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ASSESSMENT OF A MANGROVE REHABILITATION PROGRAMME USING REMOTE SENSING AND GIS: A CASE STUDY OF AMPHUR KHLUNG, CHANTABURI PROVINCE, EASTERN THAILAND

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ABSTRACT: The Mangrove Rehabilitation Program (MRP) is a program conducted throughout the coastal regions of Thailand by the Royal Forest Department (RFD). The program focuses on coastal areas where mangrove forests currently occur or once existed. MRP has been initiated to cope with the mangrove degradation problems that have been accelerating during the past two decades. The RFD has conducted the MRP since 1997. The main objectives of this program are to: protect the existing mangrove forests, increase and rehabilitate mangrove forest area by reforestation, promote forest extension and conservation awareness among local people. To assess the achievement of the MRP, remote sensing and GIS were employed to obtain the spatial data for comparing the current mangrove situation with the situation prior to the start of the program. This was done by classifying land cover on Landsat TM images recorded in 1996 and 2000.

1. INTRODUCTION

Until recently, tropical forests have been used as a renewable resource. With pressure of increasing population, however, more agriculture land is needed and urban areas expand. As a result, forest areas have declined at an alarming rate. In response to this, there has been increasing research and development for sustainable forest management. However, these studies have been conducted mostly in the upland forest while the 'mangroves' were 'the forgotten forests'.

Mangrove forests perform multiple ecological functions such as production of woody trees; provision of habitat, food, and spawning grounds for fish and shellfish; provision of habitat for birds and other valuable fauna; protection of coastlines and accretion of sediment to form new land. Mangrove areas have high biological productivity associated with heavy leaf production and leaf fall and rapid decomposition of the detritus. The mangrove ecosystem is dynamic, changing in both location and composition, and has great resilience with the ability to restore itself after heavy damage, as long as seed sources and water flow are maintained. There are also many direct economic benefits from mangrove resources such as a source of firewood and charcoal, self-renewing sites for collecting fish and shellfish, sites for collecting honey and attraction for tourism.

Despite the benefits that they offer, mangrove forests are increasingly under threat. Due to pressures from growing populations, which lead to changes in land use and over-utilization of the resources, mangroves are being rapidly depleted and degraded. The depletion of mangroves is a cause of serious environmental and economic concern to many developing countries. This stems from the fact that at the interface between the sea and the land, mangroves play a pivotal role in moderating monsoonal tidal floods and in coastal protection. At the same time, their primary production supports numerous forms of wildlife and avifauna as well as estuarine and near-shore fisheries. Consequently, the continuing degradation and depletion of this vital resource will reduce not only terrestrial and aquatic production and wildlife habitats, but more importantly, the environmental stability of coastal forests that afford protection to inland agricultural crops and villages will become seriously impaired (FAO, 1994).

Mangrove forest is found along the coastline of 22 provinces in the East and the South of the country (NRCT, 1991). The extent of existing mangrove forest in 1979 was approximately 2873 km^2 or 1,795,675 rai (1 rai = 0.16 ha). At present, mangroves cover only 1,675 km^2 (RFD, 1998). During 1961-1979 the extent of destruction was 80,592 ha. (Klankamsorn and Charuppat, 1982). The decrease in mangrove forest area within a more recent 7-year period (1979-1986) is approximately 909 km^2 or 32 %, with high annual depletion rate 5 %, or about 130 km^2 annually (NRCT, 1991). The most serious factor leading to the progressive destruction of mangrove forests is the population increase resulting in over-exploitation and clearing of mangroves for tin-mining, salt ponds, and especially shrimp farming. This has been most active in coastal areas of the central region of Thailand.

The rapid decline and deterioration of mangrove ecosystem in Thailand implies the need to recognize the importance of conservation, management, and restoration of mangrove forests. A balance needs to be struck between meeting increasing present-day needs, on one hand, and conserving the environmental support system provided by mangrove forests, on the other. To cope with this problem, many measures have been employed by the Thai government through the Royal Forest Department. Among these measures is the designation of mangrove forests into 3 zones. These three zones are: **Conservation zone**: mangrove areas designated for nature conservation; **Economic A**: mangrove areas that can be used as productive forests, such as forest concessions or community forests and **Economic B**: mangrove areas where other land uses and developments are allowed, subject to consideration of environmental impacts.

Enforcement of forest laws and forest extension has been implemented as well, although many of these did not fully achieve their purposes. Nevertheless, there is the need to use the mangrove areas, and conflicts between the local people and the government agency responsible for mangroves still remain. New, active programs have therefore been initiated. The Mangrove Rehabilitation Program (MRP) is one such program in response for the above-mentioned problem.

Because it was only implemented in 1997, it is not yet clear how well MRP is operating. Hence, there is a need to monitor the progress of the program in terms of both its ecological (mangroves area) and socio-economic impacts. The objectives of this study were to assess the performance of the Mangrove Rehabilitation Program, and to determine the extent to which remote sensing and GIS can support such an assessment.

2. MATERIALS AND METHODS

The study area is located in the coastal zone of Amphur Khlung, Chantaburi Province. It is located on the east coast of the Gulf of Thailand. The study area covers an area of 14,415 ha the mangrove forest. The area is about 250 kilometers from Bangkok. In 1979, mangroves in Chantaburi Province covered an area of 240 km^2. In 1996, only 39 km^2 of mangroves remained.

Aksornkoae (1976) studied the structure of mangrove forest at Amphur Khlung and reported that " The mangrove community at Amphur Khlung, Chantaburi Province consists of more than 27 genera of trees and other plants, but only a few are dominant in the structure of the ecosystem. *Rhizophora candelaria* and *R. mucronata* are the dominant plants found both on the banks of the brackish estuaries and on the edges of the channels running through the forest."

Two main method lines were used in this research. The first involved the detection of changes in the mangrove forests on satellite images of two different dates:

- Landsat TM data recorded on December 26, 1996.
- Landsat TM data recorded on January 4, 2000.

The second involved the use of questionnaires to determine villagers' satisfaction towards the Mangrove Rehabilitation Program. However, this paper will concentrate on the change detection analysis of the remotely sensed data and its use in assessing mangrove rehabilitation program. Figure 1 show the general methodology of this research.

Fieldwork activities were conducted in August and September 2000. There were 3 major groups of activities, namely:
1) visits to resource agencies,
2) Mangrove tree data collection, and
3) Interviewing the villagers.

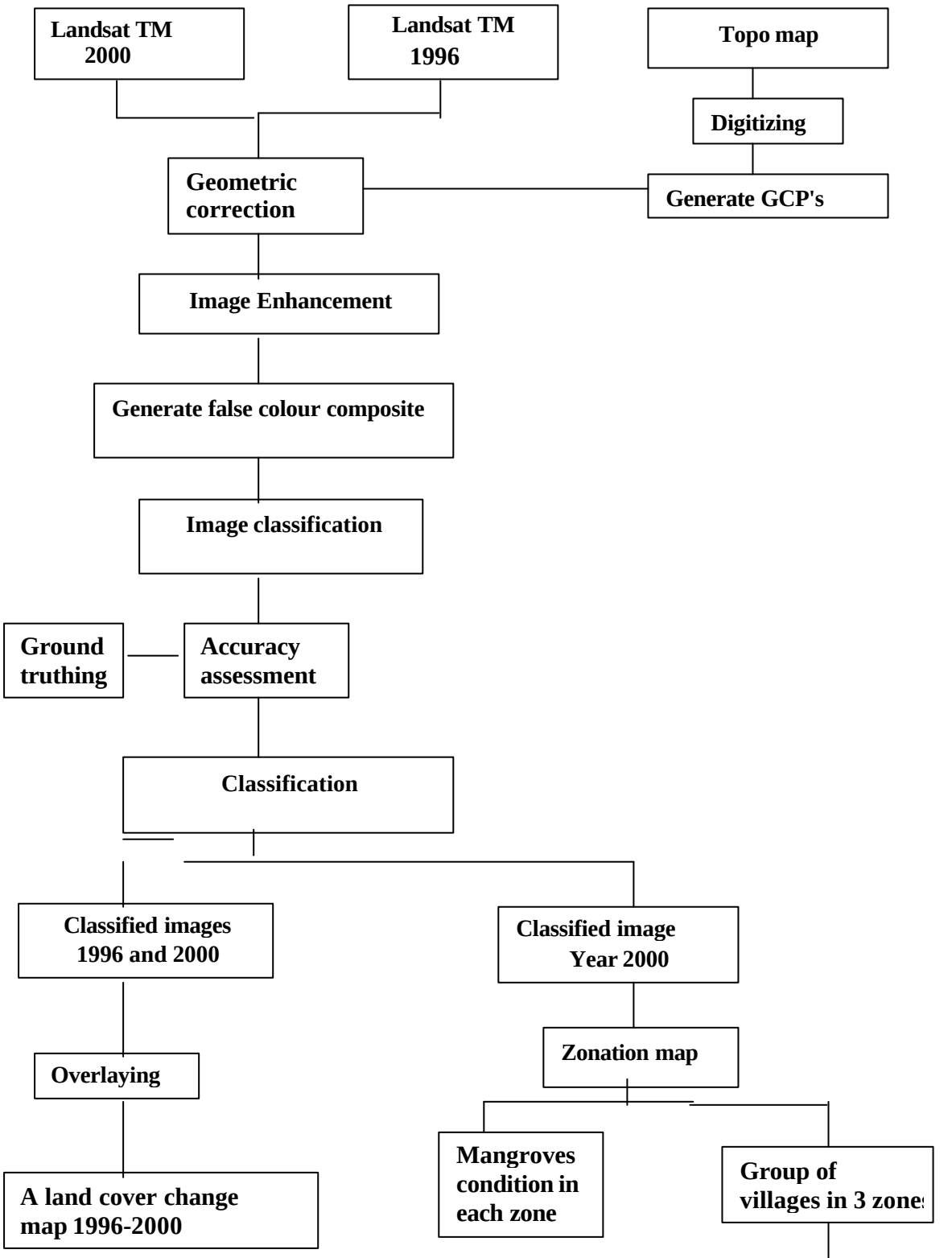

Figure 1. Flowchart of the research methodology

Ground truth data were collected from about 70 plots that located using stratified random sampling. For each plot, which has an area of 500 square meters or radius of 12.62 meter, data on DBH, height, crown cover percentage, number of trees were collected.

After carefully checking, four classes of land cover types were distinguished: dense mangroves, degraded mangroves, grassland, and shrimp farms. Water bodies were excluded from the classification process, because they give the same reflectance values as shrimp farms. Supervised maximum likelihood classification was used to classify the two Landsat TM images of 1996 and 2000. The cross-map function of GIS was used to achieve the change detection analysis of the two images.

At the completion of a classification process, it is necessary to assess the accuracy of the results obtained. This allows a degree of confidence to be attached to the results. Classification accuracy was determined by selecting a sample of pixels from the thematic map and checking their labels against classes determined from reference data gathered during site visits.

3. RESULTS

The classification results of TM images of the two years 1996 and 2000 a re shown in Table 1 and in Figures 2 and 3

Table 1. Image classification result (area in ha)

Class	**1996**	**2000**
mangrove forests	769	3481
degraded mangroves	4918	3919
grassland	4674	2419
shrimp farms	4058	4595
Total	14420	14415

According to the classification, in 1996 mangrove forests covered an area of 76 ha. The area of this class increased to 3481 ha, or 3.57 times more than in 2000. Degraded mangroves occupied an area of 4918 ha in 1996, but this decreased by 999 ha to 3919 ha in 2000. In 1996 the area of grassland was 4674 ha, which decreased to 2419 ha. in 2000. The area of shrimp farms showed a comparatively small (537) ha increase between 1996 and 2000.

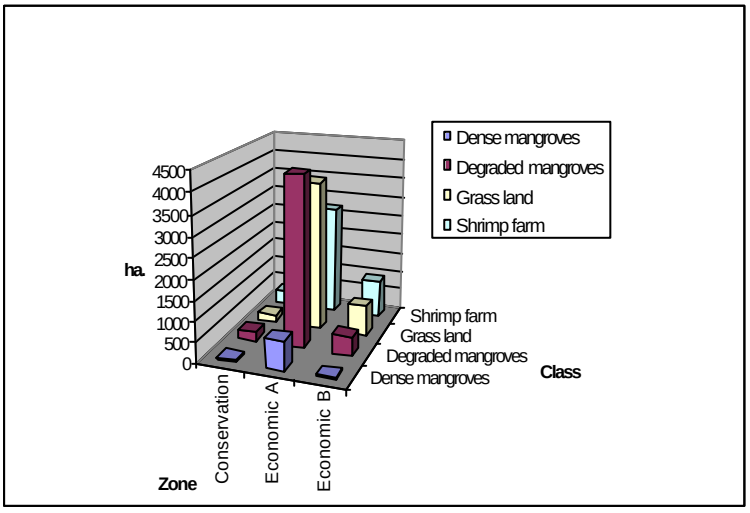

Figure 2. Land c over types of each zone in 1996.

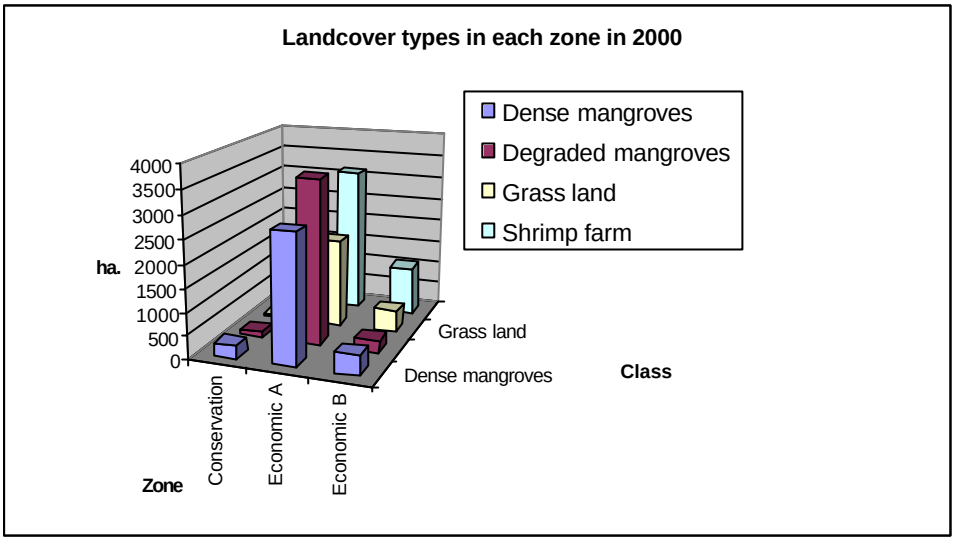

Figure 3. Land cover types of each zone in 2000.

According to Figures 2 and 3, during 1996-2000, mangrove forests are increasing in every commercial zone from 769 ha to 3481 ha., especially in Economic A which increasing from 694.81 ha to 2777 ha while Degraded mangroves and Grassland are decreasing. Shrimp farms seem still increasing in some extent, mostly in Economic B where as 9 ha in Conservation zone, 421 ha in Economic A and 106 ha in Economic B.

Land cover types in the study area were divided into four classes: 1) Dense mangroves, 2) Degraded mangroves, 3) Grassland, and 4) Shrimp farms. During the three years period from the beginning of the MRP (1996-2000), the areas of these land cover types changed as follows:

The area of **dense mangroves** increased dramatically in every zone: in Conservation zone (zone C) from 49 ha to 280ha, in Economic A (zone Ea) from 695ha to 2,778 ha and in Economic B (zone Eb) from 25 ha to 424 ha The area of **degraded mangroves** declined as follows: in zone C from 230ha to 116ha, in zone Ea from 4214 ha to 3,546 ha and in zone Eb from 474 ha to 256 ha. The area of **grassland** also declined: in zone C from 185ha to 63ha, in zone Ea from 3,739 ha to 1,889 ha, and Eb from 750 ha to 467 ha. The area of **shrimp farm** slightly increased, by 3.7% of the total study area. This increase was distributed as follows: in zone C from 368 ha to 377 ha, in zone Ea from 2,746 ha to 3,168 ha, and in zone Eb from 4,058 ha to 4,595 ha.

Although there has been some increase in the area of shrimp farms, land cover change data from the two classified images indicate that that the Mangrove Rehabilitation Program is already proving successful in its aim of increasing the mangrove forest area.

4. CONCLUSIONS

This research shows that information from remotely sensed data can benefit the MRP by providing the needed data for GIS to support the decision-making process.

The results show that the project is successful in conserving the existing mangroves area, increase the areas of mangroves by establishing new mangrove trees plantations.

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