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Full Paper

Geographical information system assessment of mangrove area changes under state versus community management in two communities in Trang province, southern Thailand

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Abstract: Mangrove forests are decreasing in the Asia-Pacific region. The objective of this study is to evaluate and compare the changes of two mangrove areas, one being a state forest and the other a community forest. Multitemporal Landsat data of 1988 and 2004 were employed to classify land use/land cover. Remote sensing and geographical information system (GIS) techniques were used to determine the change of the mangrove areas over the 1988-2004 time period.

Keywords: mangrove forest, remote sensing, geographical information system (GIS), community management, Trang province, Thailand

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INTRODUCTION

A mangrove forest provides numerous ecological services including nursery habitat for many wildlife species, biodiversity and nutrient cycling [1]. In addition, the forest plays critical roles in protecting against or reducing both infrequent disturbances (e.g. tsunami) and chronic disturbances (e.g. climate change) [2]. It was revealed that Indo-Pacific mangroves are among the most carbon-rich forests in the tropical zone, containing on average 1,023 Mg carbon per hectare [3]. However, mangrove forests are disappearing by 1-2% per year worldwide, and more rapidly in developing countries, where over 90% of the world's mangroves are located [1]. Over the past half century, the areas of mangrove forest have declined by 30-50% as a result of coastal area conversion and over-cutting. Mangrove deforestation influences global climate change by increasing carbon emissions with consequent increae in global temperature. Currently, deforestation accounts for 8-20% of global carbon dioxide emissions, second only to fossil fuel combustion [3].

In southern Thailand, the degradation of mangrove forests has motivated local communities to establish community forests in their locality [4-6]. Locally-initiated forest conservation can lead to successful conservation outcomes [7-12]. The main objective of community management is to sustainably utilise, protect and manage mangrove resources. Evaluation on the effectiveness of community management is important for all stakeholders because it provides information on whether community management achieves its objective of better condition and sustainability. Generally, the effectiveness of management practices can be evaluated by comparing quantitative data, e.g. income and abundance and condition of resources before and after implementation of the project [13]. However, there are a few studies that evaluate the effectiveness of local community in sustainably managing and protecting mangrove forests in Thailand [6, 14].

Satellite images provide data to gauge the outcomes of management. They are also useful in assessing the coastal resources and monitoring the land use or land cover changes in coastal area [15, 16]. Data from satellite images allow an efficient, rapid and low-cost analysis of a region [17]. Using multitemporal satellite data, researchers can compare land cover change of areas that might lack historical, ground-based data. Satellite data, therefore, have been used in mangrove studies especially for mangrove inventory and mapping, change detection and management purposes [18-20].

In this study, multitemporal Landsat data of 1988 and 2004 were employed and analysed through remote sensing (RS) and geographical information system (GIS) techniques to find the changes occurring in two mangrove areas located in Trang province, southern Thailand, one being under state management and the other being under community management. The former, a state mangrove forest, is owned and managed by the state, and the communities have limited or no right to utilise or manage its resources. The latter, a community forest, refers to that for which a locally-derived formal governance structure is developed to manage, protect and utilise the forest resources.

STUDY SITES

Trang province is located in southern Thailand between 7°15′-7°45′ N and 99°15′-99°45′ E on the coast of Andaman Sea (Figure 1). The climate is tropical with seasonal monsoon and a rainy period between June-November with an annual rainfall of 1,830-1861 mm. The annual mean temperature at the study sites is 27.5-27.6°C. Local tides have a semi-diurnal regime with maximum amplitudes of 2.9 m. The mangrove forest covers about 4,918 km^2 in the districts of Sikao, Kantang, Yan Takao and Palian. The dominant genera of these mangroves are *Rhizophora*, *Ceriops* and *Bruguiera* [6].

Tong Tasae village and Tab Jak village are small rural communities located at Yan Takao district, the landward site from Andaman coastal area. Most of the villagers are Muslims. The village area is surrounded by mangrove forest (Figure 1). Thus, mangrove resources are significant for villagers who have long depended on these resources. Villagers still continue to use mangrove wood for various domestic purposes. In addition, they catch aquatic animals for daily household consumption and sell them at the local market for income [6].

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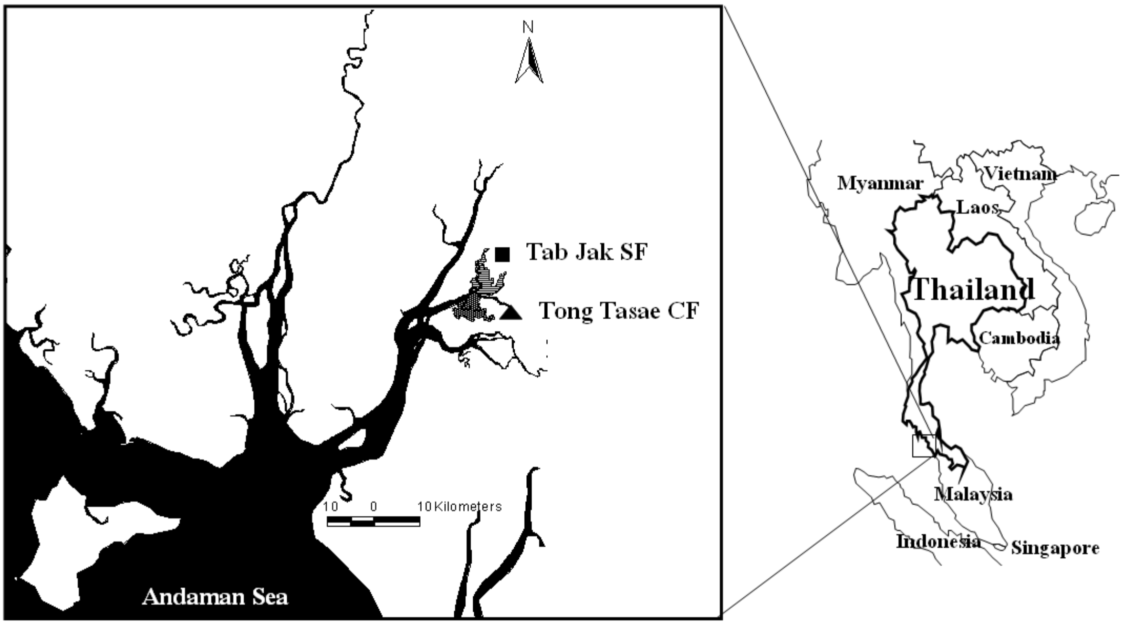

Figure 1. Map of Tong Tasae community forest (CF) and Tab Jak state forest (SF) located at landward site in Trang province

There are clear differences in institutional arrangements between Tong Tasae community forest and Tab Jak state forest [6]. At Tab Jak state forest, the state manages the mangrove without sharing responsibility with the local community. Wood cutting is prohibited by state law. The forestry officers and police have the authority to arrest violators and punishment is applied according to the state law [6]. At Tong Tasae village, membership of the community forest user group (CFUG) is open to anyone in the village who verbally expresses an interest in membership during a CFUG meeting. Membership in the CFUG provides more harvesting rights to the member, but requires participation in rehabilitation (mangrove replanting projects) and monitoring. The mangrove community forest committee (MCFC) consists of CFUG members who are selected for leadership by the group. Rules governing use, management, protection and sanctions are created by the MCFC. Members of the CFUG can seek approval to cut timber for house construction, and a CFUG member has to replant five mangrove seedlings for each tree cut. Forest monitoring in Tong Tasae community forest has been done by the CFUG since the establishment of the forest. During the initial stages of the community forest establishment (3-4 years), the forest was not visited on a daily basis by CFUG members and therefore required intensive patrolling by the MCFC. Afterwards, monitoring became informal and occurred only when CFUG members would access the forest to harvest products [6].

To prevent inappropriate harvesting, signboards were erected at Tong Tasae providing the basic rules and sanctioning system of the CFUG. When illegal activities were observed, the CFUG member would report to the MCFC, who would send 2-3 MCFC members to open a dialogue with the violator and the leader of other village (if the violator lived outside the village) to explain the rules of the community forest. According to our interviews, in all cases this prevented further encroachment into the forest by non-village members. Moreover, the MCFC set up rehabilitation activities to improve the condition of mangrove forest including replantation of mangrove seedlings collected from the forest and weeding of climbers and unwanted shrubs [6].

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METHODS

In this study, RS and GIS were applied to detect the change of mangrove areas at the two villages over a 16-year period (1988-2004). The processing for mangrove change detection was conducted step by step as schemed in Figure 2. The RS-GIS processing was performed by Environment for Visualising Images (ENVI) and ArcView GIS software.

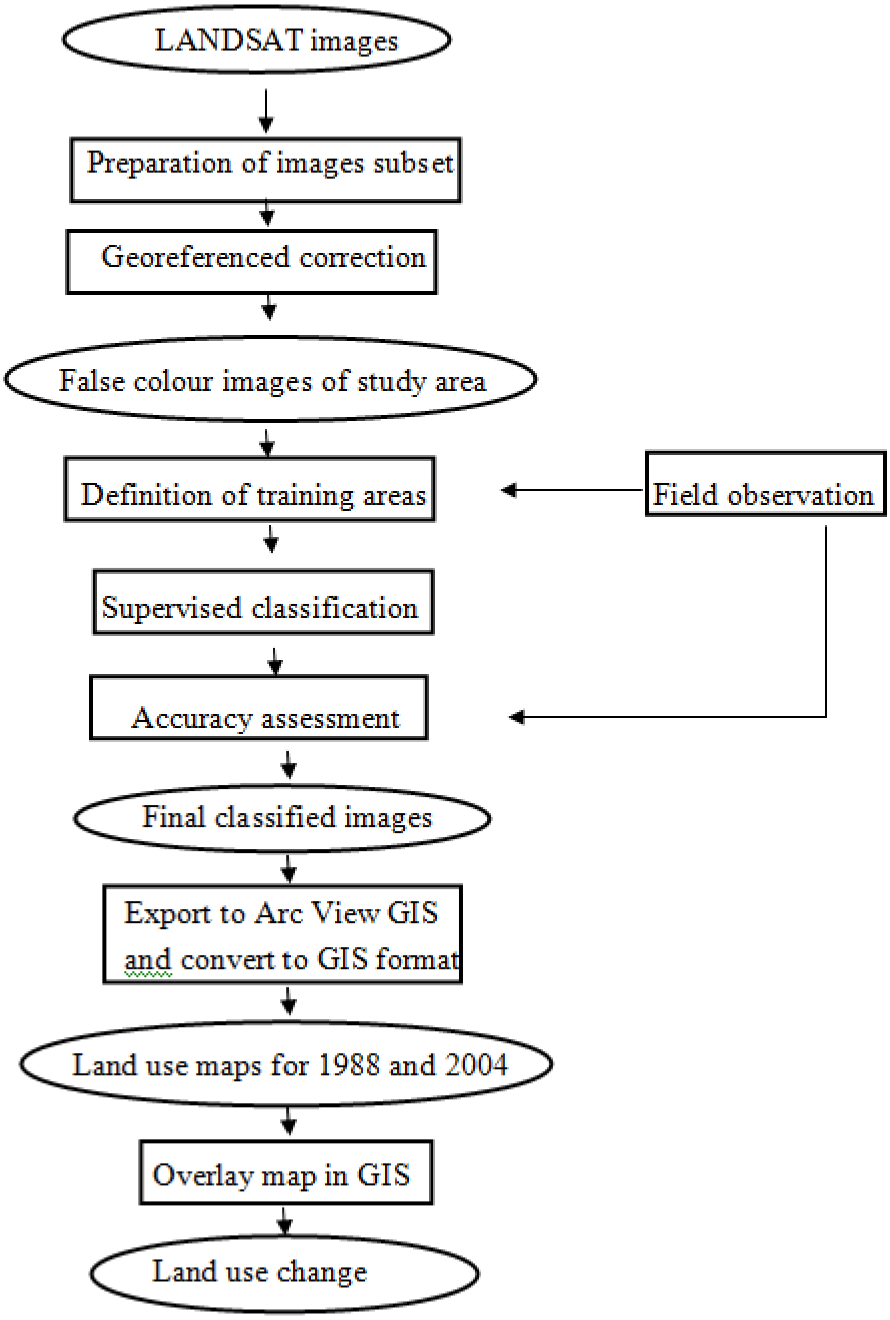

Figure 2. Procedure in mangrove area change detection

Data Used

Landsat Thematic Mapper imageries provided by Geo-Informatics and Space Technology Development Agency (GISTDA) were used in this study. The Landsat data for February 1988 and March 2004 were acquired (Figure 3). Of the seven spectral bands, one visible red band (band 3;

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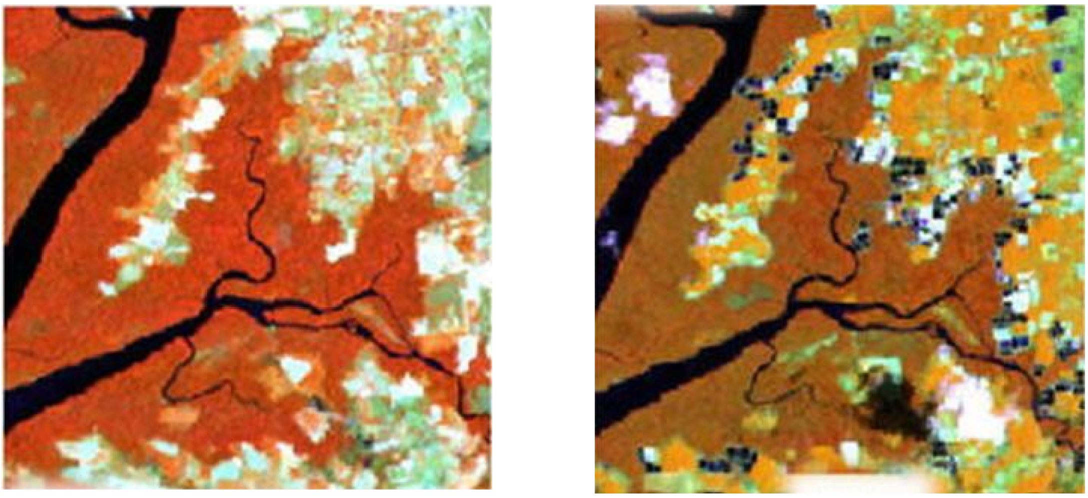
0.63-0.69 µm), a near infrared band (band 4; 0.76-0.90 µm) and a mid-infrared band (band 5; 1.55-1.74 µm) were selected because of their vegetation/land cover characterisation. In the classification process, the combination of those bands (False Colour Composite: RGB453) was used to separate mangrove forest from terrestrial forest.



(a) 1988 (b) 2004

Figure 3. False colour composite of LANDSAT images (RGB 453)

Georeferenced Correction

Due to the large size of original images, a subset image was prepared and georeferenced in ENVI. Seventeen ground control points were selected in the imagers and registered with the reference maps, which were digital topographic maps from the Royal Thai Survey Department at 1:50,000. A residual mean square error of less than 0.5 pixel was accepted for the polynomial transformation and nearest neighborhood resampling.

Field Observation and Delineation of Study Areas

Global positioning system (GPS)-guided field investigations were conducted during March and May 2005. The field survey supported the interpretation in classification and provided independent reference data for the accuracy assessment. Moreover, the delineation of the study areas by GPS tracking was conducted along with field observation.

Study Areas Delineation

The vector data from GPS tracking were used to delineate the areas of the state and community forests. Each subimage of the study areas from large images was performed by using ENVI system for future classification processing.

Supervised Classification

To produce land use maps for 1988 and 2004 and determine mangrove changes that occurred over the period, a supervised classification was performed by the maximum likelihood algorithm [21]. Training areas were selected based on digital topographic maps and information gathered during the field trips. The mean of spectral reflectance and their standard deviation were considered for the homogeneity of each training area. Forty to one hundred pixels of each training area were used to define the following land use/land cover: mangrove, shrimp farm, scrub and grassland, agricultural area and development area. All activities related to image processing were performed in ENVI.

Accuracy Assessment

The accuracy of land use/land cover classification was assessed by comparing the geographical data derived from ground survey with the image classification output. Accuracy estimates were prepared from the error matrix. The precision of classification was estimated by applying the kappa coefficient K (= observed accuracy – chance agreement/1 – chance agreement), which ranges from -1.0 to 1.0. When the kappa coefficient was closed to 1.0, it was interpreted that the classification process was better than random classification [17]. Seventy-two random reference points were compared to verify the classification of land use map. The overall classification accuracy and kappa coefficient were 72.8% and 0.7 respectively.

Image Conversion and GIS Database

The final classified images were then converted from ENVI raster maps into the vector format and exported for GIS procedure. The land use polygon themes for 1988 and 2004 were produced by Arc View software.

Detection of Land Use Changes

All land use themes for 1988 and 2004, derived from Landsat image classification and subsequent GIS analysis, were overlaid in ArcView to assess land use/land cover changes in the state and community forests.

RESULTS AND DISCUSSION

The land use maps of state and community forests for 1988 and 2004 are presented in Figures 4 and 5. Area estimates for each land use class are shown in Tables 1 and 2. Considering the patterns of land use change in the landward site, the land use maps show the distribution of shrimp ponds along the outer edge of Tab Jak state forest. Some shrimp ponds are also located in the core zone of the state forest. In Tong Tasae community forest, the land use maps also show degraded mangrove areas along the boundary of the forest. However, there are no shrimp farms and the mangrove area remains more or less constant in the community forest while a decline of mangrove area occurs in the state forest. The GIS analysis shows a decline of 7.2% of the mangrove area in Tab Jak state forest over the 16-year period, whereas the Tong Tasae community forest increased 0.85% over the same period. It should be noted that the proportional loss of mangrove in Tab Jak was nearly 10 times as much compared to that in Tong Tasae.

Shrimp farms operated in Tab Jak were small scale, intensive and high-productive systems with an average of 2 or 3 ponds with each pond being 1 hectare in size. At the beginning of shrimp culture in these areas, local people operated shrimp farms in their private estates located near the mangrove forest. Since they had only small area to operate shrimp farms, expansion of shrimp ponds into the mangrove adjacent to the farm was quite a common strategy to enlarge their business.

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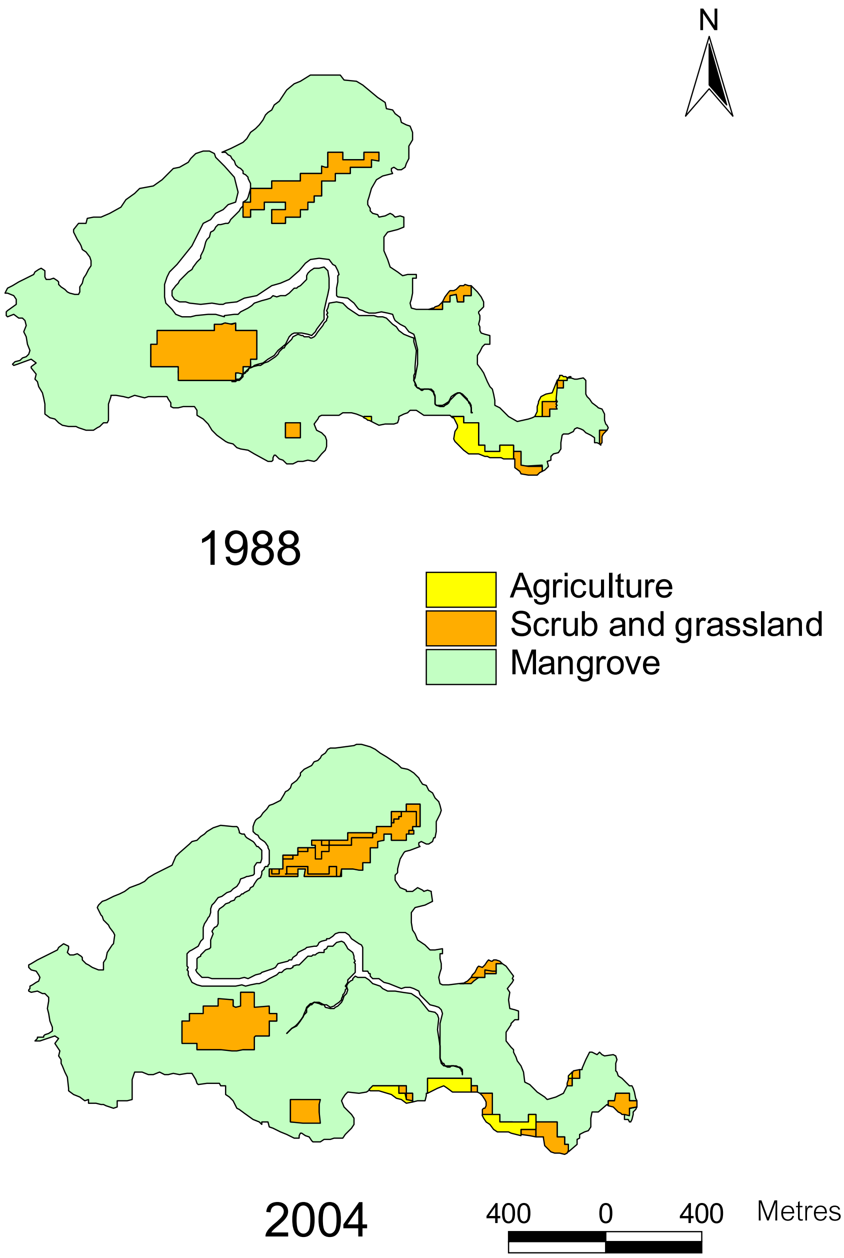

Figure 4. Land use maps of Tong Tasae community forest in1988 and 2004

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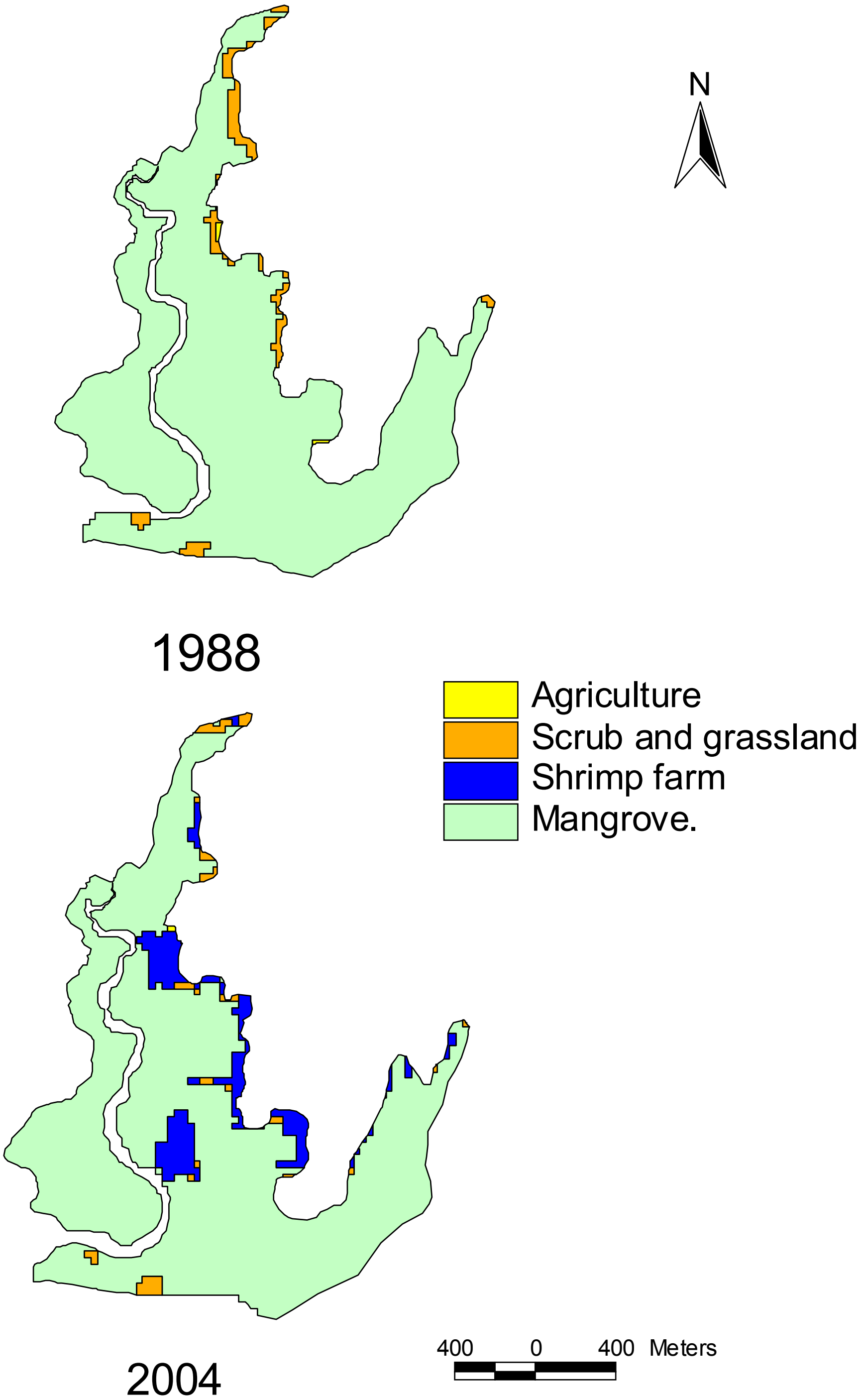

Figure 5. Land use maps of Tab Jak state forest in 1988 and 2004

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Table 1. Land use change in Tong Tasae community forest between 1988 and 2004

	1988		2004		Change (1988-2004)	
	Ha.	%	Ha.	%	Ha.	%
Mangrove	177.88	84.61	179.40	85.33	+1.52	+0.85
Shrimp farm	0.00	0.00	0.00	0.00		
Scrub and Grassland	15.51	7.38	17.47	8.31	+1.96	+12.64
Agriculture	2.38	1.13	2.37	1.13	-0.01	-0.42
Development area	14.47	6.88	11.00	5.23	-3.47	-23.98
Total	210.24		210.24			

Table 2. Land use change in Tab Jak state forest between 1988 and 2004

	1988		2004		Change (1988-2004)	
	Ha.	%	Ha.	%	Ha.	%
Mangrove	208.57	90.57	193.61	84.07	-14.96	-7.17
Shrimp farm	0.00	0.00	16.35	7.10	+16.35	
Scrub and Grassland	7.41	3.22	4.33	1.88	-3.08	-41.57
Agriculture	0.35	0.15	0.08	0.03	-0.27	-77.14
Development area	13.96	6.06	15.92	6.91	1.96	+14.04
Total	230.29		230.29			

Mangrove conversion to shrimp ponds as in Tab Jak also occurs in other parts of Thailand. Up to 50%-60% of mangroves in Thailand have been converted to shrimp ponds [22]. Shrimp farming in Thailand increased significantly during 1983-1996 in response to increasing global shrimp demand. However, shrimp farming in Thailand is short term and unsustainable. More than 80% of the farm are abandoned after 5-6 years of operation as a result of water quality and disease problems as well as lack of knowledge in shrimp culture techniques [23]. During 1983-1996, shrimp farms expanded every year to replace abandoned ones. As a result, the shrimp culture activities caused a permanent loss of 50-60% of mangroves in Thailand [24].

Unchanged mangrove areas in community forests, on the other hand, suggest a positive impact of community management activities for mangrove protection. Many studies indicate that the forest cover/condition has improved under the management of community forest [8, 14, 25, 26,]. To cite an example, the area of mangrove in Laem Makham community forest increased by 0.8 hectare (4.7%) over the period 1988–2004 while that in To Ban state forest was reduced by 7.8 hectares (13.6%) over the same period, most of the degraded mangrove in the state forest being replaced by shrimp ponds [14].

The differences in the change in mangrove areas of the two types of forest clearly stem from differences in management practices. Based on the community forest rules, all activities that degrade mangrove forest or convert the forest to other forms of land use are totally banned in the community forest [6]. In this study, shrimp ponds were not found in Tong Tasae community forest area, but they were found in the surrounding area of the community forest. The CFUG of Tong Tasae apparently played the key role in monitoring and protecting the forest from violators. It also employed graduated sanction with higher punishment for repeated violators [6]. Living and working near the mangrove area, local people have an advantage in monitoring resource use over government agents operating in the state forest. Thus, the sustainability of mangrove community forests reflect the effectiveness of community management towards mangrove protection.

CONCLUSIONS

This study provides another example of a successful local management regime for protecting against mangrove deforestation. Therefore, the prevention of mangrove deforestation by way of a community forest should be seriously considered and applied as an important alternative management tool.

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