, image classification etc.

RS provides a viable source of data from which update land cover information can extracted efficiently and cheaply in order to inventory and monitoring these changes effectively. Thus change detection has become a major application of remote sensed data because of repetitive coverage at short intervals and consistent image quality (13).

Despite the undoubted potential application of RS technique to study feature on earth, there are still limitation and practical problems encounter in their uses. The limitation of using satellite data at least six points are follows: (14)

1. Spectral range. Sensor system mounted on elevated platform has multispectral. For example, Landsat satellite compose of MSS (4 spectral ranges) and TM (7 spectral ranges). In each spectral range is designed for each object or material studies. As a result, user should to consider before choose spectral range in his research.
2. Data and image. Sensor has recorded feature on the earth in digital form. There are processed many steps before produced thematic map.
3. Ground resolution. In each satellite (i.e. SPOT, LANDSAT, NOAA, JERS-1) has different ground resolution. User should be careful to choose satellite data which it is matched with size of material or area studies.
4. Land elevation. Most of satellite has not three dimensions data. They can not create contour line or elevation data. 3-D satellite data is difficult to record and has many problem to processes.
5. Cloud cover. Most serious constraint faced in the use of satellite data from passive remote sensing. The used of active remote sensing system, i.e. microwave sensor and airborne, is the only way to overcome cloud cover problem. However, microwave data can not totally replace passive remote sensing data for all studies such as ocean color.
6. Receiving data. Ground receiving in Thailand has received satellite data from other countries satellite such as Landsat from U.S.A., JERS-1 from

Japan. If they do not send signals, we has not receive satellite data for analyzing.

The research documents used RS tool in Rayong province compose of Chueysai (15) classified land cover of Rayong basin. The study compared the use of Landsat 5 TM data (bands 2, 3, 4 and 5) to those enhance stretch technique. The result shows that better accuracy was achieved from utilizing the enhanced data and their resultant classifications were markedly different from original data. Enhancement neither improved the accuracy of the well defined data type nor highly mixed types with definite boundary. The land cover in Rayong basin was classified into seven types: water body, paddy field, pineapple, rubber trees, other trees, residential area and idle land. The classified areas averaged 1,019, 4,735, 2,204, 5,263, 6,197, 3,592, 13,845 ha., respectively. Leeruksakiat (16,17) used satellite image from Landsat 5 TM to classify shrimp farm and mangrove areas in Rayong and Trad provinces in 1986 his result is very different from fisheries statistic data. From satellite image visual interpretation, shrimp culture area in Rayong and Trad are approximately 3,263.84 ha., 7,208.24 ha., respectively while data from randomize survey are 556.00 ha., 1,645.28 ha. Furthermore, Looijen (18) recommended the major conflict of interest is between the rapid expansion of shrimp culture and the conservation or rehabilitation of mangroves. The multi-objective decision support system for environmental management was used to selected to support decisions with a finite set of alternatives in relational to finite number of criteria and to determine how much land was available and where, considering different policy options.

Other case studies to apply RS in Thailand which it was applied for monitoring and resource management application more than 20 years (19). It was widely usefulness application to study forestry, agriculture, geology, hydrology, disaster, cartography to environmental studies etc. So, RS is a new tool to analysis and present coordinate, size, status and natural resource changing more accuracy and consistent. RS was used to survey mangrove forests, shrimp culture area and classify shrimp pond activity. Tonnyapas et. al (20) investigate mangrove forest in Pattani bay and recommend that Landsat TM data band 3, 4, 5 (BRG) are better to distinguish different between mangrove from forest and band 2, 3, 4 (BGR) are better showed sedimentation in the bay. In aquaculture activities, Thompolkrang (21) represented coastal culture area and water quality in Songkhla lake and aquaculture around it by satellite image and Geographic Information System (GIS) and present the area via map. Suvanachai (22) used OPS system data from JERS-1 satellite apply to calculate shrimp culture area and classify shrimp pond activity (dry pond, grow-out pond, stocking pond and mud pond) in study area. Furthermore, he could calculate shrimp production roughly from study area because he divided shrimp pond activity into two groups are dry pond and water cover pond. In reality shrimp pond is cover with water may be not running. From field survey shrimp farm in Rayong province during September 21 –22, 1999, many shrimp farm was stop because of environment problem especially many big farm has still stopped running more than 3 years although in pond was cover by water all the time. This kind of pond the area is estimately 640.00 ha. and dike was cover by grasses.

Remote sensing application for detecting land use change

It has several analysis method to use imagery data from satellite detecting land use change. So, the research tried to develop technique which suitable and usefulness in his field. The publication about land use change such as Mas (13) tested six change detection procedures using Landsat multispectral scanner (MSS) image for detecting areas of change in the coastal zone of Mexico. The change detection techniques considered were image differencing, vegetative index differencing, selective principle components analysis (SPCA), direct multivariate supervised classification, post-classification change differencing and combination of image enhancement and post-classification comparison. Post-classification comparison was found to be the most accuracy procedure and present the advantages of indicating the nature of changes. Landsat MSS data of both dates were independently classified using the maximum likelihood classifier. Moreover, methods based on classification were found to be less sensitive at these spectral variations and more robust when dealing with data captured at different times of the year. Other researcher using this method is land use and land cover change case study at Klang - Langat river basin in Malaysia (23) Images in different dates were classified using maximum likelihood method and followed by post-classification processing for detecting the change, and a spatial model were created by using conditional analysis. Miller (24) Landsat multispectral scanned data were used to characterize land cover type, land cover change in northern forest of New England. MSS data were classified in each scene using supervised classification technique. Training site for water and forest type were identical for all scene, and they were selected in overlap area of adjacent scene, in areas were not obstructed by clouds and that did not change over time. Training sites for opened land, cloud and cloud

shadows were selected for each individual scene because these classes varied in each year. Water, open land, cloud shadow were classified using a parallelepiped algorithm because these surface types are discrete class in spectral space, so that the parallelepiped algorithm is a reasonable classifier. A maximum likelihood algorithm was used to classify the forest types. That the forest types are probably part of a continuum. The probabilistic nature of maximum likelihood classifier was more suitable for these data. After classified each band, a multitemporal analysis of the spectral classification from each year was performed to estimate land cover change during period of study and present land cover and land cover change via the map. In other case of change detection by Sunar (25), an analysis of changes in a multi – date set : a case study in the Ikitelli area, Turkey. The different date of Landsat TM were registered together using an automated procedure base on correlation in the spatial domain and treated as a single ten – dimensions data array. In this study four change detection methods, image overlay, image differencing, principle component analysis and classification comparisons, were employed to observe and analysis land cover/use change. Among the methods implemented, image overlay and image differencing were relative straightforward. PCA and classified imaging of a combined multi – date data sets highlighted differences distinctly attributable to change.

The case study of Travaglia (26), ERS SAR satellite data have been processed spectral and spatial analysis to separate shrimp culture area from other in each year and applied them for inventory and monitoring shrimp farm expansion. Speckle noises was removed from SAR data by filtering and used ISODATA unsupervised procedure and then the image can be analyzed by mean of supervised classification to

classify water body, high – reflection surface dyke and other surface. The dyke surrounding shrimp farm may also be identify edge detection by Sobel filter. The proximity analysis examines the boundaries of water bodies obtained from the unsupervised classification and locate both highly reflective surfaces in the classified image and edge image and edge in Sobel filtered image. The summary image allow the operator to locate the areas where there is a greater evidence of the occurrence of shrimp farm and help in tracing the farm' boundaries.

Geographic information system

There are several definitions for a geographic information system (GIS), each defined depend upon its perspective (development or disciplinary) such as;

A geographic information system (GIS) is an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a data base system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data (27).

GIS is a computer–assisted system that can input, retrieve, analyze and display geographically referenced information useful for decision making (12).

GIS applications

Many applications of GIS have been in the field of land use management, agriculture, forestry and urban development such as cadastre and transportation. Only in recent years has there been widespread applications in environmental and aquatic sciences, and socioeconomics. GIS has also been used in the military, global climate

modeling and geosciences, especially with three-dimensional GIS. Table 2-7 shows some of the applications of GIS in the coastal zone, especially in fisheries (12).

Benefits of GIS in resource management and planning (12)

The benefits of using GIS in resource management are generally recognized, and have been widely documented from applications developed in various countries for different types of natural resources such as conservation area and forestry management. In general, the main benefits including as follows:

1. ability to integrate data of various types (graphic, textual, digital, analog) from a variety of sources;
2. ability to greatly enhance capacity for data exchange among various disciplines and departments concerned;
3. ability to process and analyze data more efficiently and effectively than can be achieved manually;
4. ability to model, test and compare alternative scenarios before the proposed strategy is imposed on the real-world system;
5. facility for efficient updating of data, especially graphic; and
6. ability to handle large data volumes.

Being an integrative system, GIS can undertake multi-criteria modeling which can be useful in coastal zone and resource management where a holistic or integrated approach is required.

Table 2-7 Some applications of GIS in the coastal zone (12)

Field of application	Brief description
Cartography	A study by the United States Geological Survey to produce topographic maps of the nation for a use of federal and state agencies, commercial companies and individual citizens at 1:24,000 scale series.
Land Management	Profiles developed for each drainage basin based on GIS inventories of the extent of forest land, cultivated land, urban area, stream shore, lake shore, silt soil, sand soil areas of 3-6 % slope and other parameters for water resource assessment.
Freshwater Habitat Management	A case study on impact assessment of contaminants. Creating data-bases for habitat potential, attribute file of habitat condition and stream dimensions, watershed boundaries, point file of contaminant discharge. Describing downstream impact in terms of proportion of fish production loss. Analyzing habitat affected by contaminants and converted habitat areas into fish production.
Marine Habitat Management	Creating database for various attributes, point data, bathymetry, sediment type. Establishing criteria for suitable habitat model by describing relationship between spatial variables. Overlaying maps to produce the desired output.
Potential for Aquaculture Development	<ul style="list-style-type: none"> - Data sets used are salinity requirements, soil characteristics, rain-fall pattern, land use (mangrove vs. non-mangrove area) for determining potential areas for shrimp farming. - Data sets used are environmental parameters, infrastructure, land use, soil types, hydrographic factors, coastal geomorphology and meteorological characteristics for determining potential area for aquaculture development. - Data sets used are water quality, existing land-use patterns, distance from water source, geomorphological features and distance from existing aquaculture farms for determining potential area for shrimp and fish hatcheries.
Coastal Resources Study	Identifying socio-economic variables which might influence Developments in a coastal environment. Data sets used are population, Employment statistics, income levels, educational background, Infrastructure and public amenities.

Landsat satellite

National Aeronautic and Space Administration (NASA) initiated the first civilian program specializing in the acquisition of remotely sensed digital satellite data. The mission objective of these satellites: To provide, on an operational basis, sensors capable of identifying "earth resources". The continuous nature of the operation also makes changes in resources identifiable. There have been several Landsat satellites launched since 1972. Landsats 1, 2 and 3 are no longer operating, Landsat 4 and 5 are still in orbit gathering data (28). Landsat 6 was launched in October, 1993, but failed to obtain orbit. The current satellite Landsat 7 launched in April, 15 1999 (29). At present in Thailand, Landsat 5 data can be only required. Thailand satellite ground receiving station will acquire data and procedure the master film as well as the original product from Landsat 7 satellite. The service of this satellite data will be serviced via internet in middle B.C. 2000 (30).

Landsat -5 TM (28)

Launch of satellite: Landsat 5 March 1, 1984. The TM (thematic mapper) scanner is a multispectral scanning system much like the MSS, except that the TM sensor records reflected/emitted electromagnetic energy from the visible, reflective-infrared, middle-infrared and thermal-infrared regions of the spectrum. TM has higher spatial, spectral and radiometric resolution than MSS.

Table 2-8 Detectors record in each band of Landsat – 5 (TM)

Band	Wave length	Usefulness	Application
1	0.45 - 0.52 µm. blue	Useful for mapping coastal water areas, differentiating between soil and vegetation, forest type mapping and detecting cultural features.	Useful for analyzing suspended sediment in shallow water (31). Strongest capacity penetrating 20 m. with peak at 0.48 µm. (32).
2	0.52 – 0.60 µm. green	Corresponds to the green reflectance of heating vegetation. Also useful for cultural feature identification.	Plant in water and chlorophyll high reflectance (31). High density of diatom and blue green algae will high reflectance value (33).
3	0.63 – 0.69 µm. red	Useful for discriminating between many plant species. It is also useful for determining soil boundary and geological boundary delineation as well as cultural features.	High reflection in turbidity water. This band reflectance converse with turbidity of water (31). It also useful for detect organic matter (33). It was able to penetrate less than 3 m. (32).
4	0.76 – 0.90 µm. reflective – infrared	This band is especially responsive to the amount of vegetation biomass present in a scene . It is useful for crop identification and emphasizes soil/crop and land/water contrasts.	On which region of higher salinity appear lighter (34). It was absorbed strongly by water body but it still able to penetrate some water body less than 2 m. (32).
5	1.55 – 1.75 µm. mid-infrared	This band is sensitive to the amount of water in plant, which is useful in crop drought studies and in plant health analyses. This is also one of few bands that can be used to discriminate between cloud, snow and ice.	Less reflectance in blue green algae (33).

Table 2-8 Detectors record in each band of Landsat – 5 (TM) (cont.)

Band	Wave length	Usefulness	Application
6	10.40- 12.50 µm. thermal- infrared	This band is useful for vegetation and crop stress detection, heat intensity, insecticide applications, and for locating thermal	
7	2.08 – 2.35 µm. mid-infrared	This band is important for the discrimination of geologic rock type and soil boundaries, as well as soil and vegetation moisture content.	Band 2, 5 and 7 have relationship with blue green algae concentration (33). Middle-infrared (3.0-5.0 µm.) may be more sensitive to change in forest property than the reflectance in visible and near-infrared wavelength (35).

Landsat –7 (29)

In 1992, the US Congress authorized the procurement, launch and operation of a new Landsat satellite. This new system, Landsat 7, was launched in April, 1999. It will be the latest in a series of earth observation satellites dating back to 1972. The twenty – two year record of data acquired by the Landsat satellites constitutes the longest continuous record of the Earth's continental surfaces. Preservation of the existing record and continuation of the Landsat capability were identified in the law as critical to land surface monitoring and global change research.

The earth observing instrument on Landsat 7, the Enhanced Thematic Mapper Plus (ETM+), replicates the capabilities of highly successful Thematic Mapper instruments on Landsat 4 and 5*. The ETM+ is similar to the ETM instrument on

Landsat 6. The ETM+ also includes new features that make it a more versatile and efficient instrument for global change studies, land cover monitoring and assessment, and large area mapping than its design forebears. The primary new features on Landsat 7 are:

- A panchromatic band with 15 m. spatial resolution
- On board, full aperture, 5% absolute radiometric calibration
- A thermal IR channel with 60 m. spatial resolution

Table 2-9 Landsat 5 / Landsat 7 comparisons (36)

Satellite	Landsat 5	Landsat 7
Manufactures:	General Electric	Lockheed Martin Missiles and space
Spacecraft Instrument	Hughes Santa Barbara Remote sensing	Hughes Santa Barbara Remote sensing
Mission	Currently operated by Space Imagine continue to receive TM images at U.S. Ground station and International ground stations	A) Continuity of unenhanced Landsat data sufficiently consistent with previous Landsat data to allow comparisons for global and regional change detection characterization B) Acquire and refresh periodically an archive of generally cloud free images of all land surface
Instrument(s):	Thematic Mapper Plus (TM) [Scan mirror spectrometer]	Enhanced Thematic Mapper Plus (ETM+) [Scan mirror spectrometer]
Mass	2200 kg.	2200 kg.
Swath Width	185 km.	185 km.
Revisit Interval	16 days	16 days

Table 2-9 Landsat 5 / Landsat 7 comparisons (cont.)

Satellite	Landsat 5	Landsat 7
Orbit	705 km., sun-synchronous, 98.2 degrees inclination; Equatorial crossing time = 10.00am 1/-15 min.	705 km., sun-synchronous, 98.2 degrees inclination; Equatorial crossing time = 10.00am 1/-15 min.
Bands	Spectral range : Ground Res. Band 1 : 0.45 – 0.52 μm . : 30 m. (blue) Band 2 : 0.52 – 0.60 μm .: 30 m. (green) Band 3 : 0.63 – 0.69 μm .: 30 μm . (red) Band 4 : 0.76 – 0.90 μm .: 30 m. (Near IR) Band 5 : 1.55 – 1.75 μm .: 30 m. (Shortwave IR) Band 6 : 10.4 – 12.5 μm .: 120 m. (Longwave or Thermal IR) Band 7 : 2.08 – 2.35 μm .: 30 m. (Shortwave IR) 30 Meters (Resampled to 25 meters)	Spectral range : Ground Res. Band 1 : 0.450 – 0.515 μm . : 30 m. (blue) Band 2 : 0.525 – 0.605 μm .: 30 m. (green) Band 3 : 0.630 – 0.690 μm .: 30 μm . (red) Band 4 : 0.750 – 0.900 μm .: 30 m. (Near IR) Band 5 : 1.55 – 1.75 μm .: 30 m. (Shortwave IR) Band 6 : 10.4 – 12.5 μm .: 120 m. (Longwave or Thermal IR) Band 7 : 2.35 – 3.09 μm .: 30 m. (Shortwave IR) Pan: 0.520 – 0.900 μm .: 15 m.
Scene Acquisition Rate		250 –31450 sq.km. images per day at primary receiving station Collect and transmit up to 532 scenes/days
Launch Date	April 1984	Early 1999
Mission Duration	5 years	5 years

JERS-1 satellite (37)

JERS-1 is an earth observation satellite whose primary objective is to gather data on global land masses while conducting observation for land surveys, agricultural-forestry-fisheries, environmental protection, disaster prevention and coastal surveillance, with emphasis on locating natural resources. In order to optimize accuracy in measurements, JERS-1 was equipped with SAR (Synthetic Aperture Radar), which is an active microwave sensor, and OPS, an optical sensor that measures light reflected from the earth's surface ranging from visible light to short-wave infrared light. JERS-1 is a joint project of NASDA and MITI. NASDA was responsible for the main satellite unit and MITI was responsible for the measuring instruments. Since its launching in 1992, the satellite had continued to supply observation data to users in Japan and abroad. Though the design life of JERS-1 was 2 years, the satellite had obtained observational data for more than 6 years, and ended the mission on October 12,1998.

Table 2-10 Main Characteristics of the JERS-1

JERS-1	Characteristic
Shape	Structure Box type Approx, 1m ×1.8m ×3.1m Synthetic aperture radar Approx, 12m ×2.5m Solar cell paddle Approx. 8m ×3.4m
Weight	Approx. 1.4 t
Attitude control	Three-axis stabilized (zero momentum)
Design life	2 years
Launch vehicle	H-I Launch Vehicle

Table 2-10 Main Characteristics of the JERS-1 (cont.)

Launch site	Tanegashima Space Center, Kagoshima
Launch date	February 11, 1992
Orbit Type	Sun synchronous subrecurrent orbit
Altitude	Approx. 570km
Inclination	Approx. 98 deg
JERS-1	Characteristic
Period	Approx. 96 min.
Recurrent period	44 days
Sensor	<p>OPS (OVN)</p> <ul style="list-style-type: none"> - Resolution 18 X 24 m. - Band spectrum <ul style="list-style-type: none"> Band 1 0.52 – 0.60 μm. Band 2 0.63 – 0.69 μm. Band 3 0.76 – 0.86 μm. Band 4 0.76 – 0.86 μm. <p>SAR</p> <ul style="list-style-type: none"> - Resolution 18 X 18 m. - Observation 1.275 GHz - Frequency (L band) - Off Nadir Angle 35°

Utilization

Data obtained from the JERS-1 is useful for observations of the earth, focused on earth resources, and environmental protection, agriculture, forestry, fishery, land use, disaster prevention and coastal monitoring. The satellite will contribute to improving society by solving global problems of resources, food and the environment. The integrated earth resource observation system using the JERS-1 will be an

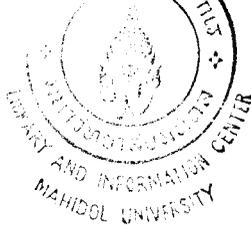
essential part of the international cooperation in the field of the future earth observation.

Thailand remote sensing center

Thailand satellite ground receiving station is located at Lad Krabang, Bangkok. On a routine basis, the receiving station acquires data and produces the masters as well as the original digital data. The user who are interested in obtaining the satellite data require by Thailand ground receiving station. The available imagery are in the form of photographic products : film and paper print and digital product : computer compatible tape – CCT and exabyte. The list of satellite data services show on Table 2-11 .

Table 2-11 Summary of available satellite data of NRCT

Satellite	Recurrent period	Sensor	Data acquisition period	Resolution
Landsat -5	16 days	TM (optical)	Dec, 1987 – until now	30 m. x 30 m.
		MSS (optical)	Dec, 1987 – until now	80 m. x 80 m.
Landsat - 4	16 days	MSS (optical)	Apr, 1983 – Oct, 1987	80 m. x 80 m.
JERS-1	44 days	OPS (optical)	Sep, 1992 – Aug, 1998	18.3 m. x 24.2 m.
		SAR (radar)	Sep, 1992 – Aug, 1998	18 m. x 18 m.
MOS-1	17 days	MESSR (optical)	May, 1988 - Apr, 1996	50 m. x 50 m.
		VTIR (optical)	May, 1988 - Apr, 1996	900m.(VS), 2700m.(IR)
		MSR (microwave)	May, 1988 - Apr, 1996	32 km. x 23 km.
ADEOS	41 days	AVNIR (optical)	Nov, 1996 – Jun, 1997	16 m. /P, 8 m./Mu
		OCTS (optical)	Nov, 1996 – Jun, 1997	700 m. x 700 m.
IRS -1D	24 days	PAN	Apr, 2000	5.8 m.
		LISS-III		23 m.(VIS and NIR)
		WiFS		70 m. (SWIR) 188 m.



CHAPTER III

METHODOLOGY

This study composes of two parts. The first part is to study multitemporal for monitoring land use change, trend and direction of expanding from the past and evaluate the spatial relationship of shrimp farm and mangrove forest. The second part is to assess the compliance to land use plan of shrimp farm.

Equipment

Hardware:

1. Personal Computer with a specification of Intel Pentium II Processor 550 MHz., 64 MB SDRAM, 6.4 GB. Hard disk
2. Plotter
3. Printer HP 670 C
4. 8 mm. Tape, CD-RW
5. GPS Receiver
6. Camera and Film

Software:

1. Image analysis software: ERMMapper® Ver. 5.5
2. GIS software: ArcView® 3.2
3. Microsoft Office® 2000

Study area

The study area is conducted at Klang district in Rayong province where the coastal shrimp culture is one of key activities. In addition shrimp culture area in Nayaiarm sub-district, Chantaburi province as well as the remaining existing mangrove forest. They were located around Prasae and Pangrad rivers which are the main stream and the study area coordinated between 1393000 N - 1416000 N and 787000 E – 811000 E (Figure 3-1). Land use within this area is classified principally as mangrove, shrimp ponds and agriculture. Expansion rate and density of shrimp pond are high, particularly along both rivers. Much of mangrove forest has been deforested for shrimp pond, port and settlement. The climate is warm and humid with average annual rainfall and temperature in 1999 1,501.7 mm. and 28.2 °C. Based on precipitation, river discharge, winds and temperature, season with its period can be identified as follows : dry season from middle of February to April, a tropical rainy season from May to October and winter season from November to February.

Procedures

1. Data preparing
2. Field surveying
3. Data processing
4. Result and discussion

The details of each step are described as follows:

1. Data preparing

Required data compose of :

1.1 1:50000 Topographic maps (base map from aerial photographs
date on April 1990 and map information as of 1991)

- Sheet 5334 I Ban Noen Punsin November, 1992
- Sheet 5334 II Ban Kod Hoi November, 1992
- Sheet 5334 III Ban Leam Thong Lang November, 1992
- Sheet 5334 IV Amphoe Klang June, 1992

1.2 Thematic map

1.2.1 1:50000 Soil suitability for economic plant map from
Land Development Department, 1980.

1.2.2 1:50000 Mangrove forest zoning use map from Royal
Forest Department, 1987.

1.2 Satellite data

- Landsat –4 (MSS) band 1-3 (1977)
- Landsat –5 (TM) band 1-7 (1987, Dec 9, 1990 and
Jan17,1999)
- JERS-1 band 1-3 (Jan 22, 1994 and Apr 22, 1997)

2. Field surveying

GPS receiver was used to record coordinate at two land cover types
which are shrimp farm and mangrove forest. Physical features of the land and land
use type around recorded point were also collected.

3. Data processing

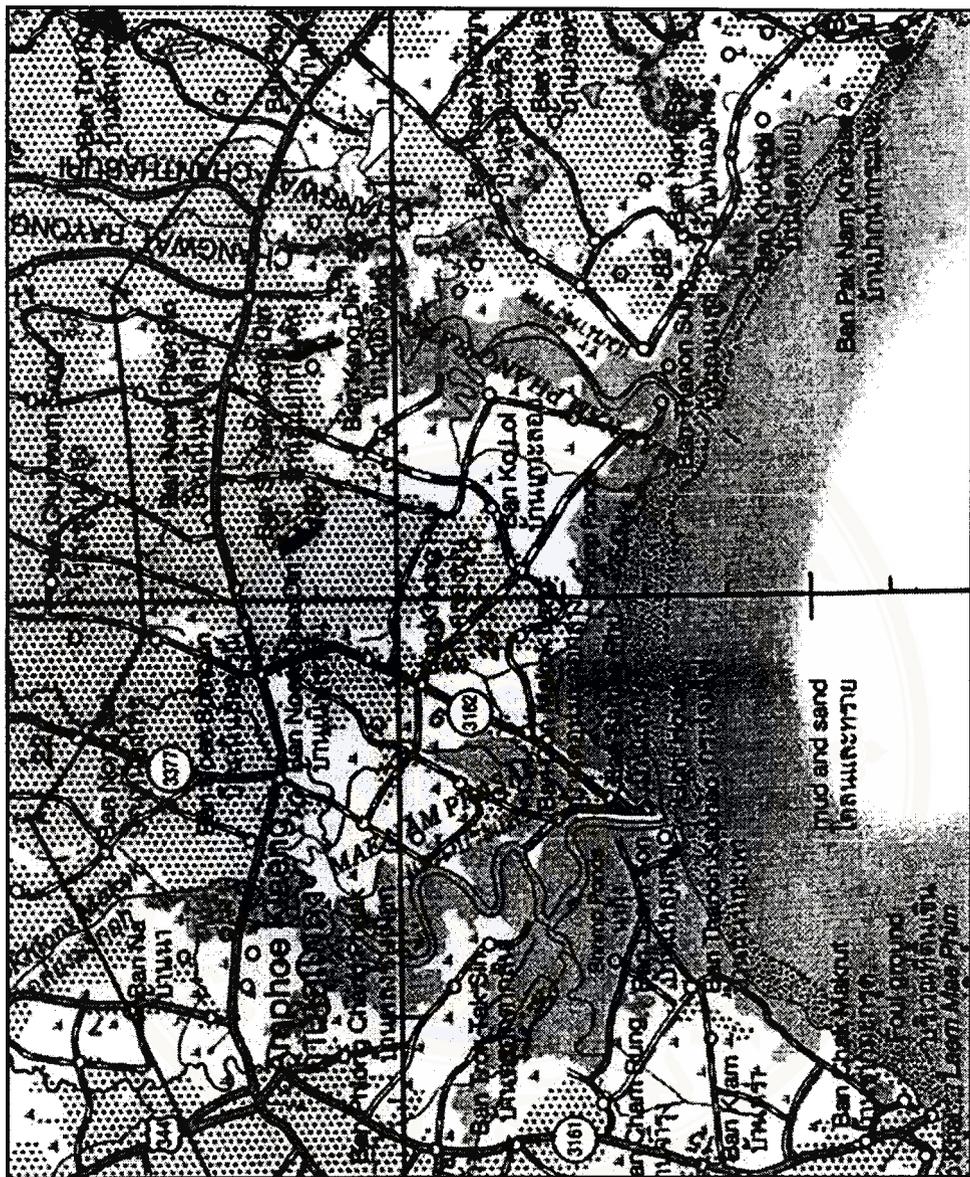
The framework illustrating the stages of work involved in this research
is presented in Figure 3-2. Digital image processing was performed using

ERMapper® and ArcView® software. The stages of processing are described as follows:

1. The satellite data were sub-set according to study area boundary.
2. Satellite data from Landsat and JERS-1 were geocoded to topographic map with the scale of 1:50000. The geometric registration process was carried out using standard techniques with ground control point and a first degree polynomial equation. Map projection was Universal Transverse Mercator (UTM) and root mean square error less than 1.0 pixel.
3. On – screen Digitizing technique was applied for obtaining shrimp farm and mangrove forest boundary, then conversed to coverage to be further used in ArcView® software.
4. Classified image at each date were overlaid for detecting land use change, and also mapped out the spatial relationship of shrimp farm and mangrove area.
5. Shrimp culture area from satellite data in 1999 was overlaid with thematic map from other government agency and show the area which either is complied or conflicted with the other coastal zone management policies.

4. Result and discussion

The output is presented on map, graph and table where appropriate.



(Source: Topographic map "Changwat Rayong, Thailand" scale 1: 250000, 1994)

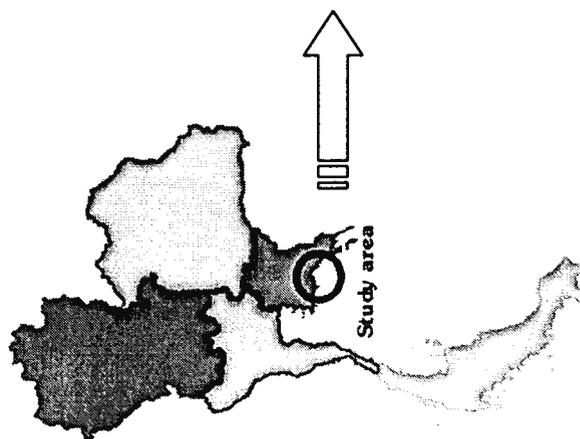


Figure 3-1 Study area

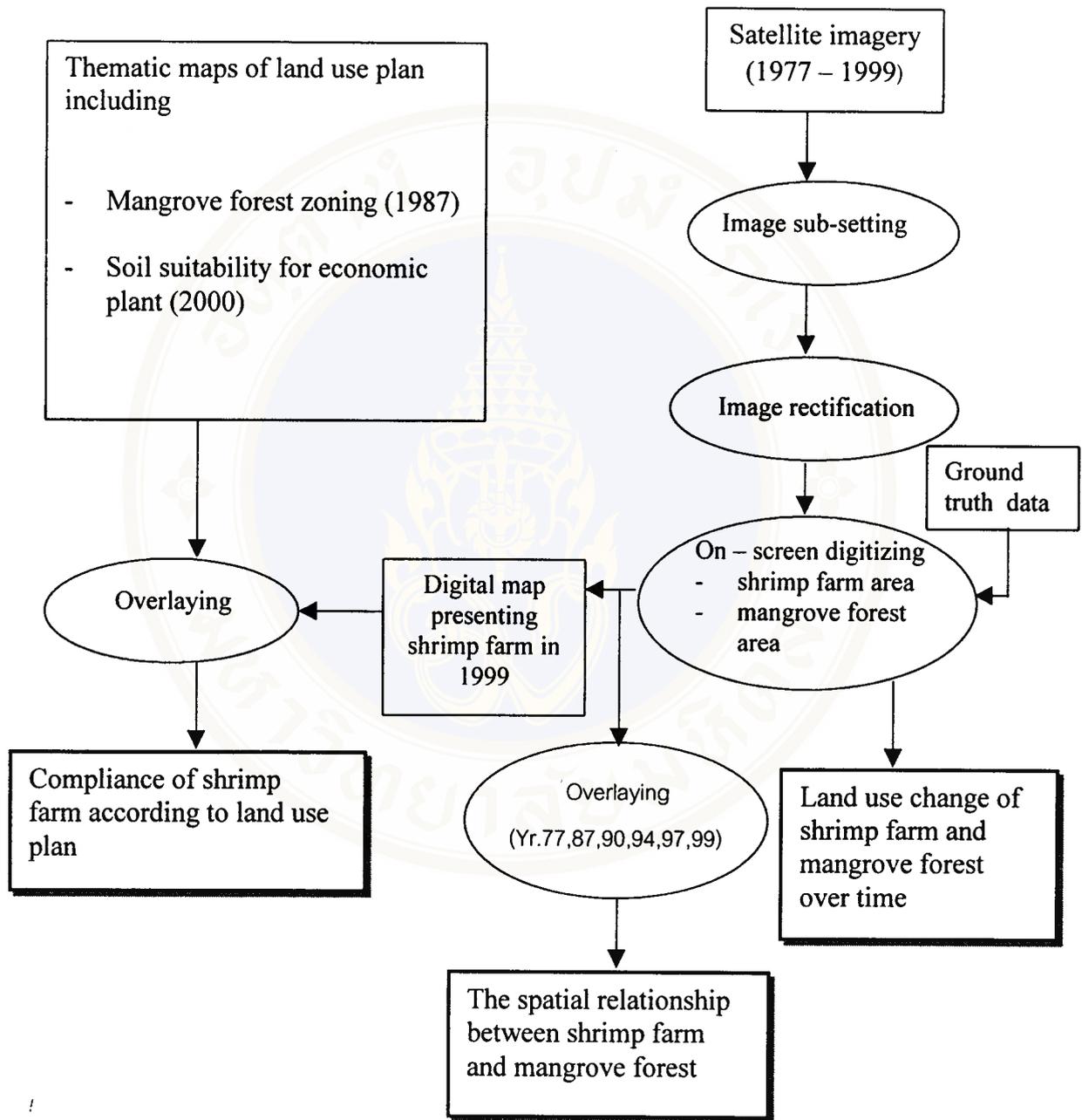


Figure 3-2 Diagram showing methodology used in this study

Field verification

Field verification was carried out by three-person team in September 1999 and April 2000. Areas tentatively identified as shrimp farm and mangrove forest. In order to cover as much of the area of interest as possible, verification sites were selected that are adjacent to roads. In order to confirm the accuracy of interpretation class from satellite imagery.

At each verification site, a location in UTM coordinates were obtained using a GPS receiver. The location of the sites field – checked, the estimated positioning error and the result of verification are reported in Table 11 and pictures of mangrove forest and shrimp farm area from field surveying showed in Figure 3-3, 3-4 and 3-5.

The ground truth indicated an 100 percent accuracy of the interpretation. The accuracy of shrimp farm mapping and mangrove forest after the field verification, is thus estimated to be accept the accuracy of the study.

Table 3-1 Location of points and results of the verification

Point	Date	N	E	Ground truth	Image interpretation
1	09/21/99	1401085.0	782846.0	shrimp	shrimp
2	09/21/99	1400596.0	783666.0	shrimp	shrimp
3	09/21/99	1400544.0	783609.0	shrimp	shrimp
4	09/21/99	1402398.0	789238.0	shrimp	shrimp
5	09/21/99	1405218.0	791454.0	mangrove	mangrove
6	09/21/99	1404995.0	792917.0	mangrove	mangrove
7	09/21/99	1405928.0	793007.0	mangrove	mangrove
8	09/21/99	1405614.0	791426.0	shrimp	shrimp
9	09/21/99	1408211.0	791136.0	shrimp	shrimp
10	09/21/99	1411171.0	803575.0	shrimp	shrimp
11	09/21/99	1406840.0	801193.0	shrimp	shrimp
12	04/09/00	1411645.2	804324.8	shrimp	shrimp
13	04/09/00	1410792.1	804118.0	shrimp	shrimp
14	04/09/00	1409950.4	803006.2	shrimp	shrimp

Table 3-1 Location of points and results of the verification (cont.)

Point	Date	N	E	Ground truth	Image interpretation
15	04/09/00	1410087.5	803641.6	shrimp	shrimp
16	04/09/00	1410021.3	803783.8	shrimp	shrimp
17	04/09/00	1411572.5	803321.5	shrimp	shrimp
18	04/09/00	1405574.0	803157.8	shrimp	shrimp
19	04/09/00	1406839.7	798293.4	shrimp	shrimp
20	04/09/00	1407409.5	795952.6	shrimp	shrimp
21	04/09/00	1408229.8	793994.1	shrimp	shrimp
22	04/09/00	1409393.7	791734.2	shrimp	shrimp
23	04/10/00	1402288.2	789299.0	shrimp	shrimp
24	04/10/00	1402605.8	789299.0	shrimp	shrimp
25	04/10/00	1403812.8	790567.2	shrimp	shrimp
26	04/10/00	1406099.7	793517.3	shrimp	shrimp
27	04/10/00	1406013.2	790169.1	shrimp	shrimp
28	04/10/00	1407631.9	788981.8	shrimp	shrimp
29	04/10/00	1407274.4	788967.9	shrimp	shrimp
30	04/10/00	1412025.0	790424.1	shrimp	shrimp



Figure 3-3 Dense mangrove forest along the canal (1404995 N, 792917 E)

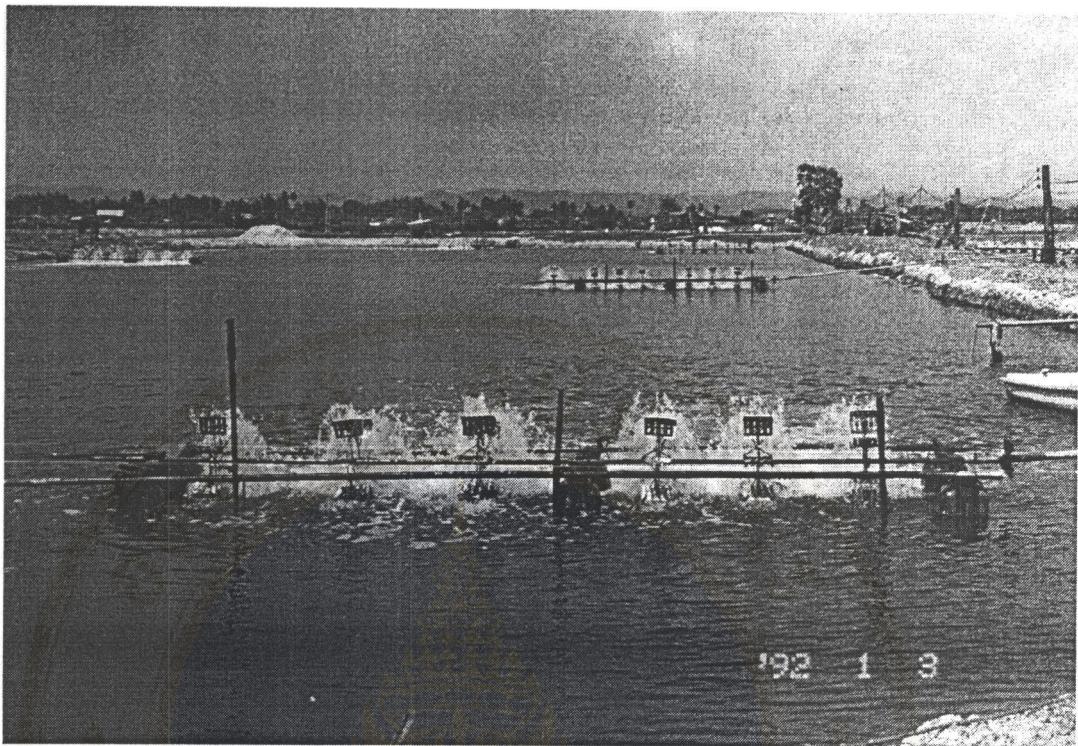


Figure 3-4 The square - shaped shrimp pond (1410087.5 N, 803641.6 E)

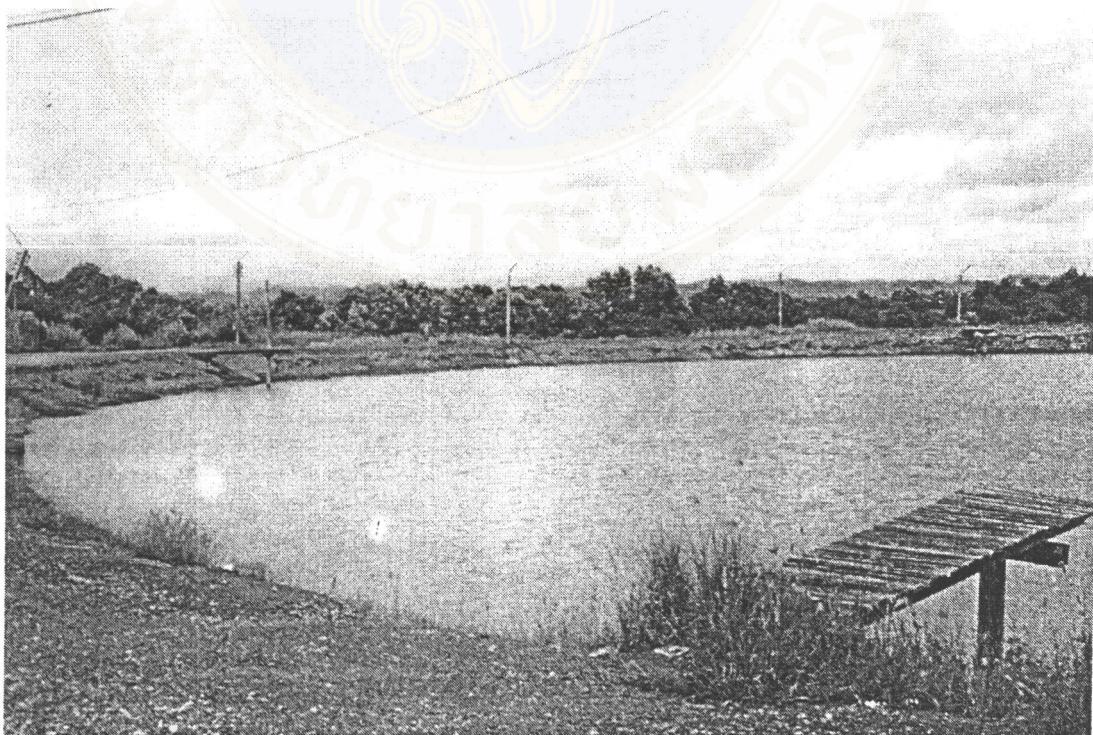


Figure 3-5 The round – shaped shrimp pond (1411572 N, 803321 E)

CHAPTER IV

RESULTS

The methodology described in the previous chapter with interpretation multitemporal for monitoring marine shrimp farm and mangrove forest changed during 22 years (1977-1999) and assessing existing shrimp farm area in 1999, its compliance to government land use plan. The satellite data require in 1977, 1987, 1990, 1994, 1997 and 1999 with UTM grid have been prepared. Most of satellite data were choose during recorded in winter and summer season which it was less of cloud cover. The study area showed on Figure 4-1.

The monitoring started in 1977, the imagery from Landsat – 4 (MSS) with pixel size 80 x 80 m., which it's low resolution. So, it could not present land cover clearly. The data was processed by band composite technique (RGB:432). It's showed mangrove forest in dark brown but it could not separate form other land use distinctly. So, to find out the boundary of mangrove forest used unsupervised classification filtering and visual interpretation together.

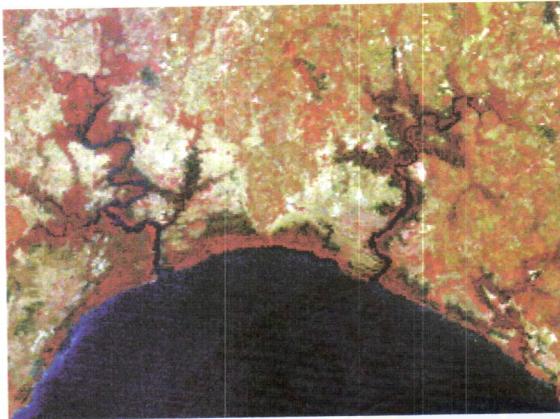
In 1987, the imagery from Landsat – 5 (TM), band 1 - 4 with the resolution 30 x 30 m. After band composite RGB:432, the image showed that mangrove forest and terrestrial vegetable presented same red color. So, it's hardly to separate boundary apart

from terrestrial vegetable. In this year some of mangrove forest in 1977 was converted shrimp farm which the boundary of shrimp farm could be detected by visual interpretation.

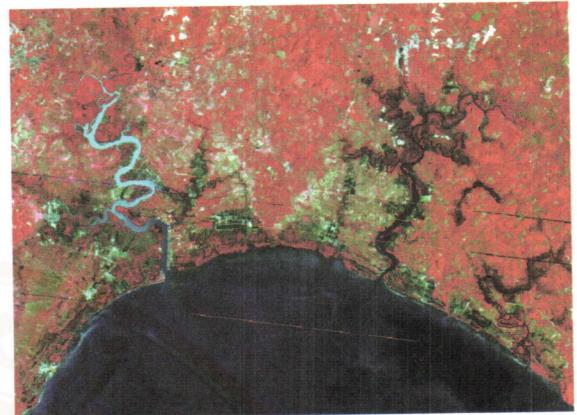
The next in 1990, imagery data band 1-7 from Landsat -5 (TM). Band composite RGB:453 presented color of mangrove forest in dark - red which different from terrestrial vegetable in orange color. The image could be classified mangrove better than the image in 1977 and 1987. So, it's easy to digitized on - screen to mark the boundary of mangrove forest and shrimp farm.

In 1994 and 1997 the imagery data from JERS-1 satellite, the resolution 18 x 24 m. The detail of image presented as same as the data from Landsat -5 but the wave length less than data of Landsat satellite. The false color composite RGB:321 showed the mangrove forest and terrestrial vegetable in red color, so, mangrove forest classification must referred to the mangrove forest area in former year. During this period mangrove forest and shrimp farm area changed in small area.

In 1999, source of data and band composite as same as in 1990. The mangrove forest and shrimp farm changed small area nearly in 1994 and 1997.



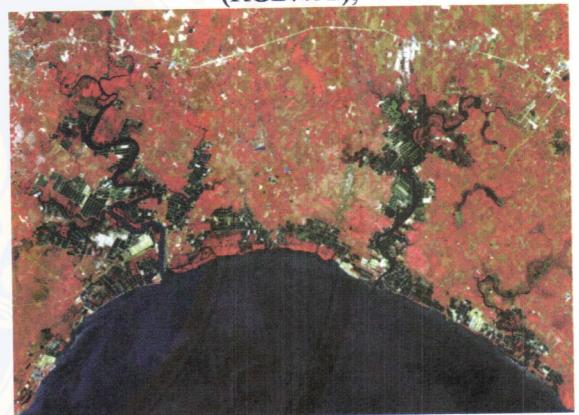
Landsat -4 (MSS) False color composite (RGB:432), 1977.



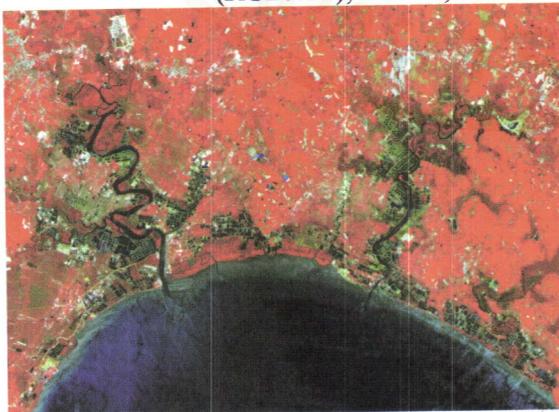
Landsat -5 (TM) False color composite (RGB:432), 1987.



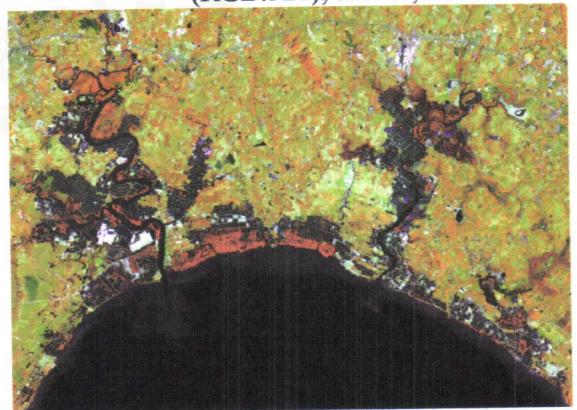
Landsat -5 (TM) False color composite (RGB:453), Dec 22, 1990.



JERS-1 (OPS) False color composite (RGB:321), Jan 22, 1994.



JERS-1 (OPS) False color composite (RGB:321), Apr 24, 1997.



Landsat -5 (TM) False color composite (RGB:453), Feb 17, 1999.

Figure 4-1 False color composite of study area 1977 - 1999

4.1 Land use change monitoring

The monitoring result of shrimp farm and mangrove forest mapping is shown on Figure 4-3 – 4-12 and Table 4-1. Figure 4-3 – 4-7 are expansion shrimp farm mapping and Figure 4-8 – 4-12 are mangrove forest decreasing mapping in study area. Figure 4-2 presented the quantify the result of shrimp farm and mangrove forest and the value is on showed Table 4-1.

In 1977, shrimp farm did not appeared in study area and then 10 years later in 1987, shrimp farm had been started along the coast line which it's the area of mangrove forest former and the area about 231.46 ha. and increase continuously to 4,212.56 ha. in 1999 with the annual rate of raised 180.96 ha./yr. The shrimp farm area expanded continuously since 1987. The enormous expansion was during 1987 – 1990, the area increased from 1987 about 3,317.03 ha. (1,105.69 ha./yr.) which it's highest increasing rate. The expanded area located along the coast line and both of the river from the mouth river to upper (Figure 4-3). After 1990, shrimp farm still increased but not much which expansion rate during 1990 – 1994, 1994 – 1997 and 1997 - 1999 were about 53.63, 77.83 and 108.01 ha./yr., respectively. The shrimp farm expanded from the boarder of shrimp farm in previous period (Figure 4-4 – 4-6). Moreover, in this part could be defined the shrimp farm sustainable area since 1987, 1990, 1994, 1997 and 1999. The shrimp farm area in each year has been still remained until 1999 about 187.91, 2,533.48, 2,885.5, 3,338.95, 4,112.56 ha. or 81.18, 71.39, 76.68, 83.55, 97.63 percent, respectively. The map showed on Figure 4-7.

Table 4-1 Area of shrimp farm and mangrove forest from 1977 – 1999

Year	Shrimp farm					Mangrove forest		
	Area (ha.)	Raised (ha.)	Annual rate of change	Remained area until 1999	% of remained area	Area (ha.)	Loss (ha.)	Annual rate of change
1977	-	-	-	-	-	6,307.95	-	-
1987	231.46	231.46	23.15	187.91	81.18	4,259.73	2,048.22	204.82
1990	3,548.54	3,317.03	1,105.69	2,533.48	71.39	2,499.58	1,760.15	586.72
1994	3,763.07	214.53	53.63	2,885.50	76.68	2,185.68	313.91	78.48
1997	3,996.55	233.48	77.83	3,338.95	83.55	2,080.46	105.21	35.07
1999	4,212.56	216.01	108.01	4,112.56	97.63	2,013.86	66.60	33.30
Difference 1987-1999	3,981.10	3,981.10	180.96	-	-	4,294.08	4,294.08	195.19

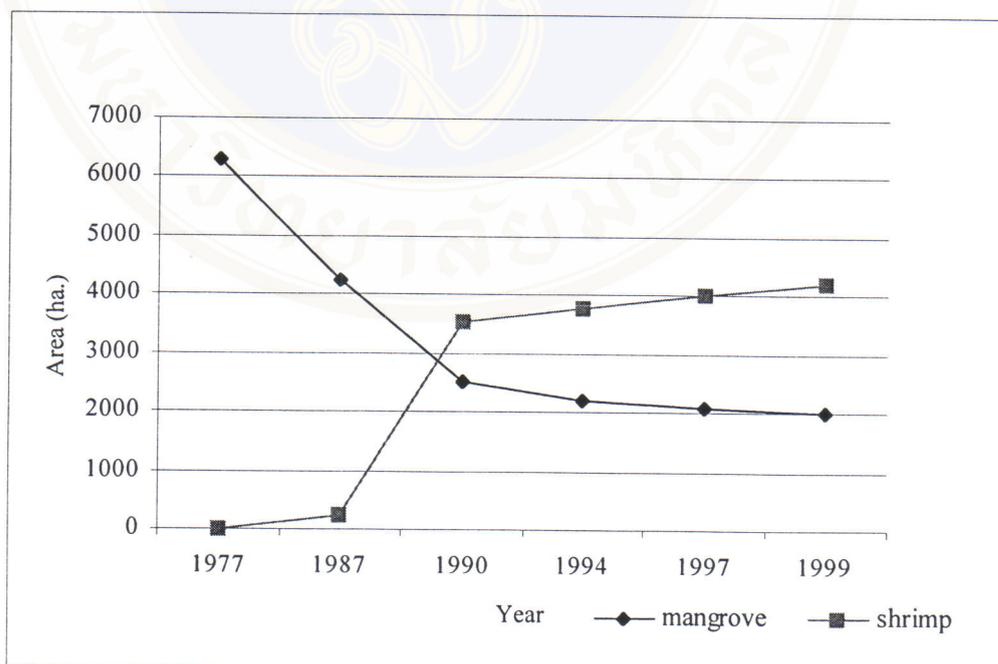


Figure 4-2 Quantify the result of shrimp farm and mangrove forest

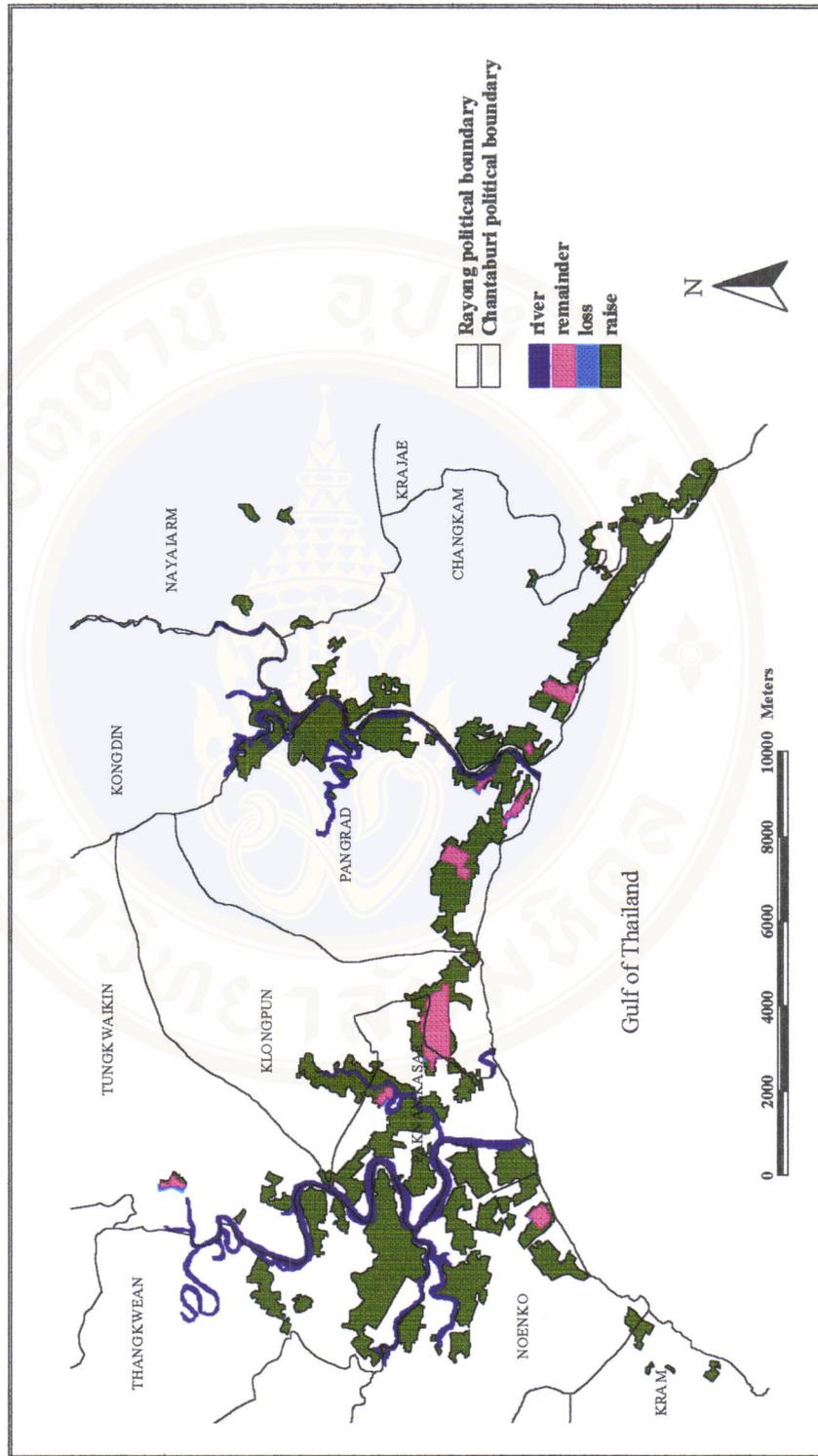


Figure 4-3 Shrimp farm changed during 1987 - 1990

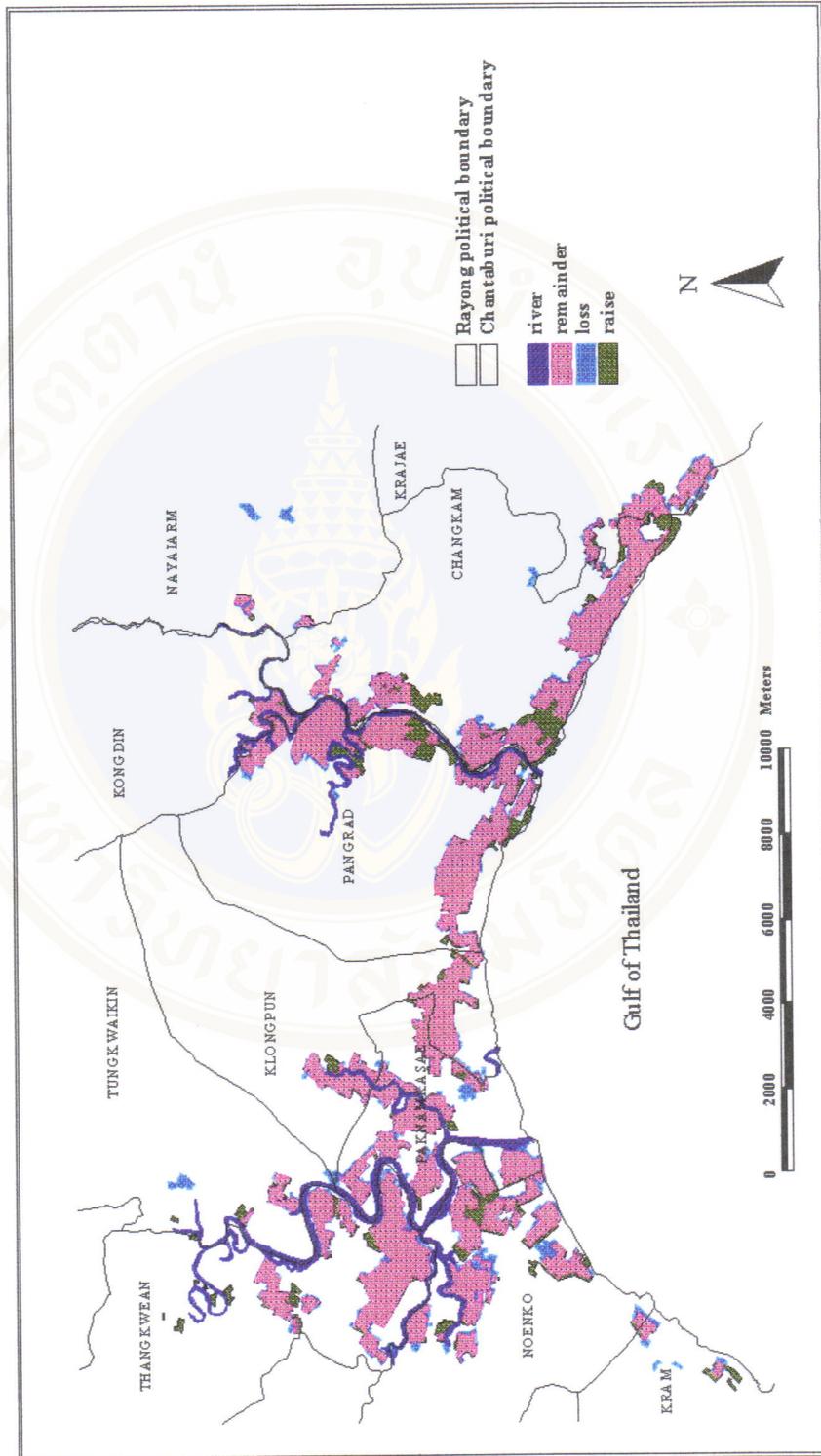


Figure 4-4 Shrimp farm changed during 1990 - 1994

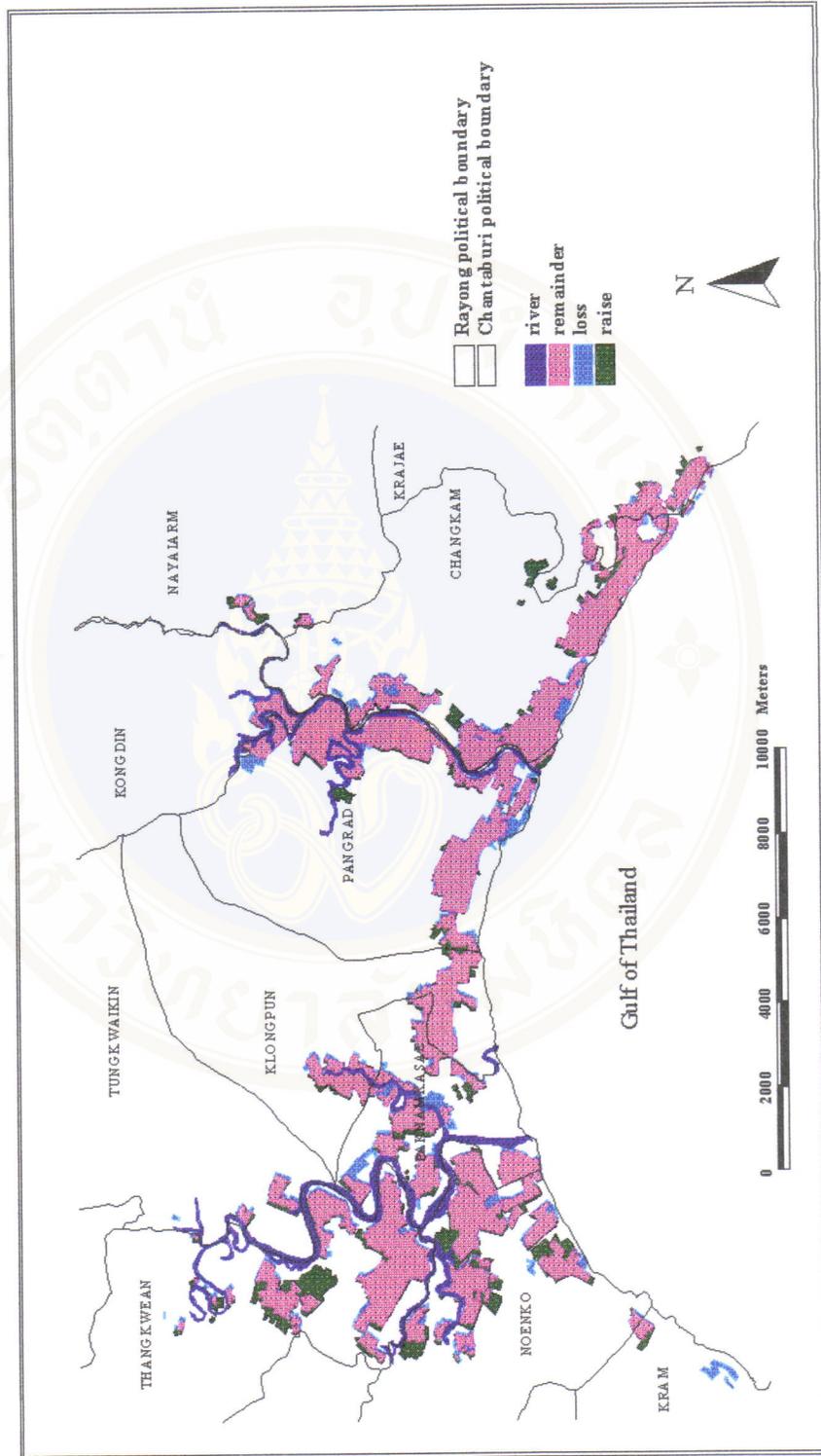


Figure 4-5 Shrimp farm changed during 1994 - 1997

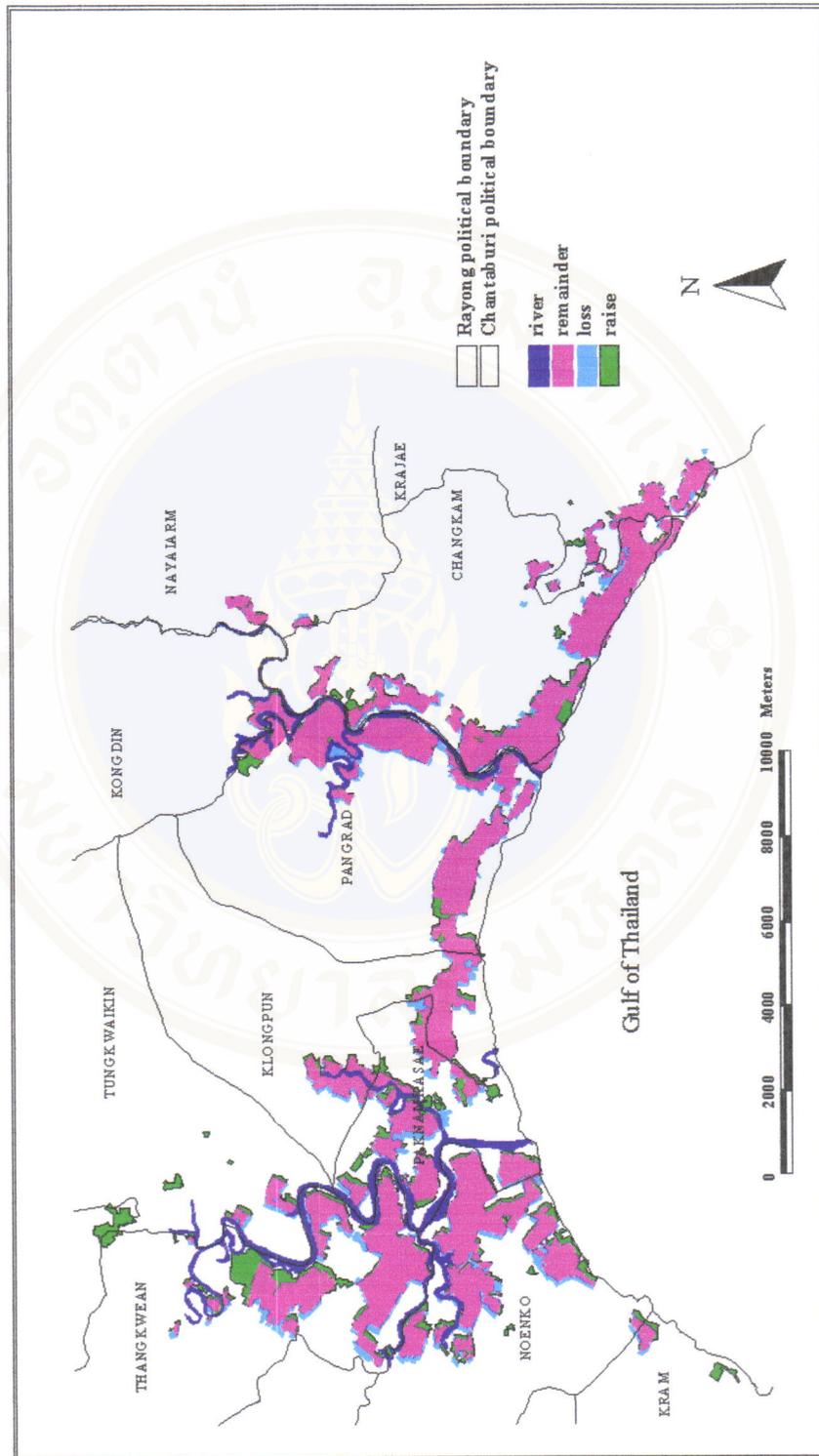


Figure 4-6 Shrimp farm changed during 1997 – 1999

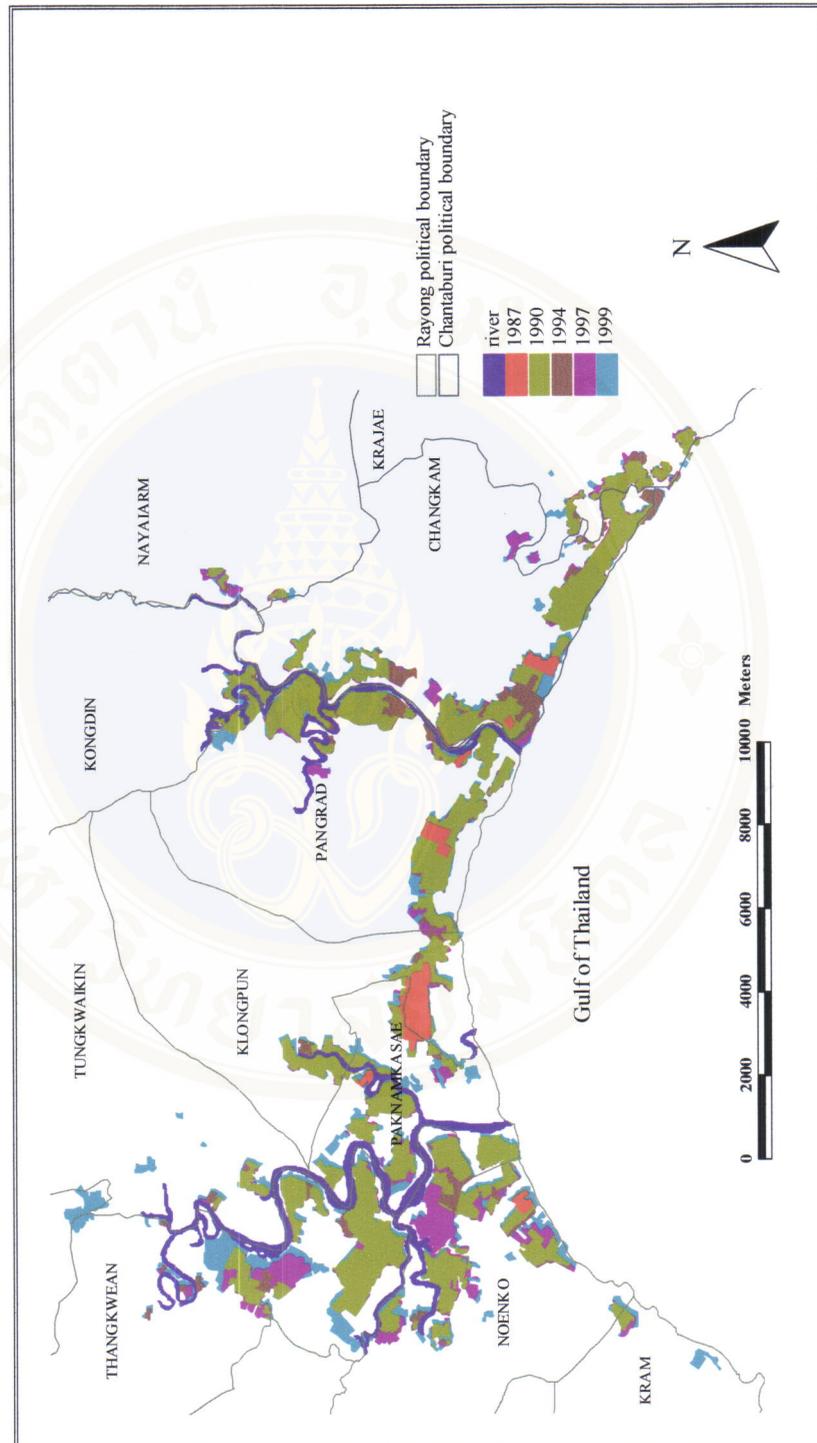


Figure 4-7 shrimp farm in 1999

In 1977, the mangrove forest located on coastal line and along both river about 6,307.95 ha. The area was changed continuously as same as shrimp farm but in opposite direction. During 1977 –1987, the area lost 2,048.22 ha. or 204.82 ha./yr. around border of mangrove forest which located on coast line and both sides of river (Figure 4-8). The next during 1987-1990, mangrove forest had been lost mostly along the bank of both rivers and the area nearby the sea about 1,760.015 ha. or 586.72 ha./yr. (Figure 4-9). After that during 1990 – 1994, 1994 – 1997 and 1997 – 1999 the decreased area nearby the border of mangrove forest about 313.91, 105.21 and 66.60 ha. with rate of change 78.48, 35.07 and 33.30 ha./yr., respectively. The loss of area was same direction like as the former study period but the decreasing rate had better trend and some parts of them has been increasing (Figure 4-10 - 4-12).

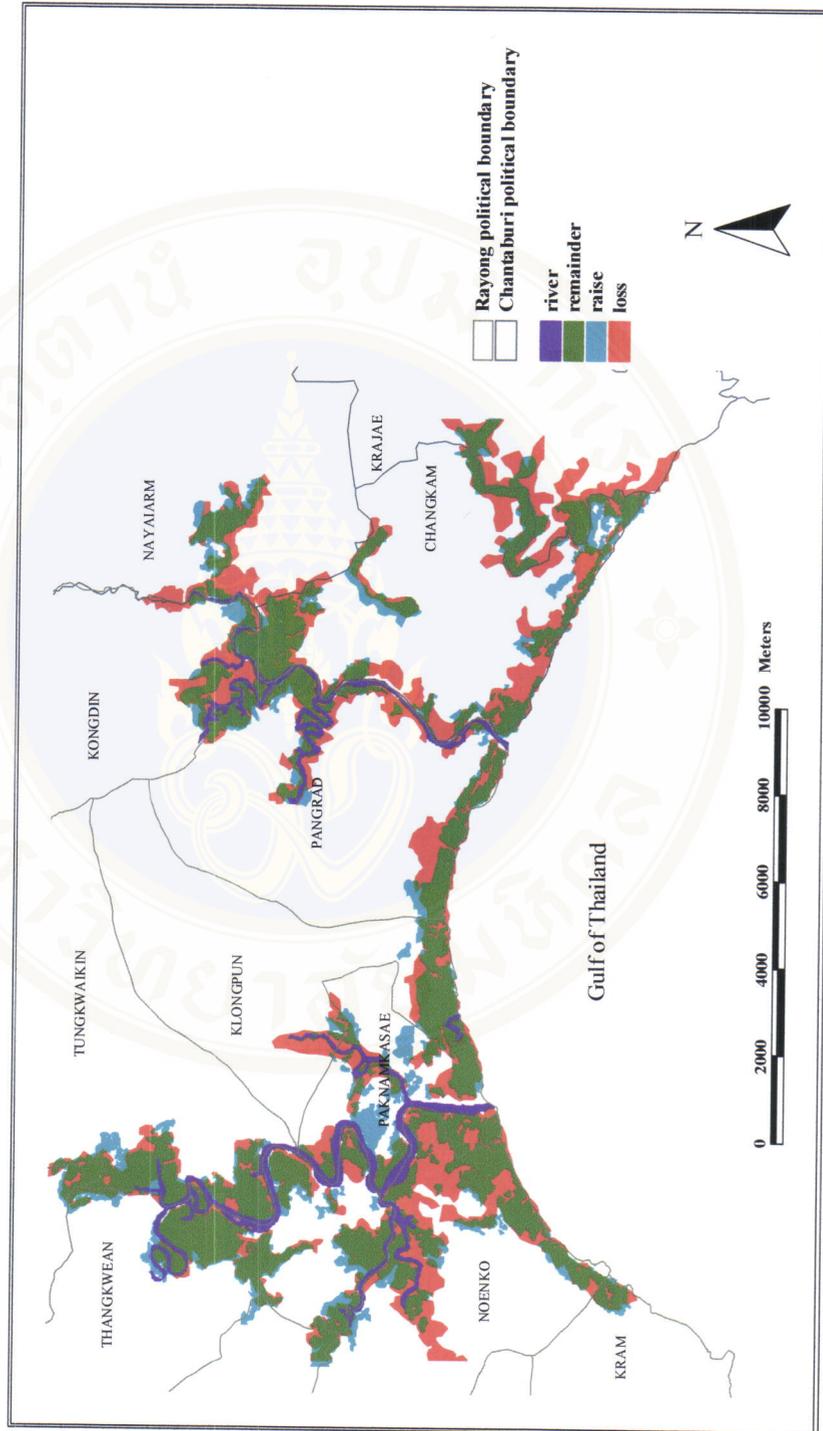


Figure 4-8 Mangrove forest changed during 1977 - 1987

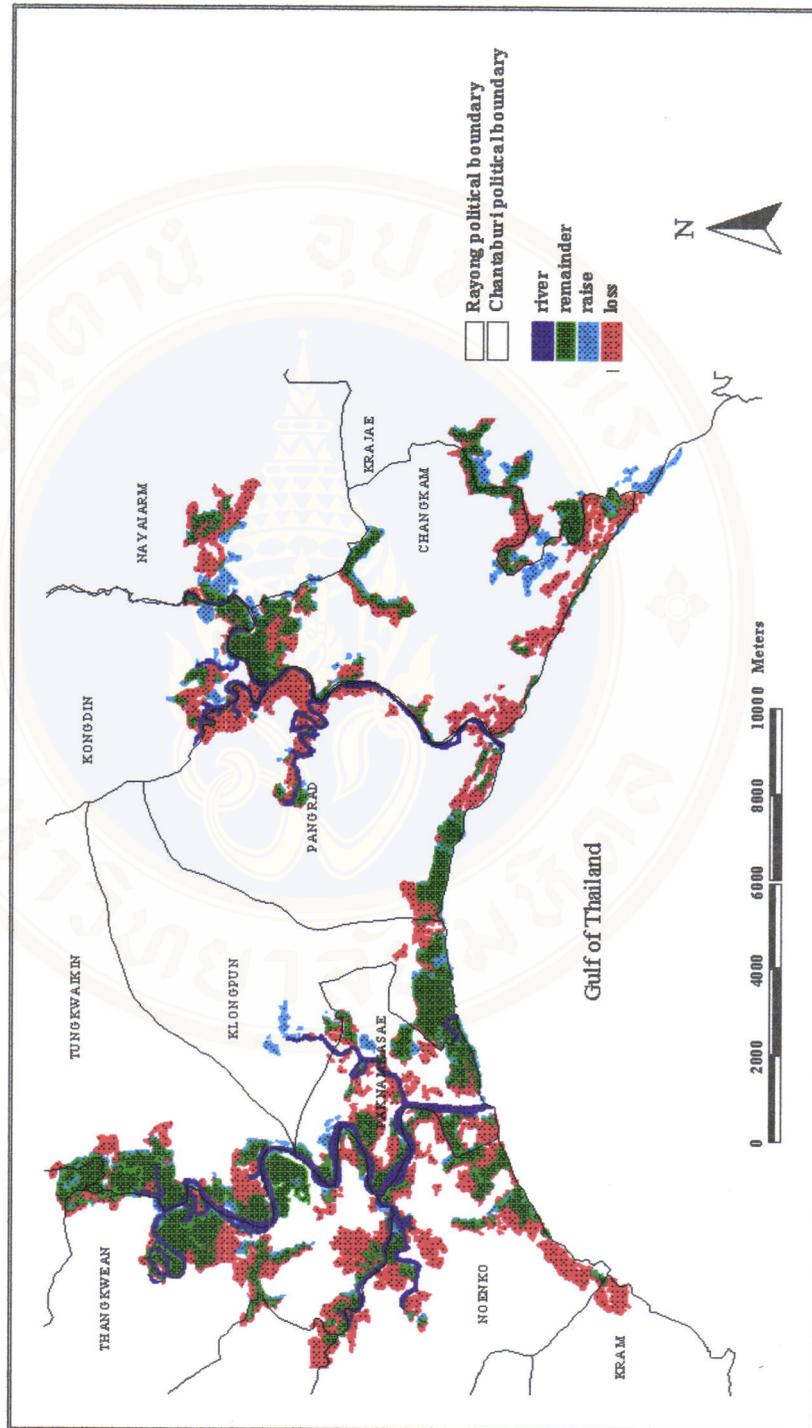


Figure 4-9 Mangrove forest changed during 1987 – 1990

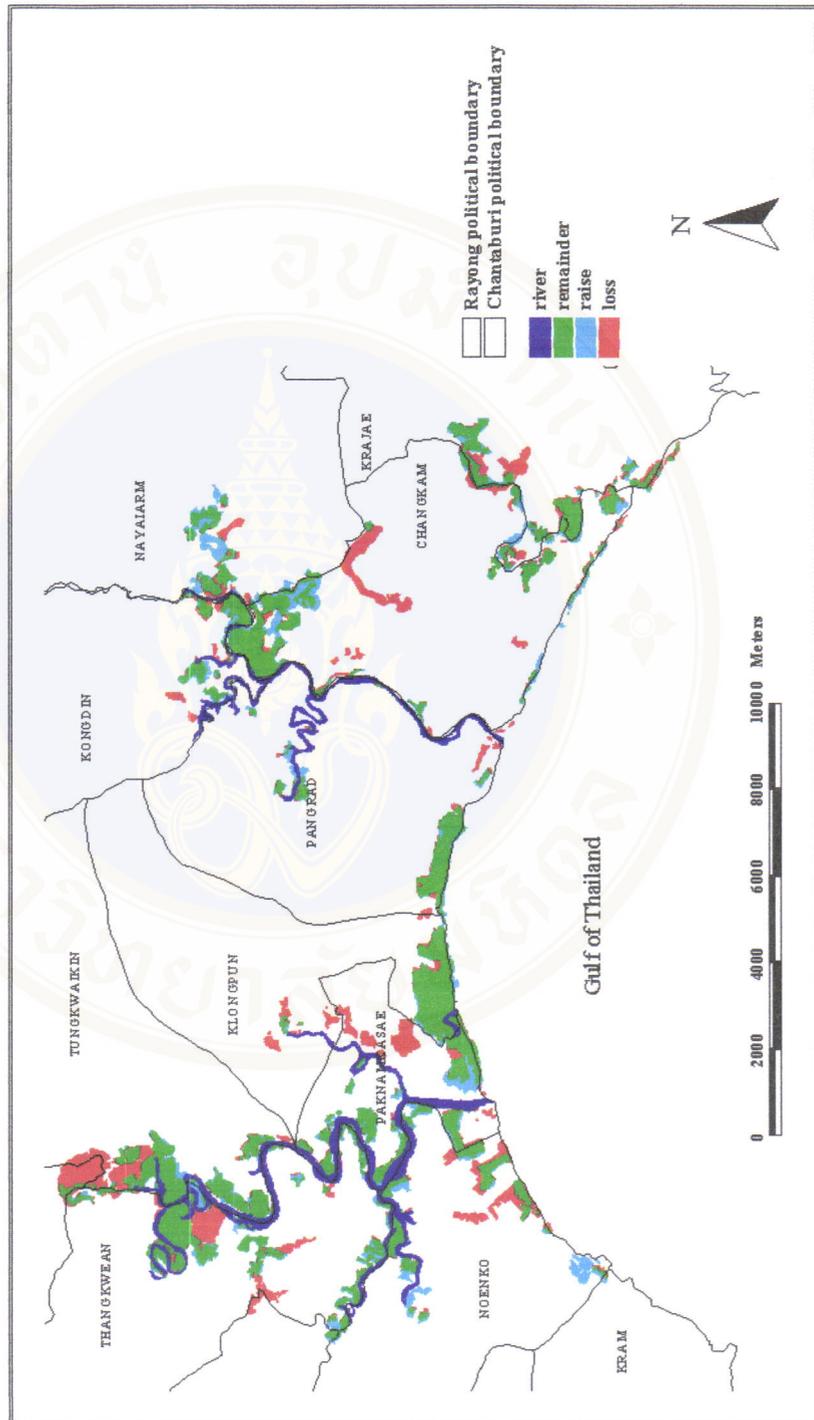


Figure 4-10 Mangrove forest changed during 1990 - 1994

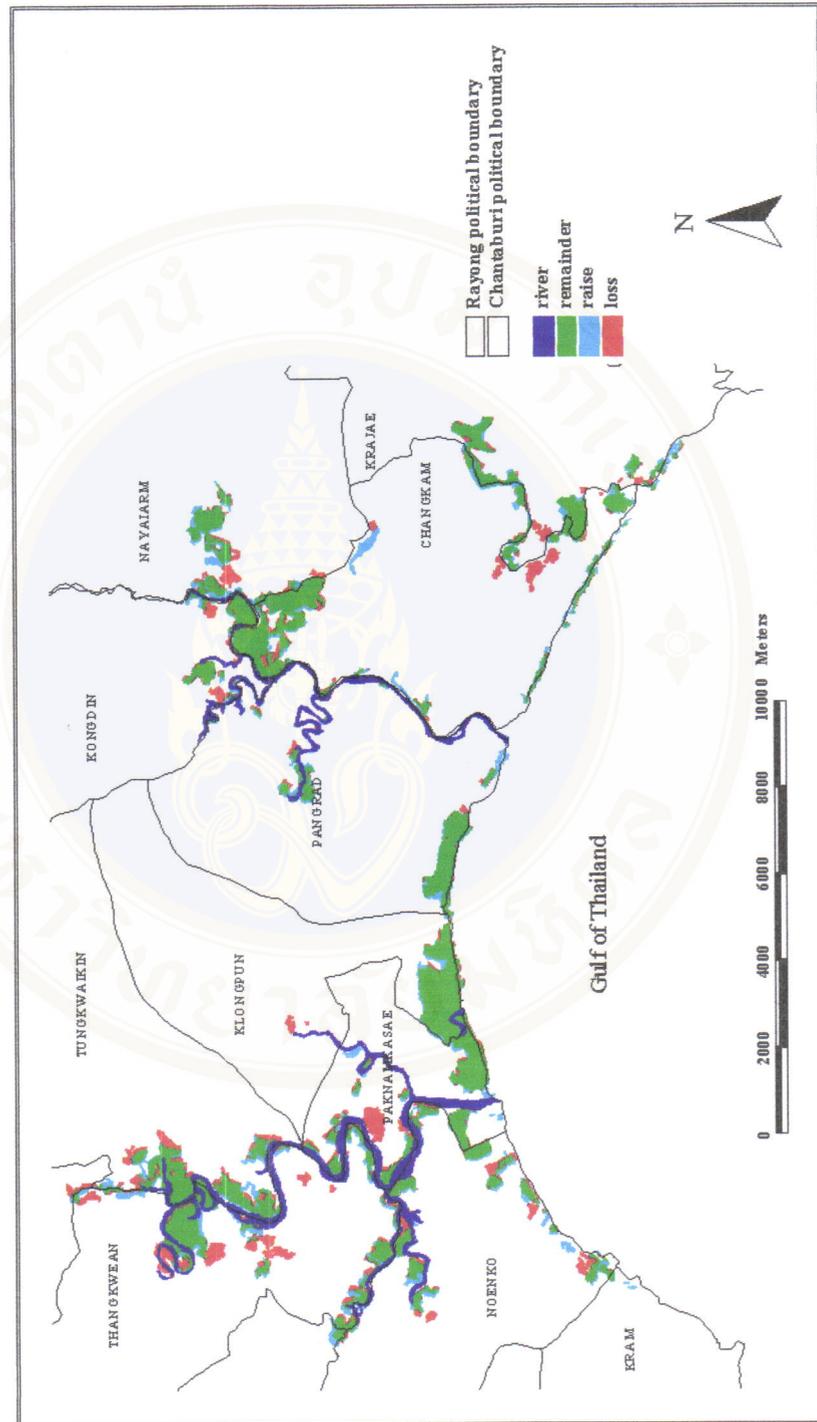


Figure 4-11 Mangrove forest changed during 1994 - 1997

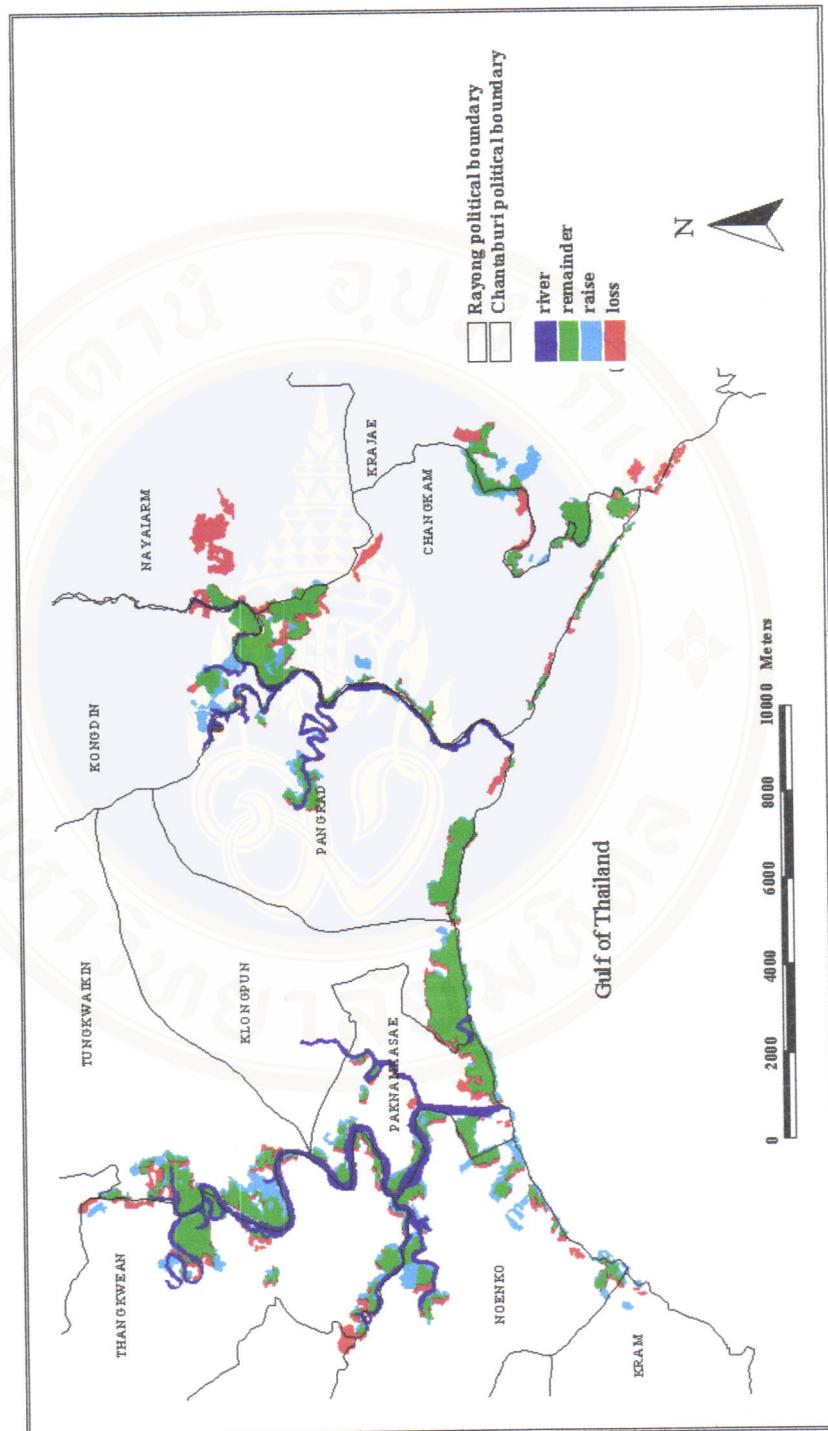


Figure 4-12 Mangrove forest changed during 1997 - 1999

4.2 The spatial relationship between mangrove forest and shrimp farm

The spatial relationship of shrimp farm and mangrove forest during study period showed on Figure 4-13 and the value referred to Table 4-2. During 10 years between 1977 to 1987, mangrove forest lost about 2,048.22 ha. and the area was converted to shrimp farm only 107.49 ha. or 5.25 % of total mangrove forest change. The converted area was around mangrove forest border on coastal line and on the bank of rivers (Figure 4-14). In 1990, mangrove forest was converted to shrimp farm 1,097.28 ha. or 62.34 % which its highest conversion when the same time of shrimp farm bloom. The loss area showed on Figure 4-15 which it's expanded from previous shrimp farm along the coast line and both sides of river . After that, the shrimp farm accessed into mangrove forest not much and the average area accessed into mangrove forest around 168.09 ha. The direction was same as the previous date. The maps showed on Figure 4-19 – 4-18.

Table 4-2 Mangrove forest converted to shrimp farm

Year	Mangrove forest loss (ha.)	Converted to shrimp farm	
		Area (ha.)	% of total mangrove forest loss
1987	2,048.22	107.49	5.25
1990	1,760.15	1,097.28	62.34
1994	313.91	111.76	35.60
1997	530.27	139.78	26.36
1999	655.31	252.72	38.57
Total	5,307.85	1,709.03	32.20

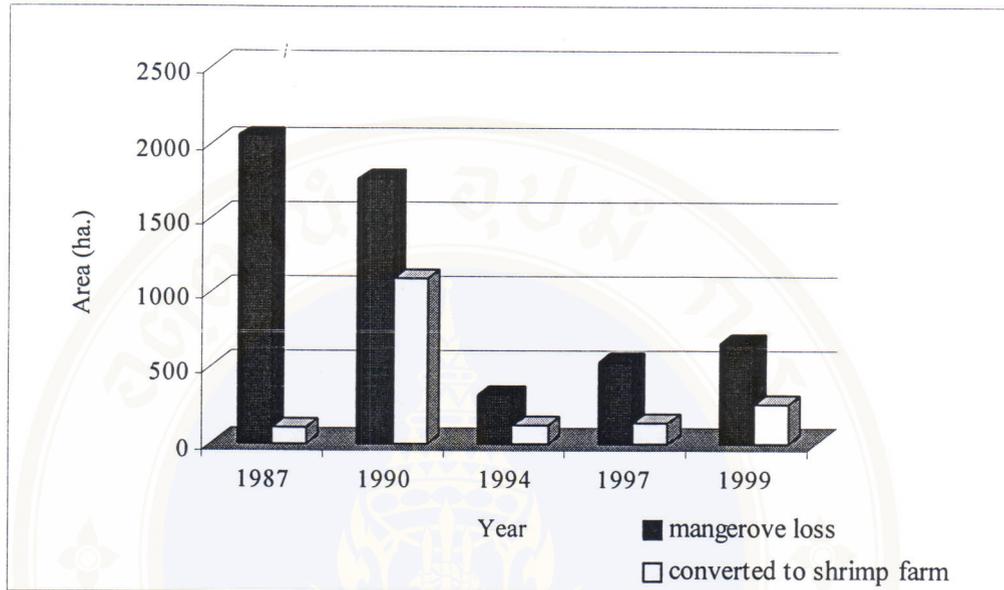


Figure 4-13 Shrimp farm located on mangrove forest

Shrimp farm overlaid on mangrove forest in previous date, the intersected area could not indicated that the total of mangrove forest destroyed for shrimp farm because the study period during more than 2 years so mangrove forest might be cut for wood, agriculture firstly and then turn to bare land or deteriorate mangrove forest and converted to shrimp farm finally. In the ideally for detecting shrimp farm construction impact on mangrove forest decreasing directly should used the satellite data closely year by year which the result will be most accuracy.

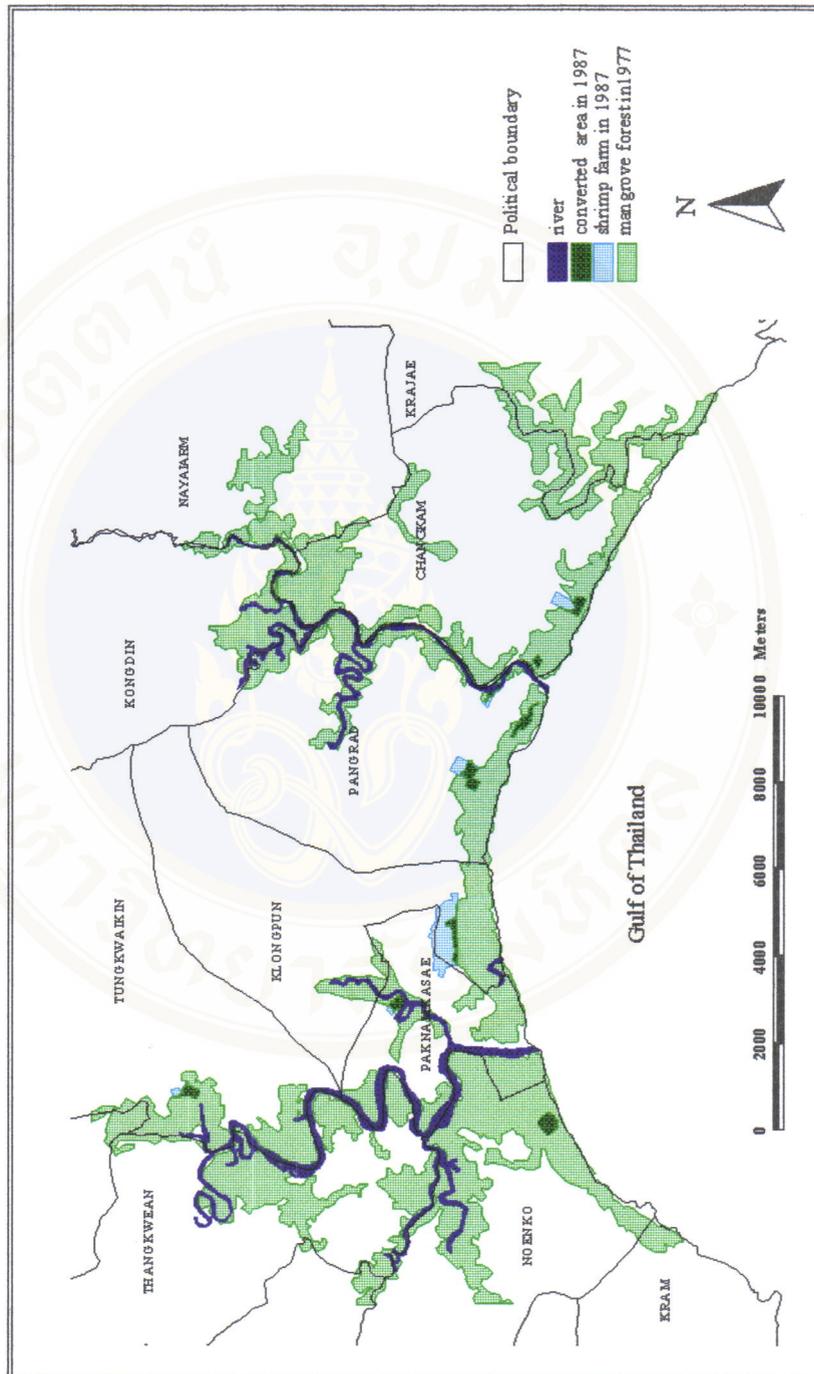


Figure 4-14 Shrimp farm converted from mangrove forest in 1977

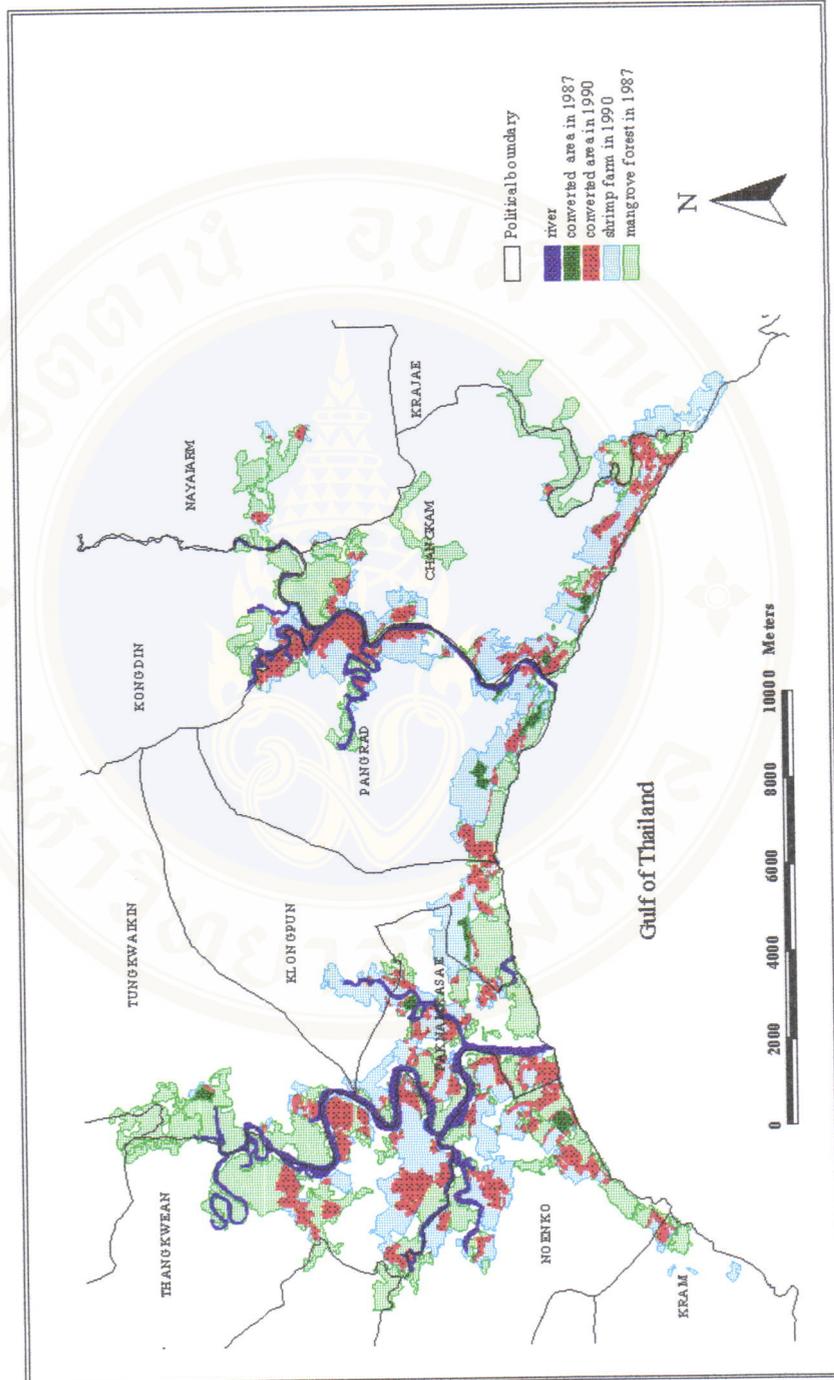


Figure 4-15 Shrimp farm converted from mangrove forest in 1987

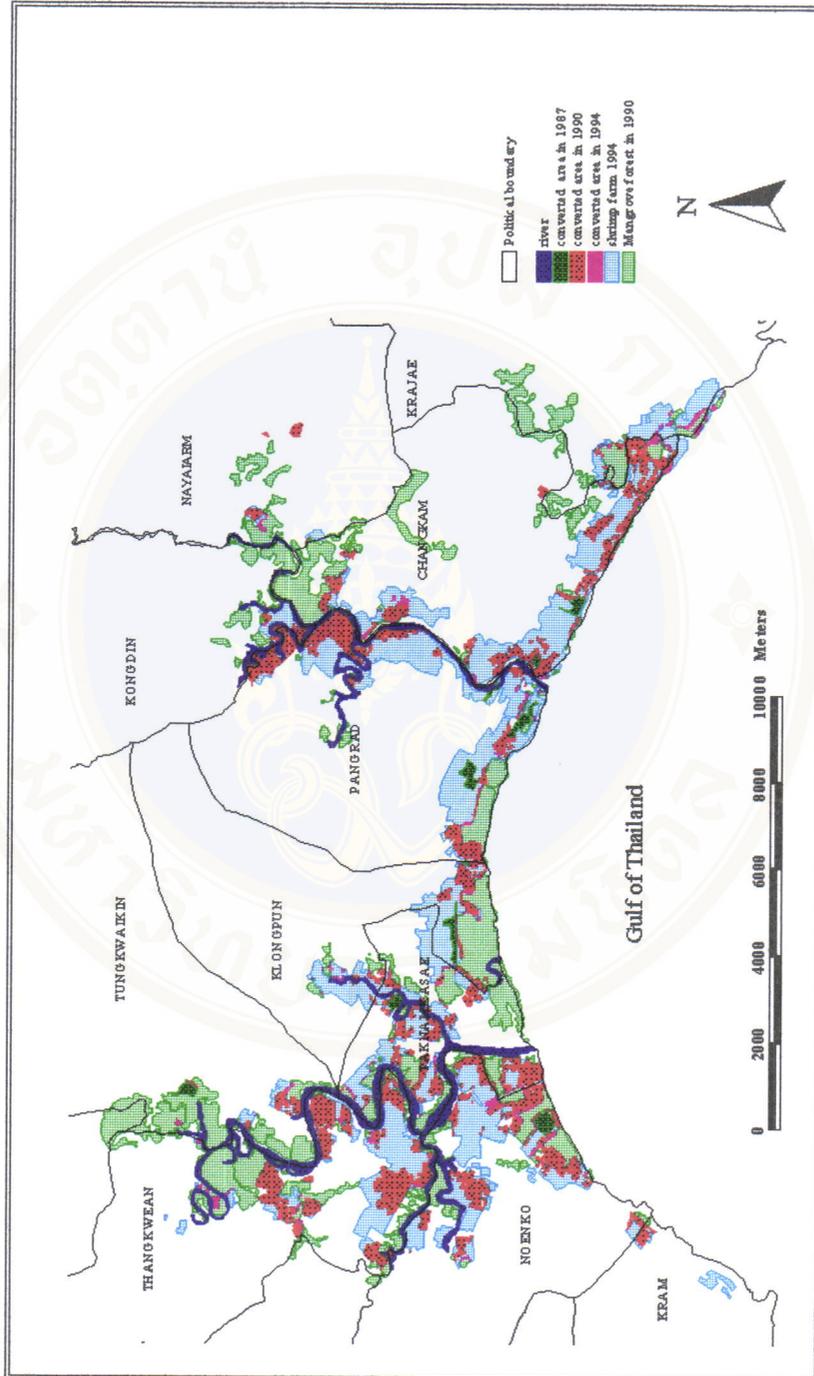


Figure 4-16 Shrimp farm converted from mangrove forest in 1990

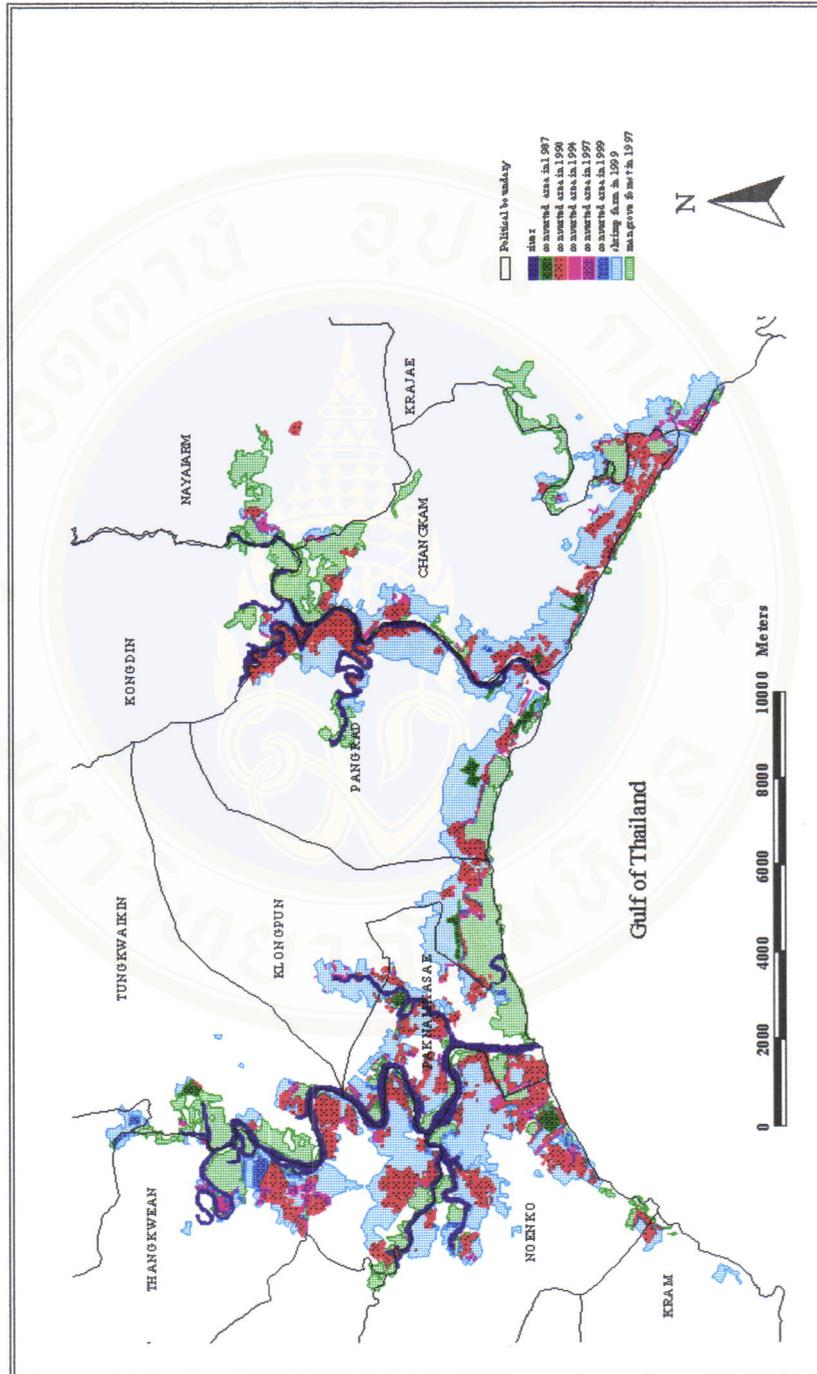


Figure 4-18 Shrimp farm converted from mangrove forest in 1999

4.3 The shrimp farm comply with coastal management plan

This section, to find out existing shrimp farm area comply which according to land use plan from the government agencies for management and development coastal area. The result was presented Figure 4-19 and 4-20. Table 4-3 showed the area after overlaid between shrimp farm in 1999 and mangrove forest zoning (Figure 4-21), soil suitable for economic plant (Figure 4-22). The overlapping area of shrimp farm on preservation zone 6.47 ha. or 0.15 % of total shrimp farm area and on conservation zone 1,480.30 ha. or 35.09 % of total shrimp farm area where closely coast line and the river bank, on development zone 1,070.68 ha. or 25.28 % of total shrimp farm area and on outer zone 1,673.38 ha. or 39.51 % of total shrimp farm area. In normally the suitable area of shrimp farm should be locate on the development and outer zone, the conflict area is shrimp farm where covered on the preservation and conservation zone. The map of overlapping area showed on Figure 4-23.

Shrimp farm at 1999 was overlaid on soil suitable for economic plant (paddy field, field crop and orchard). The shrimp farm covered on soil suitable for the economic plant 23.07 % of total shrimp farm which located on paddy field suitable area 436.05 ha. or 0.77 % of total shrimp farm, orchard suitable area 508.21 ha. or 12.00 % of total shrimp farm area and field crop suitable area 32.74 ha. or 0.77 % of total shrimp farm area. Non – conflict shrimp farm area covered on pond construction suitable area 24073 ha. or 0.58 % and the outer zone 3,225.27 ha. or 76.16 % of total shrimp farm area. The map of overlapping area showed on Figure 4-24.

Table 4-3 The area of existing farm conflict on management plan

Class	Area (ha.)	% of total shrimp farm area
• Mangrove forest zoning		
- Preservation zone	6.47	0.15
- Conservation zone	1480.30	34.95
- Development zone	1070.68	25.28
- Outer zone	1673.38	39.51
- Total	4230.82	100
• Soil suitable for economic plant		
- Paddy field	436.05	10.30
- Orchard	508.21	12.00
- Field crop	32.74	0.77
- Pond	24.73	0.58
- Outer zone	3225.27	76.16
- Total	4227.01	100

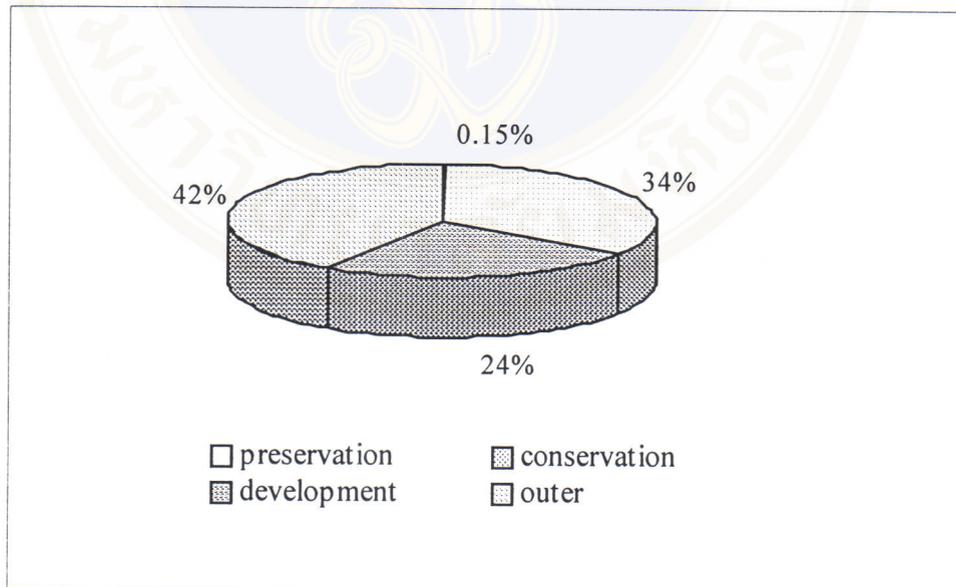


Figure 4-19 Percent of existing shrimp farm on mangrove forest zoning

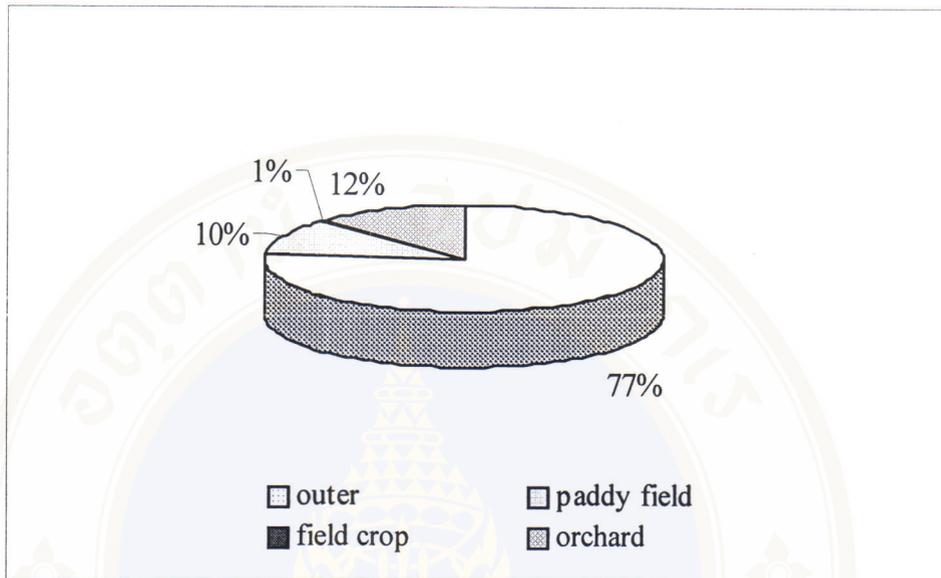


Figure 4-20 Percent of existing shrimp farm on soil suitable for economic plant

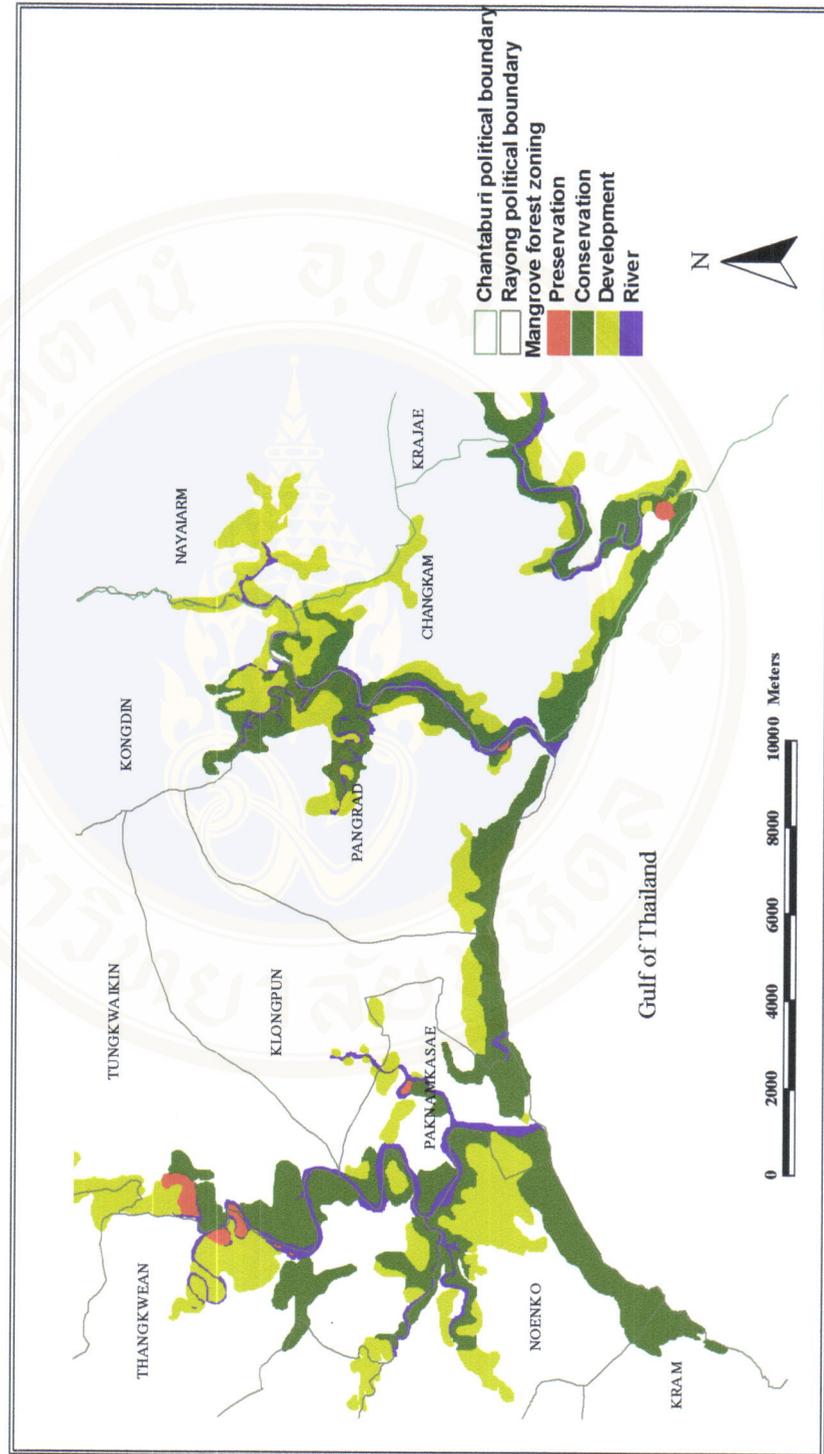


Figure 4-21 Mangrove forest zoning from RFD

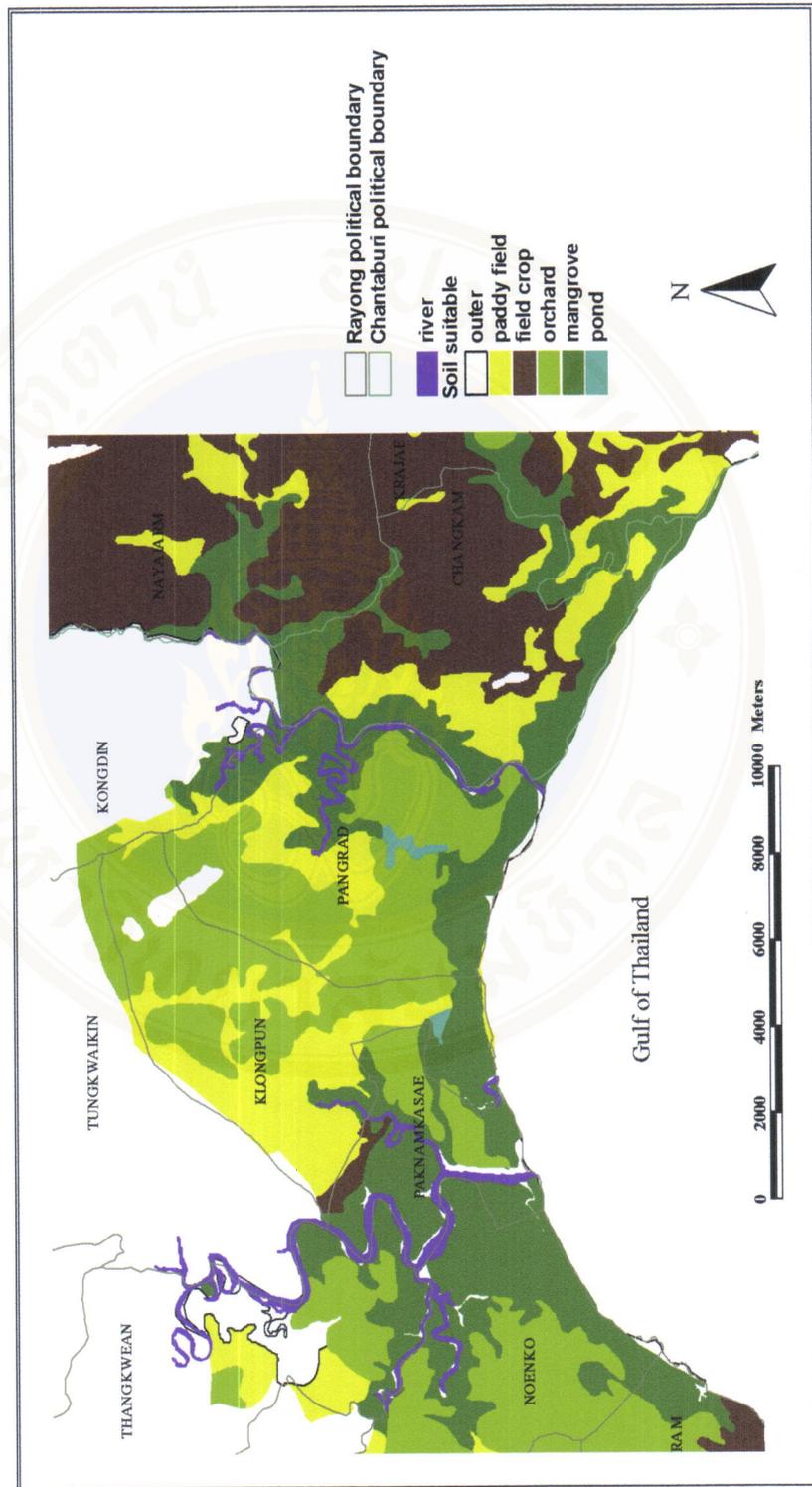


Figure 4-22 Soil suitable for economic plant map from LDD

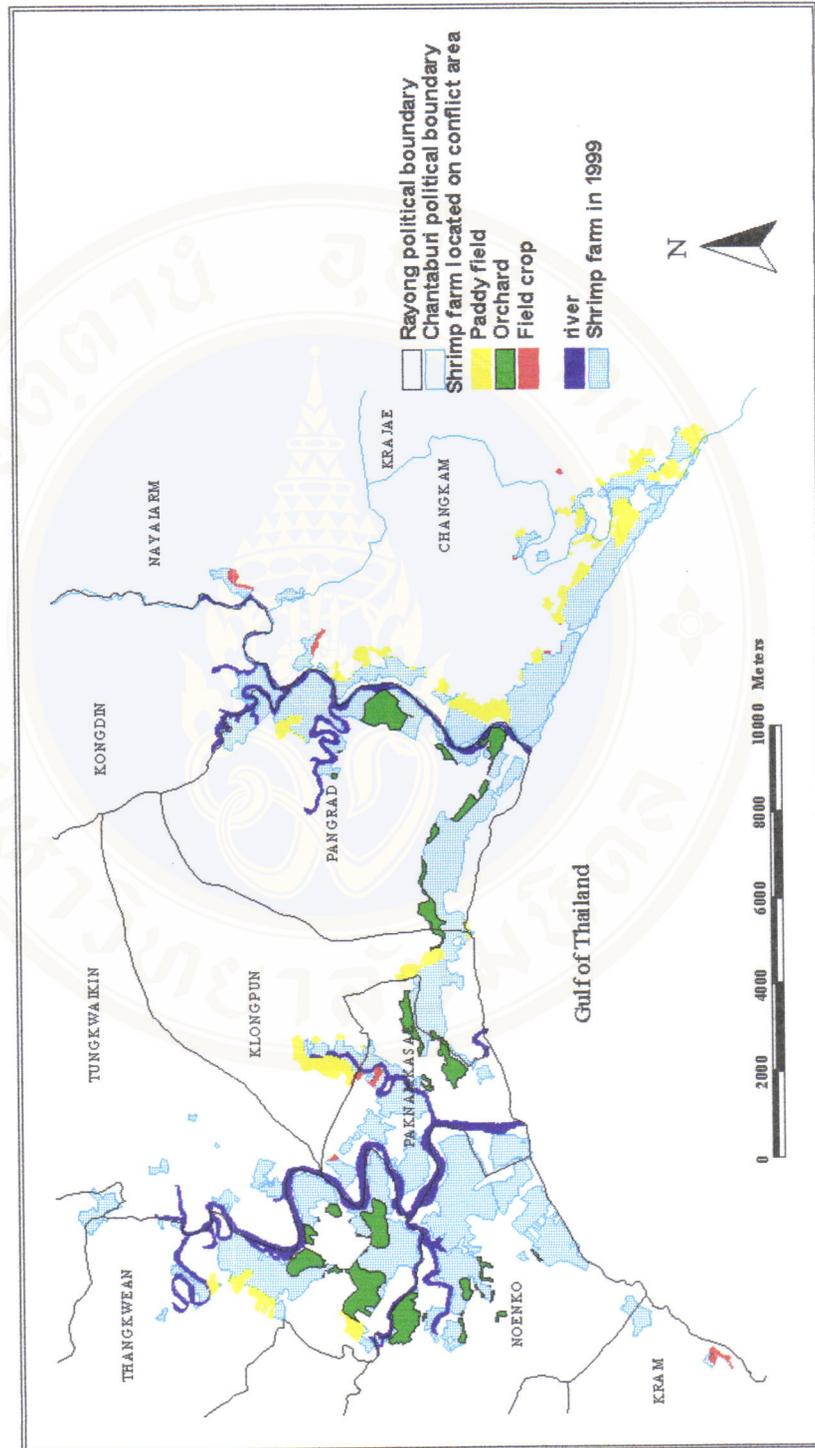


Figure4-24 Shrimp farm in 1999 conflict on soil suitable for economic plant

CHAPTER V

DISCUSSION

From chapter 4 show the mapping and quantity of land use change including conflict area on site study. The inventory and monitoring of shrimp farm and mangrove forest are necessary for decision – making on aquaculture development, regulatory law and environmental protection. The thematic map from satellite imagery are divided a moderate level of accuracy for surveying on large area and does not need more detail which both of thematic map have been for change detection monitoring with indirect method of measuring. The direct method by field survey and registering are same result but they are difficult extremely labor intensive, costly in term of time and money.

The imagery of Landsat and JERS-1 were showed to be capable of distinguishing different of spatial pattern of shrimp farm. The on – screen digitizing from visual interpretation of shrimp farm is appropriate method because of computerize classification could not classify unique shrimp farm area. However, shrimp farm digitizing by visual interpretation also had some problem such as it's sometimes difficult to estimate the area coverage of individual, small size but it's generally possible to estimate with good approximation the area coverage of cluster of shrimp farm. The area of mangrove forest would be expect from band composite and then digitized on – screen with visual interpretation which considering from color tone different between mangrove forest and terrestrial vegetation.

5.1 Land use change Monitoring

The result of previous chapter shows that mangrove forest decreasing and shrimp farm expansion were continuous changing. During 1987 – 1990 the land cover in study area was changed enormously and highest both of mangrove forest and shrimp farm which it was occurred in same period of shrimp farm distributed and rapidly bloom from central to eastern part of Thailand. The shrimp pond was early located closely on coastal line and both sides of river because of water is very important for shrimp culture. After that, it was slowly increased from the border of previous shrimp farm and nearly stable stage because of their already high density in this area before and difficult to find out new area which suitable for shrimp pond construction.

From this study, the result of mangrove forest and shrimp farm could not compared with data which presented in each province from RFD and DOF because of the site study was located on area in both of Rayong and Chantaburi province. However, the trends of change were same. To evaluate shrimp farm and mangrove forest area with satellite RS and GIS in each research document in the same area will give the different result. Leeruksakiat (16) recommended the data of mangrove forest and shrimp farm from his study area were differentiate from RFD which study at the same area. The different result came from interpretation technique and method of calculated area which up to the researcher.

5.2 The spatial relationship between mangrove forest and shrimp farm

Before 1987 mangrove forest was converted to shrimp farm in small area only 5.6 % of total mangrove forest lost. Most of them was especially a concession to work a forest with permitted and control by RFD longer than 30 years, but the mangrove forest still deteriorated because of the non – responsible of the person who got the permission for cutting by the government officer. During 1987 – 1990, shrimp farm was expanded rapidly and accessed into mangrove forest 60 % of total mangrove forest lost which its highest when compared with other period which its consensus with mangrove forest satellite observation by NRCT. Mangrove forest in eastern part of Thailand was destruction continuously especially in Rayong and Chantaburi province which had highly decreasing rate during 1987 and 1992. The next period, shrimp farm accessed into mangrove forest a little area, meanwhile the trend of mangrove forest has been increasing because of mangrove reforestation followed the cabinet issues on July, 1991 including strictly prohibit to access and use mangrove forest. Moreover, the public relation and knowledge of shrimp culture dissemination by DOF, the mangrove forest is not suitable for shrimp pond construction because of firstly the subsoil in mangrove forest contains pyrite which shows very high acidity or low pH when exposed to the air and secondary the mangrove soil is very soft and contains plenty of plant root and stumps, it 's difficult to management and risk to fail out.

5.3 Shrimp farm comply with coastal management plan

The study of shrimp farm complied with coastal management plan development by government agencies which the most of shrimp farm area was located in coastal zone which it's will be concern with several coastal zone management plan. This study area is located in outside part of national park, wildlife sanctuary, mineral preservation source, city plan and wetland of international/national importance area. Although, it was located on watershed class 4, it can be used for shrimp culture but the farmer must carefully and strictly following the regulation of government.

Shrimp farm expanded rapidly since 1987 and at present the area about is 4,000 ha. along coastal and both of river. In 1999, one of third or 35.10 % of shrimp farm overlapped on preservation and conservation zone which it is not suitable for them. In other case to overlay shrimp farm at 1999 on soil suitability for economic plant which the result showed that most of shrimp farm located in outside area. So, the main issue of conflict area which the first priority in this study was located of shrimp farm on mangrove forest because of mangrove forest zoning was declared in law. The soil suitable map from LDD is only management plan which considered only physical characteristic of soil for plant. For more accuracy of soil suitable for economic plant should be consider more factors such as saline water and marine sediment which they were not suitable for agriculture.

Result of this part is indicated that law and regulation of government could prohibit and control accessing into mangrove area. After declared mangrove forest zoning which fixed the boundary by RFD, most of shrimp farm had still accessed into

mangrove forest. It's indicated the fail of government management plan. So, the government should apply and improve the strategies to control and manage for stopping mangrove destruction and maintain existing mangrove area to be rich. Shrimp farm area on unsuitable area must be fix the boundary and strict to prohibit of expansion. Furthermore, the government can set priority to support facility on non – conflict area for leading to marine shrimp culture sustainable. Otherwise, shrimp farm was located on development zone should be give right for shrimp farmer in order to register and get support facility as same as outer zone. Its benefit for the government to control and promote for high production and sustainable yield.

However, the policy and planning for coastal zone management should be came from the brain storming of the government agencies responsible of different coastal zone resource. The finally the government will get the plan and policy which it will avoid conflict between government agencies. Moreover they can protect and preserve the resource and to maintain the ecological balance by mean of conservation efforts and integrated management.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

Conclusion

RS and GIS are the high efficiency tools for monitoring on coastal aquaculture and natural resource include of environment decision maker support. The main object of this study were shrimp farm and mangrove forest which used satellite data from Landsat 4, 5 and JERS – 1. The study period cover 22 years during 1977 – 1999 and classified the distinct shrimp farm and mangrove forest by band composite and image enhancement technique and then masking the area by on – screen digitizing. The change detection monitoring in the study area showed that both of them changed in large area with highly rate of change per year during 1987 – 1990 which the same period of shrimp farm expanded and distributed to eastern part of Thailand. Moreover in this period, mangrove forest was converted to shrimp farm over half of total area loss and the highest when compared with others period. So, from the result could assumed that shrimp farm increasing during 1987 – 1990 had impacted on mangrove forest loss because most of shrimp farm increasing in 1990 located on mangrove forest in 1987. Even if shrimp farm might not first activity was destroyed mangrove forest. Others period, the changed area of mangrove and shrimp farm did not much and a little bit area came from mangrove forest.

The shrimp farm in 1999 was overlaid on mangrove forest zoning. One of third of total shrimp in 1999 located on conservation zone which it is the sensitive area and need to protection. Therefore, government agencies who responsibility must plan to manage and control for mangrove forest conservation and environmental sustainable such as move the shrimp farm out or fix new boundary of conservation zone in order to comply with land use at present. Moreover, when overlaid shrimp farm on soil suitable for economic plant, most of shrimp farm located on outer zone which it's not conflict in this issue.

From above mention, the result of study can be used for planning and management the coastal zone for usage natural resource in balance, efficiency and sustainable. The application of RS and GIS can be apply for coastal zone management especially in this study into 3 categories.

1. Mapping for answer the question where the shrimp farm and mangrove forest are presented in study area and how different of type such as dry and active shrimp pond and mangrove type mapping etc.
2. Change detection, They are useful for monitoring shrimp farm expansion and mangrove deforestation which can tell the evolution changed area from the past.
3. Management and aquaculture activity. It has proved to monitor current shrimp farm in mangrove forest and to find out shrimp farm location which conflict on coastal zone management for who has responsibility to manage for coastal sustainable in the study area.

Limitation

The limitation of this study can divide into 2 categories:

4.1 Acquired satellite data.

The satellite data did not come from same source (satellite and sensor). The data are different resolution and wave length. So, the processed image which got after band color composite and image enhancement, showed different distinct level and it will impact on visual interpretation of shrimp farm area and on – screen digitizing. Moreover, mangrove forest classifying separated from other land use could not use same process because of satellite data in each sensor had number of band and wave length in each band difference. Band 5 of Landsat TM is useful for separate mangrove forest from forest and orchard but MSS from Landsat 4 and OPS from JERS-1 satellite did not have wave length same band 5 of TM sensor of Landsat 5 satellite. Therefore, the mangrove forest classification efficiency in each date of study were difference depend on the characteristic of wave length used.

4.2 On – screen digitizing.

On – screen digitizing of shrimp farm area from visual interpretation was depend on band color composite and enhancement technique including consider from size, shape, color and pattern of shrimp pond. However, it is still has error including from personal such as experience in RS and GIS, knowledge base on study area, image enhancement and from hardware setting such as monitor resolution, brightness and contrast etc. The shrimp farm area could not classify by used to transform

multispectral image data into thematic information classes (supervised and unsupervised classification) because of shrimp farm area composed of many object for instance water, dyke, grass, mud, building and bare land which they are reflectance and absorbency in each wave length depend on the specific characteristic of each object. Shrimp farm area will reflect high scattering and not unique value because of water in shrimp pond will reflect same value with water in the sea or river, moreover, the reflectance value of dry pond or dyke will nearly or same value with urban or bare land. The range of reflectance in each band wide and high variance not suitable on computerize classification. Therefore, visual interpretation is suitable and more accuracy method for separate shrimp farm area now, and in future we will get new suitable technique for separate shrimp farm by automatic processing.

Recommendation

RS and GIS are efficiency tools for monitoring mapping and manage coastal zone which the technique should be apply and develop for find out the suitable method for answer the complicated question. From this study, we have some recommendation like this:

1. The researcher should be develop satellite image analysis such as image differencing, classification, band ratio, principle component analysis and filtering for separated mangrove forest from terrestrial vegetation, and separate shrimp farm from other land use. The computerize classification which it will be convenience and no bias occurring. Moreover, the result can get it rapidly and more precision than on – screen digitizing by person.

2. Many source of RS data should be used for increase the accuracy and detail of study such as stage of shrimp pond which usefulness to find out abandon pond and evaluate the production. The imagery data can be used for supporting for more accuracy such as aerial photograph, IRS-1D Panchromatic res. 5 m. and data from microwave sensor and air born to overcome cloud cover etc.
3. The map from this study can be applied together with the database of shrimp farm such as the production, chemical usage, management system which the usefulness such as aerial can be update data convenience and can be presented efficiency and attractively.

Usefulness

Inventory and monitoring of land use in coastal area especially shrimp farm and mangrove forest are essential tools for decision – making on aquaculture development, including regulatory, environment protection an revenue collection. From this study, there are 2 main advantage to employing OPS satellite data for shrimp farm and mangrove forest monitoring. The first is timeliness for gathering and analysis which suitable for shrimp farm which it has high rate expansion and can update data often by ordering the acquisition of an image follow temporal resolution. The second, an importance advantage over traditional surveys, is that the resulting digital maps can be incorporated into GIS and database system. The information was planned and regulated which it is use of not only the government but valuable also to

associations of commercial shrimp farmers whose underlying purpose to maintain a dependable supply of good quality products at competitive prices.

Otherwise, we got a technique for study land use changed in coastal area and the result from this study was used as basic information data for applying in other case study. Furthermore, we can develop this image processing technique deeply for classify shrimp farm area from other land use by computerization or separate active pond from inactive pond which cover with water for predict shrimp farm area and production more accuracy and nearly truth data.

In future, technology and data will be developed for high capacity such as hardware and software will increase capacity, high quality, multiple task, complicated analysis, cheaper and more user friendly. The satellite data was improved in high resolution, more wave length which appropriate of study object. Therefore, RS and GIS were used to apply for environment study and impact on ecosystem and multidisciplinary task increasing more than present and high efficiency and accuracy.

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GLOSSARY OF TERMS AND ACRONYMS

Active remote sensing	Remote sensing methods that provide their own source of electromagnetic radiation, e.g. radar.
Band	A wavelength interval in the electromagnetic spectrum. For example, in Landsat sensors the bands designate specific wavelength intervals at which images are required.
Classification	The process of assigning individual pixels of a digital image to categories, generally on the basis of spectral reflectance or radiometric characteristics.
Color composite image	A color image prepared by combining individual band images. Each band (up to a maximum of 3) is assigned one of the three additive primary colors: blue, green and red.
Conservation zone	It's mean that the economic A zone which is able to used for forest utilization on suitable yield basis.
Development zone	It's mean that the economic B zone which is able to use for other developments natural with consideration given to the impacts on the environment.
Digital data	Data displayed, recorded or stored in binary notation.
Digital image processing	Computer manipulation of the digital values for picture

elements of an image.

Digitizing

The process of using a digitizer to automate the locations of geographic features by converting their position on a map to a series of x,y Cartesian coordinates stored in computer files.

Enhancement

The process of altering the appearance of an image so that the interpreter can extract more information. Enhancement may be done by digital or photographic methods.

GCP

Ground Control Point. A point on the ground whose position is accurately known and which can be used with other GCPs to geometrically correct an image.

Geometric correction

The correction of errors of skew, rotation, and perspective in raw, remotely sensed data.

GIS

Geographic Information System. An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. Certain complex spatial operations are possible with a GIS that would be very difficult, time consuming, or impracticable otherwise.

GPS Global Positioning system. A network of 24 radio transmitting satellites (NAVSTAR) developed by the US Department of Defense to provide accurate geographical position fixing.

Image The representation of a scene as recorded by a remote sensing system. Although image is a general term, it is commonly restricted to representations acquired by non-photographic methods.

Infra-red (IR) Portion of the electromagnetic spectrum lying between the red end of the visible spectrum and microwave radiation (700 nm to 1000 μm).

Multispectral Scanner (MSS) A scanner system that simultaneously acquires images of the same scene in various wavelength bands. Landsat MSS was one such system which was operational on Landsat series satellites from 1972-1993.

Map An abstract graphic representation of the earth's surface that displays spatial relationships among the features, generalizes their appearance to simplify them for the purpose of communication, and applies symbols to aid in interpretation. Many maps are constructed as a two-

	dimensional surface scaled down to a convenient size.
NIR	Near Infra-Red. Wavelengths around 700-3000 nm.
Passive remote sensing	Remote sensing of energy naturally reflected or radiated from the terrain.
Preservation zone	It's mean that the conservation zone which is strongly protected from any impact for its natural environment values.
Ratio image	An image prepared by processing digital multispectral data. For each pixel the value for one band is divided by that of another. The resulting digital values are displayed as an image.
Reflectance	The ratio of the radiant energy reflected by a body to that incident upon it.
Reflectance, spectral	Reflectance measured at a specific wavelength interval.
Remote sensing	The collection of information about an object or event without being in physical contact with the object or event. Remote sensing is restricted to methods that record the electromagnetic radiation reflected or radiated from an object, which excludes magnetic and gravity surveys that record force fields.

Resolution	The ability to distinguish closely spaced objects on an image or photograph. Commonly expressed as the spacing, in line-pairs per unit distance, of the most closely spaced lines that can be distinguished.
RMS error	Root Mean Square error. The distance between the input (source) location of a GCP and the retransform location for the same GCP. Measure used to assess the accuracy of geometric correction.
Scattering	Multiple reflection of electromagnetic waves by gases or particles in the atmosphere.
Sensor	A device that receives electromagnetic radiation and converts it into a signal that can be recorded and displayed as numerical data or as an image.
Signature	A characteristic, or combination of characteristics, by which a material or an object may be identified on an image or photograph.
TM	Thematic Mapper.
Unsupervised classification	Using a computer to automatically generate a thematic map from digital remotely sensed imagery by statistically

clustering pixels on the basis of spectral similarity. The clusters may then be assigned labels (e.g. habitat names) using the operator' s field knowledge.

UTM

Universal Transverse Mercator. A widely used geographical coordinate system.

Visible radiation

Energy at wavelengths from 400 to 700 nm that is detectable by the eye.

Wavelength

The distance between successive wave crests or other equivalent points in a harmonic wave.

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