APPLICATION OF REMOTE SENSING AND GIS TOOLS FOR RECOGNIZING CHANGES OF MANGROVE FORESTS IN CA MAU PROVINCE

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ABSTRACT

Mangrove forests have plaid an important role for economic development, protection of environment and natural biodiversity in coastal regions. However, in recent years, mangrove forests in Mekong Delta in general and in Ca Mau province in specific have reduced significantly. Amount of evidence demonstrated that shrimp culture has resulted in the reduction of mangrove forests. The successes of remote sensing (RS) and geographical information system (GIS) tools have been demonstrated in land use management in recent years, especially in study field of mangrove forest. Based on the analyzing of topographical map (1965) and the results of remote sensing analysis of SPOT images in 1995 and 2001, mangrove status and changes of Ngoc Hien District were identified. The dynamic processes of mangrove changes were divided into two periods. In the period of 1965-1995, mangroves decreased gradually, while in the period of 1995 - 2001, they had a significant reduction. Totally, after 36 years, mangrove forests lost more than 50 % of the areas. In addition, many areas of mangroves were not forests; they were only mangrove trees.

1. INTRODUCTION

Mangrove forests, types of coastal ecosystems in tropical zone, play an important role not only for material of biogeochemical cycle but also for human demand and economic activities including aquaculture, fishing as well as improving local living standard. Mangrove forest in the Mekong Delta used to cover more than 250,000 ha (Maurand, 1943 cited in Hong and San, 1993). Because of wars, fire and human demand, mangrove forests were disappeared incrementally. Especially, since the end of 1980s and in the 1990s, abundance of shrimp farming has replaced lots of mangrove areas (Hong and San, 1993; Hong, 1995; Hao, 1999). On the other hand, many projects of mangrove reforestation have been carried out somewhere there. Therefore the status of mangrove forest varies excessively complicated in Mekong Delta. Thus, there are difficult problems for building master plans as well as managing and developing local economy and protecting natural resources in Mekong Delta.

Mangrove habitat maps have been used for three general management applications: Resource inventory, change detection and the selection and inventory of aquaculture sites. The mangrove distribution maps can be made from investigation *in situ* or analyzing from remotely sensing images and GIS techniques (Geographical Information Systems). Many

studied results indicated that images of SPOT XS (Multispectral mode imagery from Satellite Pourl' Observation de la Terre), SPOT XP or SPOT Pan (Panchromatic mode imagery from SPOT), Landsat TM (Landsat Thematic Mapper), Landsat MSS (Landsat Multispectral Scanner), MOS-1 MESSR (Multispectral Electronic Self-Scanning Radiometer carried out on the Marine Observation Satellite), JERS-1 (Japanese Earth Resources Satellite), ERS-1 SAR (Synthetic Aperture Radar carried on the European Remote Sensing Satellite), MK6 (Russian Multispectral camera carried on the Salyut-7 Satellite), KATE-140 (Soviet panchromatic large format camera) and Aerial Photos have been for mangrove habitat mapping with different image processing techniques, including Visual interpretation, Vegetation index (NDVI – Normalized Difference Vegetation Index, and AVI – Angural Vegetation Index, BI – Brightness Index), Unsupervised classification, Supervised classification, Band ratios and Resolution merge between Landsat TM with SPOT Pan (Lorenzo *et al.,* 1979; Bina *et al.,* 1980; Untawale *et al.,* 1982; Patterson and Rehder, 1985; Blasco *et al.,* 1986; Ranganath *et al.,* 1989; Roy, 1989; Chaudhury, 1990; Dutrieux *et al.,* 1990; Gray *et al.,* 1990; Vibulsresth *et al.,* 1990; Jensen *et al.,* 1991; Kay *et al.,* 1991; Populus and Lantieri, 1991; Woodfine, 1991; Eong *et al.,* 1992; Gang and Agatsiva, 1992; Loo *et al.,* 1992; Mohamed *et al.,* 1992; Palaganas, 1992; Long and Skewes, 1994; Aschbacher *et al.,* 1995; Vits and Tack, 1995; Rasolofoharinoro, 1997; Green *et al.,* 1998). These processing methods have been acceptable for application on mangrove habitat maps in management, including mangrove inventory and mapping, change detection (deforestation) and management of aquaculture activities. The SPOT images can be classified and identified mangrove forest with the 81 – 95% accuracy achieved (Palaganas, 1992; Vits and Tack, 1995).

This paper shows the analyzed results of mangrove forest distribution by analyzing approaches of remotely sensing and GIS in Ngoc Hien district – Ca Mau province (Fig 1).

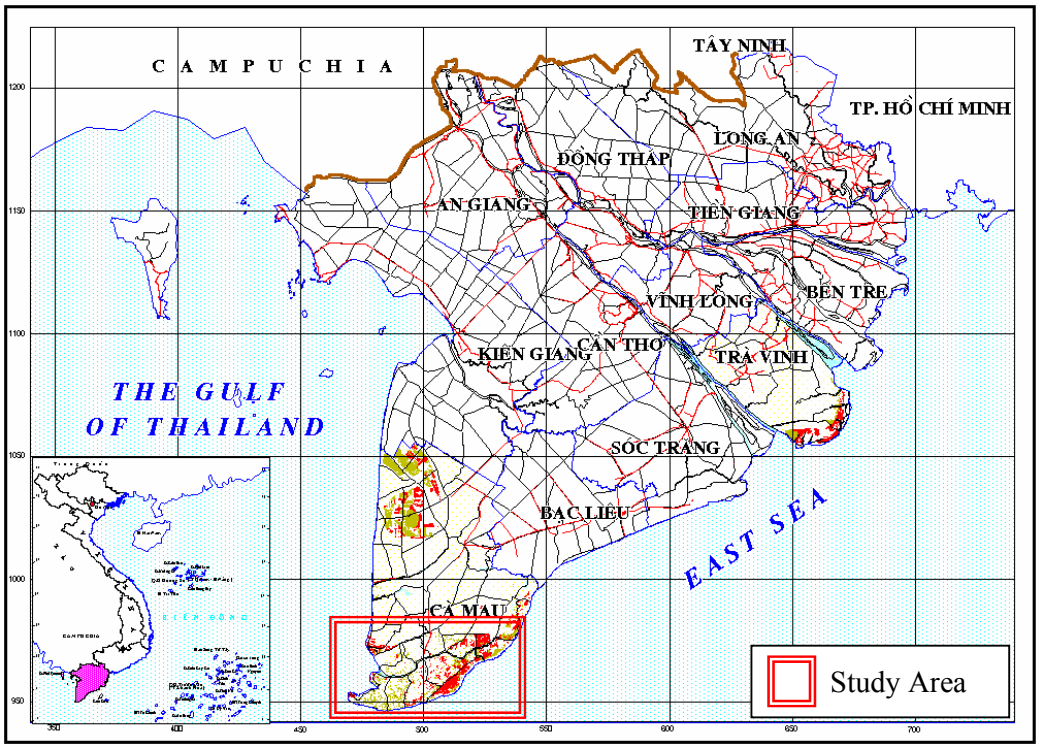

Figure 1: Location of study area

2 MATERIAL AND METHODOLOGY

2.1 Study materials

Study materials are topo-map in 1965 (Scale map: 1:50.000, UTM: Indian 1960, Zone 48 in Southern), Remote sensing images (SPOT in western Ngoc Hien on 12 December 1995 – appendix 1, there is 3 band and 20 m resolution and SPOT4 in Ngoc Hien on 10 April 2001 there is 4 band and 10 m resolution - appendix 2)

2.2 Methodology of processing to identify of mangrove forest and its changes

The processing of identification of mangrove forest and its changes was carried out step by step as shown in Fig. 2. This processing was implemented by the GIS and RS software.

3 RESULTS AND DISCUSSIONS

3.1 Mangrove distribution in Ngoc Hien District

By digital method from topo-map, situation of land use of Ngoc Hien was found out; and by methods of supervised classification in analysis remotely sensing image processing linking with field trip together, mangrove forest areas were also identified with 3 layers of mangrove forest, including high density, moderated density and low density of mangrove forest. The analyzing results of mangrove distribution Ngoc Hien are presented in Figs. 3 – 5. The mangrove forest cover in Ngoc Hien significantly changes very strongly (Table 1).

Table 1: The distribution of Mangrove forest in study areas

(result of 1965 from topo-map, 1995 and 2001 from remote sensing images)

Study Area	**1965**	***1995****	**2001**
Ngoc Hien - Camau	90,346	***23,897***	38,303

*: Small area (Western part of Ngoc Hien)

Mangrove forest has been reduced rapidly (Table 1). After 36 years, mangroves in Ngoc Hien were less 2.5 times. For that reason, from 1943 to 1993, mangrove forest was destroyed by war and other human activities such as cutting down for firewood and converting to paddy field (Hong and San, 1993) which demonstrated in Figs. 3 and 5, but from 1995 to 2001, reduction of mangrove forest in Mekong Delta was contributed by shrimp farm activities.

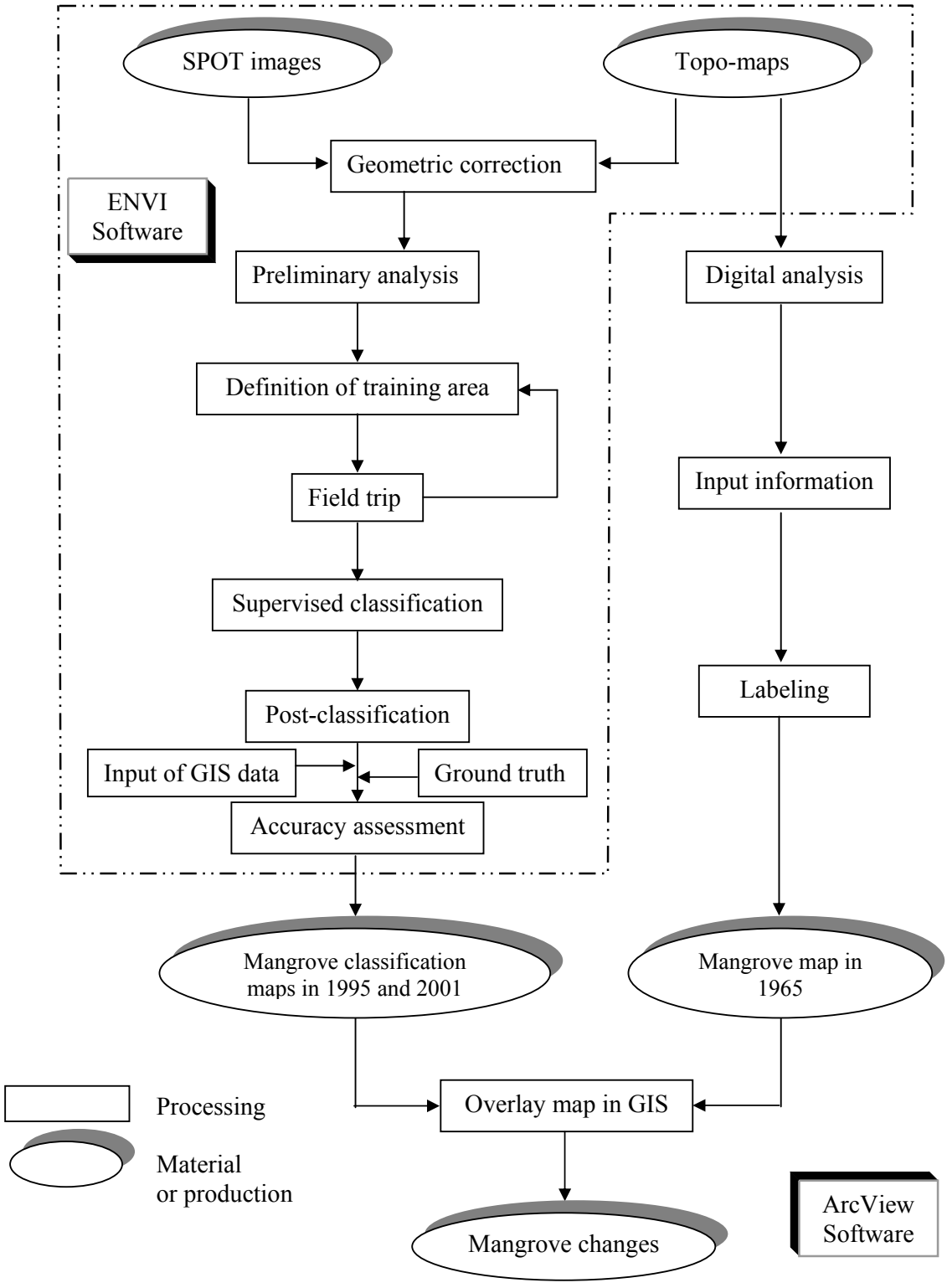

Figure 2: Slow chart to find out mangrove changing by GIS and RS

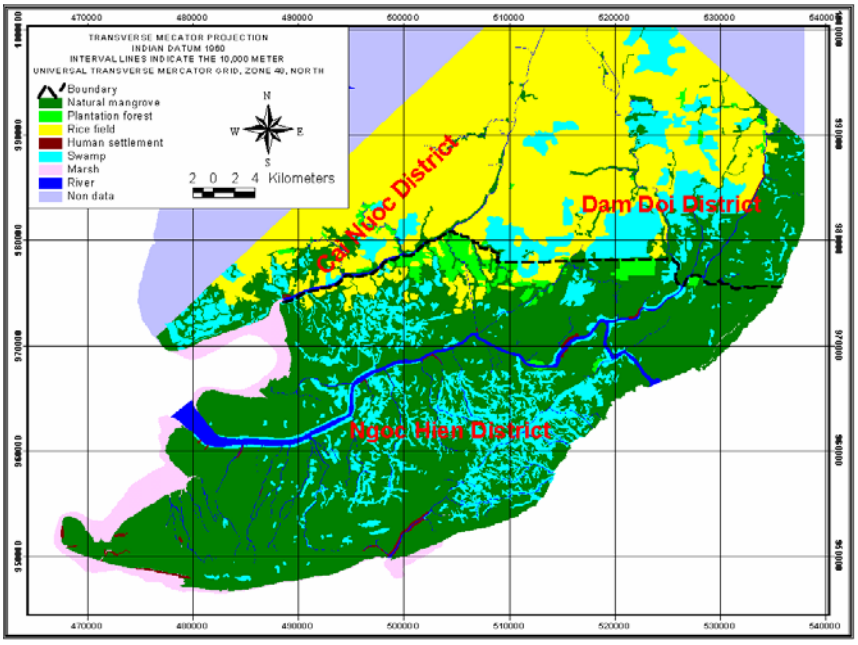

Figure 3: Status of landuse in Ngoc Hien – Ca Mau (1965) with 87,097 ha of mangrove forest and 3,249 ha of plantation areas

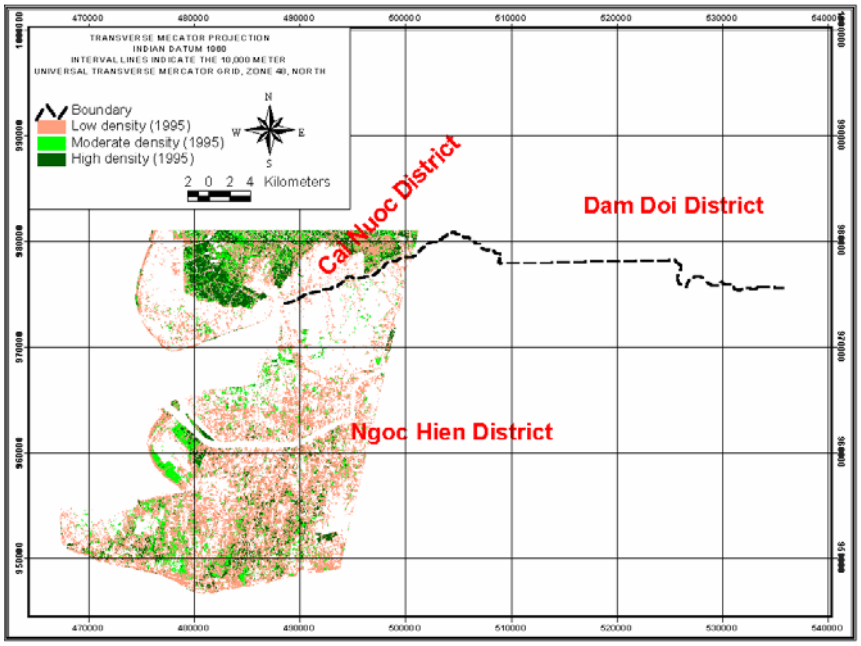

Figure 4: Distribution of mangrove forest in the western part of Ngoc Hien-Ca Mau (1995) with 2,396 ha of low density, 3,596 ha of moderate density and 17,953 ha of high density of mangrove forest

Status mangrove forests in difference periods were indicated in Figs. 3-5 and Table 2. Most land-use of Ngoc Hien was covered by mangrove forest in 1965 (Fig 3) with 90,346 ha and coverage more than 72 % of total land area, in which there were 87,097 ha of natural

mangrove forest and 3,249 ha of planting area in forestry farms (Fig. 3). Although reforestation areas were only 3.5% of total mangrove areas, they demonstrated strategies of reforestation were noted in Ngoc Hien before 1965. However, during 1995-2001 periods, mangrove planting has not increased equality to mangrove deforestation. As a result, area of mangrove forest in Ngoc Hien district has only 38,303 ha in 2001 and covered 30.67% of total land area (Table 1 and Fig. 5 and 6). Although there are factors affecting the analysis remote sensing image results in identification of mangrove forest, such as images covered by cloud and data outside images (Appendix 2), area of mangrove forest in 2001 could be higher than 38,303 ha (Fig. 5).

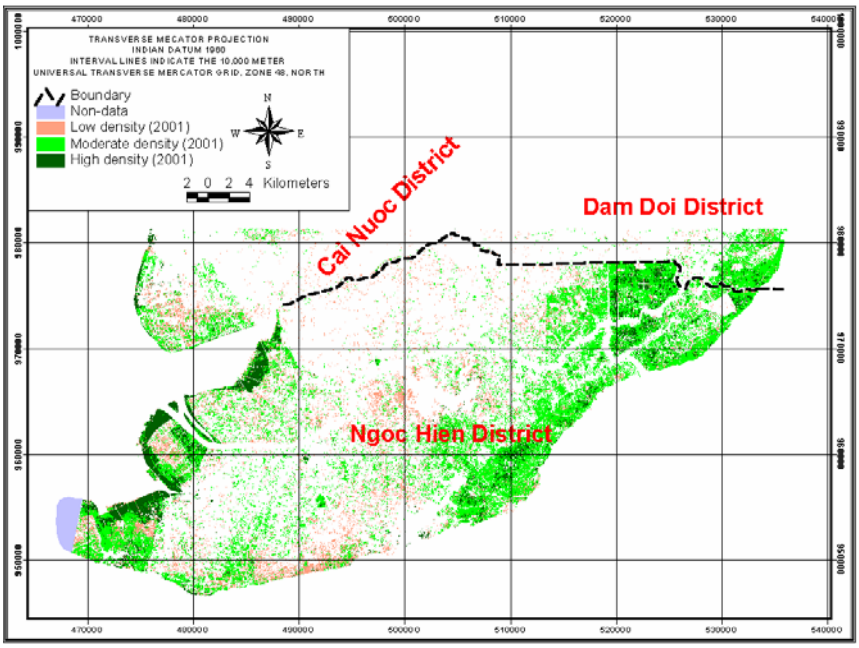

Figure 5: Distribution of mangrove forest in Ngoc Hien – Ca Mau (2001) with 8,677 ha of low density, 23,860 ha of moderate density and 5,766 ha of high density of mangrove forest

The situation in mangrove forest in other areas in Ngoc Hien also was different. In the Western part, area of mangrove forest was 36,806 ha including 36,663 ha of natural mangrove forest and 143 ha of planting mangrove in 1965. In 1995, it was 23,897 ha, in which area of the low density, moderate density and high density of mangrove forest were 2,348 ha, 3,596 ha and 17,953 ha, respectively, while in 2001, it only was 15,915 ha with 4,719 ha, 7,749 ha and 3,447 ha. Therefore, mangrove forests were reduced both in quantity and quality (area and cover degree). In another part, area of mangrove forest was 22,388 ha which includes 3,959 ha of low-density, 16,111 ha of moderate-density and 2,318 ha of high-density forests. In addition, together with results of data analysis of field trip, most low density of mangrove forest areas were areas of mixing between mangroves with shrimp culture or mangroves with canal.

Table 2: Distribution of Mangrove forest in Ca Mau

Unit: (ha)

Year	Factors	Western part	Eastern part	Total
1965	**Total**	**36,806**	**53,540**	**90,346**
	Natural mangrove forest	36,663	50,435	87,097
	Plantation forest	143	3,105	3,249
1995	**Total**	**23,897**		
	Low density	2,348		
	Moderate density	3,596		
	High density	17,953		
2001	**Total**	**15,915**	**22,388**	**38,303**
	Low density	4,719	3,959	8,677
	Moderate density	7,749	16,111	23,860
	High density	3,447	2,318	5,766

3.2. Mangrove changes

To identify mangrove changes, mangrove forests in 1995 and 2001 were supposed to have similar density. Using overlay map methods with the "Union two themes" and "Dissolve the feature based on attribute" functions in ArcView software, mangrove changes were found out in Tables 3 and Figs. 7 – 9.

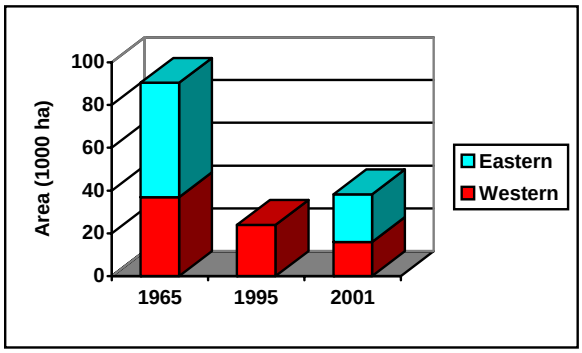

Figure 6: Distribution of mangrove forest in Ca Mau province from 1965 to 2001

Results show that mangrove forest changed highly. After 36 years, mangrove area has been reduced approximately 52,043 ha (Table 3) or 57.60 % when they were compared with mangrove forest in 1965. The rate of annual decrease in Ca Mau was 2.36%. However, these rates in different area did not also equal. These annual rates in western part and eastern part were 2.30% and 2.39%, respectively, in the 1965 – 2001 period. In two periods (table 4), mangrove areas were decreased but in last period they were lost faster than in previous one. The annual decrease rate of 1965 – 1995

and 1995 – 2001 periods are 1.43% and 6.55 %, respectively. The reduction of mangrove forest in Ca Mau was predicted due to its conversion to shrimp farms (Hong, 1995, Phuong and Hai, 1998, Minh et al., 1999, Minh et al., 2000).

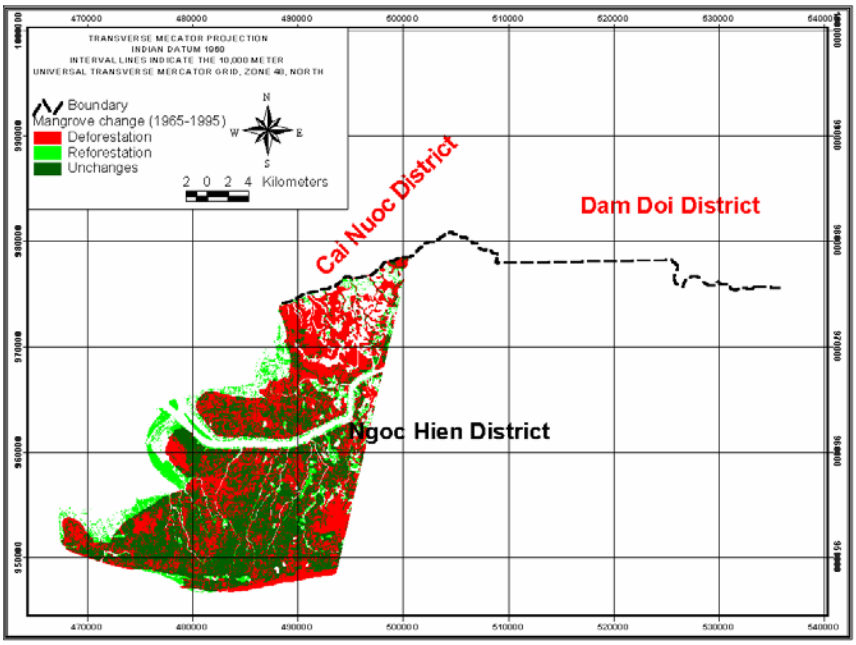

Figure 7: Map of mangrove forest changes in year of 1965 to 1995 at the Westren part of Ngoc Hien – Ca Mau

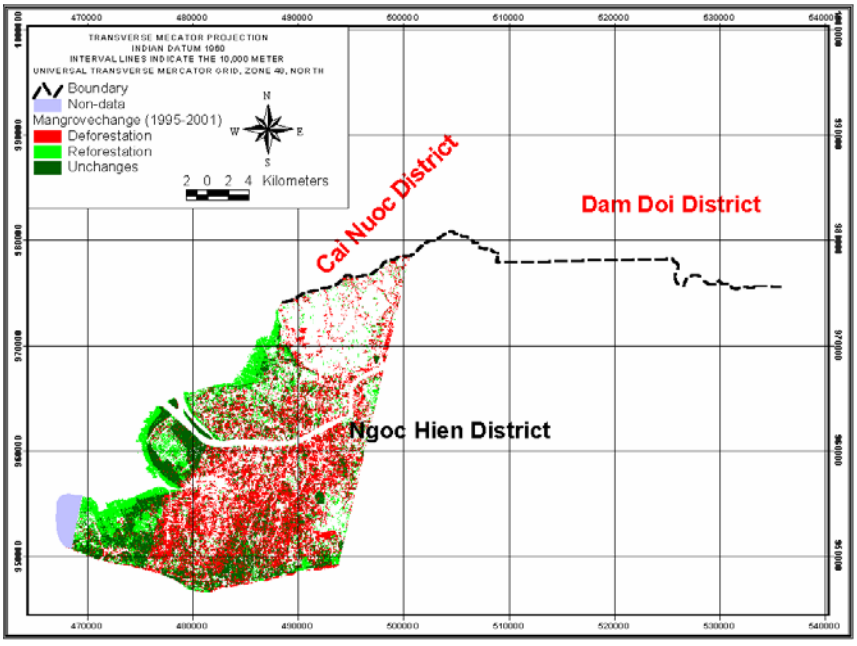

Figure 8: Map of mangrove forest changes in year of 1995 to 2001 at the Western part of Ngoc Hien – Ca Mau

Further, changes of mangrove forest were come from not only deforestation but also from replanting in some areas. These two activities, including deforestation and reforestation,

occurred seemingly at the same time in the area studied. Figs. 7 - 9 and Table 3 show changes of mangrove forest due to these activities. These activities affected mangrove areas in years of between 1965 and 2001 which were 61,398 ha and 12,323 ha, respectively, but activities of reforestation in 2nd part were lower than in 1st part (Fig. 10). In the 1st part, areas of deforestation and reforestation between 1965 and 1995 were 18,395 ha and 4,607 ha, respectively while 1995 and 2001 were 14,980 ha and 6,947 ha, respectively. Therefore, in the 1995 – 2001 period, replanting activities of mangrove forest was noted and improved more than before period. In addition, some areas of mangrove forest were unchanged but their quality was changed (Table 3 and Fig. 10). Most these unchanged areas were located in conversation parts or mangrove biosphere areas such as Dat Mui and Bird Park.

Table 3: Changes of mangrove forest (ha) in Ngoc Hien – Ca Mau

	Mangrove area			Changes		
Year	**1965**	**1995**	**2001**	**1965-1995**	**1995-2001**	**1965-2001**
Western part	36,806	23,897	15,915	-12,909	-7,982	-20,891
Eastern part	53,540		22,388			-31,152
Total	90,346		38,303			-52,043

Note: (-): decreasing mangrove areas

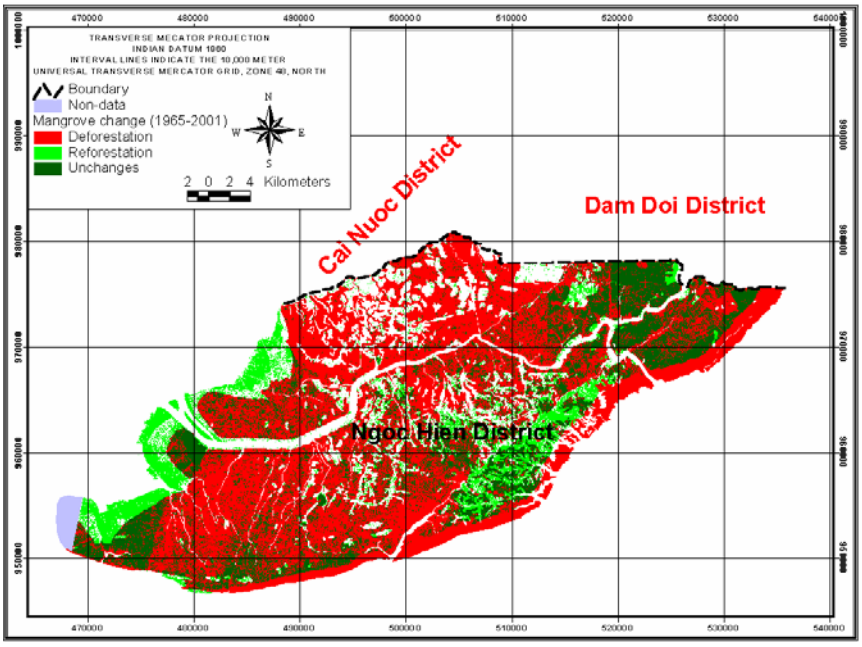

Figure 9: Map of mangrove forest changes in year of 1965 to 2001 in Ngoc Hien - Ca Mau

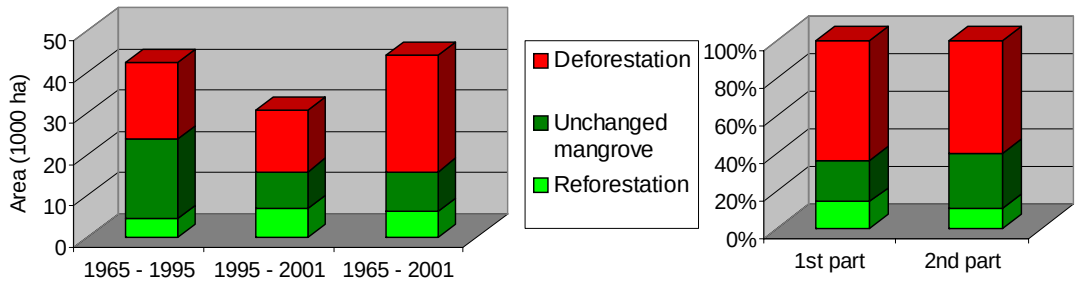

Figure 10: Mangrove forest changes in Ngoc Hien – Ca Mau from 1965-1995-2001

(Left: mangrove changes in Western part in 1965-1996, 1995-2001 and 1965-2001; Right: Comparing of mangrove changes at two parts (1st: Western and 2nd: Eastern part) in period 1965-2001)

The results of image analysis (Figs. 7 – 9) showed that the replanting activities were occurred in the mud flat of the western coasts by nature and people while in the eastern coast the erosion has happened. This was also demonstrated by the results of study on changes of coastline in recently (Hieu *et al.*, 2000). Beside restoring mangrove forest, the purpose of replanting was also the expansion of land use into the west sea. The replanting occurred after the deposition of sediment and the shallow seabed. In addition, *Rhizophora apiculata* was used in the replanting. This affected the identification processing of mangrove forest. Thus, it is crucial to further study on distribution of species of mangrove trees.

Table 4: Characteristics of mangrove forest changes in Ngoc Hien - Ca Mau

Unit: ha

Period	Status	Western part	Eastern part	All area
1965 - 1995	Deforestation	18,395		
	Reforestation	4,607		
	Unchanged mangrove	19,268		
1995 - 2001	Deforestation	14,980		
	Reforestation	6,947		
	Unchanged mangrove	8,947		
1965 - 2001	Deforestation	28,099	33,299	61,398
	Reforestation	6,350	5,973	12,323
	Unchanged mangrove	9,565	16,141	25,706

3.3. The reasons of mangrove forest degradation

From above analysis, although some areas of mangrove were replanted, mangrove forest in study areas have been decreasing quite fast both in quantity and quality. There are many factors, which degraded mangrove forest, but the major one was shrimp culture activities. Other factors such as transformation, industry, urbanization, degradation of environment and sedimentation also impacted mangrove changes. These factors also had relationship with one another.

3.3.1. Shrimp culture

Many results (Hong, 1995; Macintosh and Zisman, 1995; Macintosh, 1996; Phuong and Hai, 1998; Minh *et al.*, 1999; Lin, 2000; Minh *et al.*, 2000; Yap, 2000; Srinath *et al.*, 2000; Lakshmi and Rajagopalan, 2000) demonstrated that between mangrove and shrimp farm have a complex relationship. Mangrove forests were nursery places and supplying food of marine and brackish water animals. They also supplied seed for shrimp culture. In addition, mangrove forests were natural treatment factories of shrimp farming. On the contradictory, shrimp culture, on one hand, supplied nutrient salts for mangrove forest based on water and sediment discharge into mangrove areas. On the other hand, farmers have cut down mangrove forest and conversed to shrimp farm. Due to high price of shrimp, shrimp cultivation area has been increasing quite fast. These were indicated in Fig 11. While mangrove forest became less restricted with every passing day, shrimp culture was expanded.

Further, because of lack of information on environmental conditions, shrimp culture techniques and financial resources, shrimp culture failed in some areas or shrimp ponds were only used in a short period (Hong, 1995). After few years, land has been degraded and farmers continued to cut down mangrove forest to make new shrimp ponds. The attitude of mangrove destruction and degradation was based on short-term exploitation for immediate economic benefit, rather than longer-term but sustainable exploitation. These are major causes of mangrove deforestation in the period of 1995 – 2001 in Ca Mau but the shrimp area decreases (19,000 ha) were several times smaller than the current shrimp areas (104,000 ha).

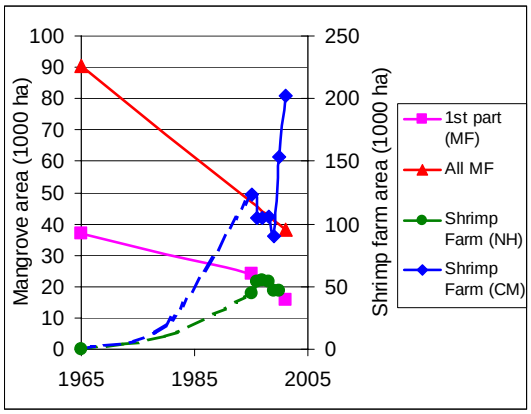

Figure 11: Relationship between mangrove forest areas and shrimp farm areas Ca mau

MF: Mangrove Forest, NH: Ngoc Hien district, CM: Ca Mau province

In addition, demand for prawn seedlings also was dangerous to mangrove. Collection of shrimp seedlings injured the roots and slowly destroyed the trees.

Furthermore, shrimp culture also affected hydrodynamic system in local area. Increasing strength of current and waves caused sedimentation and mangrove deforestation (Long, 2002).

3.3.2. Environmental factors

Mangrove ecosystems tend to act as nutrient sinks for various elements including macronutrient such as nitrogen and phosphorus, trace elements and heavy metal (Odum *et al.,* 1982; Wong, 1984). Mangrove forest plays an important role as the treatment environmental factories and as the bio-filter to treat shrimp pond effluents (Gautier *et al.,* 2001). They were very efficient at removing suspended sediment as well as exporting nutrients. Much of pollutant removal occurred through natural processes, such as sedimentation, filtration, soil absorption, denitrofication and microbial decomposition of organic matter. The activity of phytoplankton and bacteria coupled with dilution and mixing of the tidal waters is the primary mechanism controlling dissolved nutrient concentration (McKinnon *et al.,* 2002). These were some positive impact of mangrove forest on shrimp farm. However, shrimp farm activities have cut down and cleared mangrove forest, which limit treatment capacity of mangrove and cause environmental pollution and eutrophication.

In addition, destroying of mangrove forest has lost many species of flora and fauna. And then highly valuable genetic sources in mangrove system were lost. They will limit capacity of research and development in local region. Further, loss of mangrove will cause erosion in the coastal line. This was demonstrated in the southeastern region of Ca Mau (Fig. 9).

3.3.3. Other human activities

Mangrove forest did not only supply feed for organisms, but they also impact on income of local people. However, human activities impact mangrove forest. Transportation increased suspended sediment. Agriculture also increased soil acidification and agrochemical in water but agricultural production has low value (Hong and San, 1993). These chemicals impacted negative on shrimp farm and mangrove forest (Hong, 1995). In addition, other demand activities also caused conflicts of natural resources users and then affected mangrove forest. Beside of shrimp culture, huge areas of mangrove forest have been lost due to wood extraction, conversion to agriculture or salt production, coastal industrialization and urbanization and war, but these areas have been equaled to mangrove forest area which shrimp farming has been blamed for large scale losses.

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4. CONCLUSIONS

Mangrove forest in Mekong Delta has been reduced both in area and covered degree. After 36 years, mangrove forest lost more than 50 % of area but more than a half of mangrove forest, which has existed, was low density. These changes of mangrove forest were affected by two activities: deforestation and replanting but capacity of planting has been less than deforestation. If mangrove was originally at low density, then the impact of deforestation is more limited. The major reason of recent mangrove changes was shrimp farm development. The development of aquaculture has been increasing quite rapidly and in an unplanned way. Shrimp farm development and degradation also caused environmental and

natural resources problem as well as socio-economic aspects. Reforestation of ineffective shrimp ponds might be a good solution to improve the sustainability of this ecosystem before one can make a master plan of land use for the coastal zone to help solve these problems. The rule should be now to strictly prohibit any settlement in the few with high density, namely west and northeast.

5. ACKNOWLEDGMENTS

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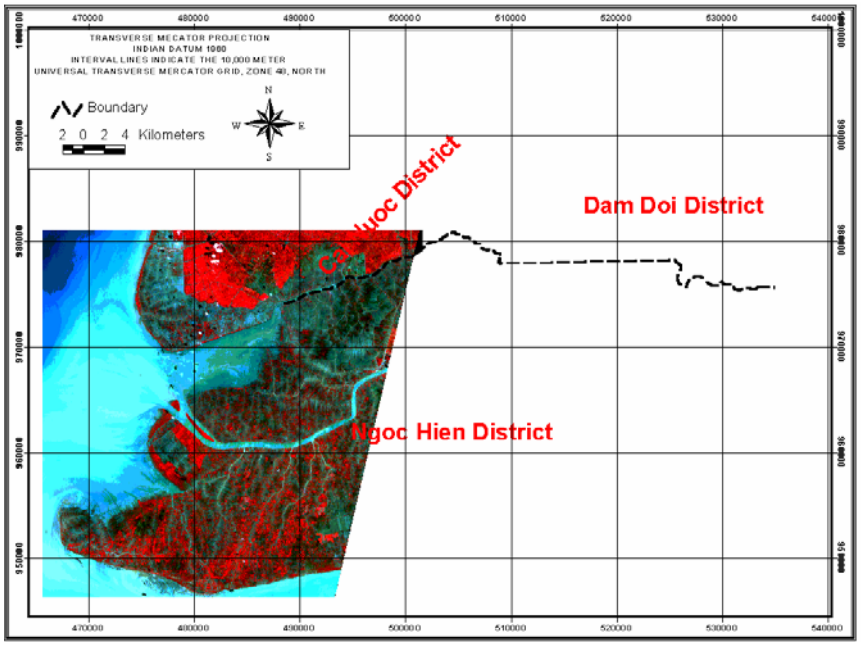
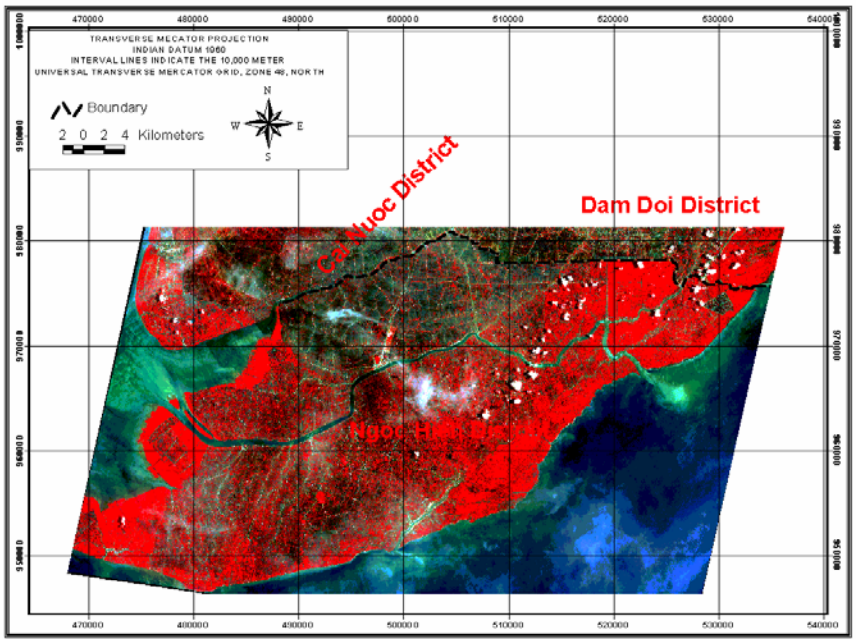


Appendix 1: SPOT Image (1995) of study site in Ca Mau displaying false color composite (Red: bank 3, Green: bank 2 and Blue: bank 1)



Appendix 2: SPOT Image (2001) of study site in Ca Mau displaying false color composite (Red: bank 3, Green: bank 2 and Blue: bank 1)