FINAL REPORT

MANGROVE FOREST STRUCTURE AND COVERAGE CHANGE ANALYSIS USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM TECHNOLLGY A CASE STUDY OF CAN GIO MANGROVE BIOSPHERE RESERVE, HO CHI MINH CITY, VIET NAM

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Content

Chapter I

Introduction

Vietnam is the peninsula (Indochinese Peninsula) with 3260 km long coastline. It has 8 International Biosphere Reserves, in which there are 7 lying in the long coastal, and rich coastal natural resources including mangroves.

It is well known that the mangrove ecosystem plays important roles in coastal regions by its functions which include supplying food and fuel wood for humans and natural protection against erosion and preventing storms, sea level rise etc. Moreover, mangrove ecosystem has become one of the key factors in considering the global warming issue and thus mangrove ecosystem is becoming increasingly important.

Thus, the management, protection and development for this coastal natural resources are extremely neccessary. However, mangrove management is quite a complex undertaking because of its geographic conditions and many other conditions.

Satellite remote sensing (satellite images) can provide basic data for these purposes. In this study, the effectiveness of satellite data for classifying and mapping of mangrove forests is reported as an example of their application for mangrove management.

Can Gio Mangrove forest in Ho Chi Minh City in Vietnam was selected for the study because well-developed mangrove habitats are currently widely observed in spite of the serious damage suffered during the Vietnam War. There are some 58,000 people living within the biosphere reserve boundaries, 54,000 of which live in the transition area. Specially, on January 21st, 2000, MAB/UNESCO committee recognized Can Gio mangrove forest as an International Biosphere Reserve. It is my origin for this study

At present, Can Gio Biosphere Reserves is being protected and developed. The application of remote sensing technology in forest study in Vietnam only limitted the building of land cover maps. But, the application of this technology to the growth, the development and the inner change of association structure of flora are not interesting. Therefore, this study is really necessary for the management, conservation, rehabilitation and development of Can Gio Biosphere Reserve.

CHAPTER II

Study area

2.1 Physical characteristics

2.1.1. Geography location

Ho Chi Minh City (formerly Saigon) is located about 1,300 km south of Hanoi and includes a mangrove area in Can Gio district. Originally, the name was Can Gio, then, from 1975-1991 it was named Duyen Hai district but on December 18, 1991 it was given back its original name, Can Gio, by the Council of Ministers. Can Gio mangrove forest lies entirely within the Can Gio district of Ho Chi Minh City. The area lies in geographic co-ordinate between 10^{o} 22' 14" N - 10^{o} 40' 00" N Latitude and 106^{o} 46’12’’ - 107^{o} 00' 59" E Longitude (Fig.2.1). It shares its boundary with Nha Be District in the North***;*** with East Sea (South China Sea) in the South***;*** with Dong Nai and Ba Ria – Vung Tau Provinces in the East and with Long An and Tien Giang Provinces in the West.

Fig.2.1. Location of the study area

It is about 65 km south of Ho Chi Minh City. It is one of 18 districts of Ho Chi Minh City and covers an area of 73,361 ha. From the north to the south it covers a distance of 35 km and at the middle portion, is about 30 km wide. A network of rivers and channels traverses the delta and the main waterways leading to the port of HCMC.

From 1964-1970, Can Gio District, like many other mangrove areas, was sprayed heavily with herbicides: 665,666 gallons of Agent Orange, 343,385 gallons of Agent White and 49,200 gallons of Agent Blue. As a result, 57% of the mangrove forest in this district was destroyed (Ross 1975). In some areas large trees of *Rhizophora, Sonneratia*, and *Bruguiera* were killed by the herbicides spraying and in many areas the vegetation was completely destroyed. Only *Avicennia* and *Nypa* were able to survive and regenerate after the application of herbicides. And new species such as *Phoenix paludosa* and *Acrostichum aureum*, a fern which presently dominates elevated land, have expanded. Some individual trees of *Avicennia officinalis* and *Excoecaria agallocha* are now found only as shrubs. After many years of chemical spraying, the degraded land still has only scattered small trees of *Avicennia*, *Ceriops, Lumnitzera, Thesphesia, Pluchea,* or *Sesuvium portulacastrum* and *Paspalum vaginatum*. Since 1978, a vast programme of reforestation has been undertaken by Ho Chi Minh City Forestry Department with the main species being *Rhizophora apiculata*. Up to now, the reforestation effort has brought vast ecological improvements to the environment. Wild animals such as monkeys, otters, pythons, wild boars, crocodiles and various kinds of birds have returned to the artificially regenerated mangrove forests. Since 1991, the Can Gio mangrove forest has been declared an "Environmental Protection Forest" by the Council of Ministers (Decree No. 173 CT/H date May 29, 1991).

2.1.2. Terrain

Topographically, the Can Gio mangrove forest forms a basin with a minimum altitude range of 0 m – 1.5 m, in the northeastern sector of the forest, with downward inclines from the east, south and west. Giong Chua Hill, in Compartment 14, is the highest point in the forest, with a maximum altitude of 10.1 m. According to Vien Ngoc Nam (1994), the terrain can be divided into the categories (Table 2.1).

Table 2.1: Altitude of Terrain form of Can Gio

Terrain form	Altitude (m)
1. Flooded twice daily	0.0 – 0.2
2. Flooded once daily	0.2 – 0.5
3. Susceptible to spring tide flooding (monthly)	0.5 – 1.0
4. Floods at occasionally high spring tides (yearly)	1 – 1.5
5. Prone to very occasional flooding	> 1.5

2.1.3. Soil

The Can Gio mangrove forest developed out of a comparatively recent brackish swamp, as the alluvium from the Sai Gon and Dong Nai rivers created the soil foundation. The development of such a mangrove forest is dependent on high precipitation and a high density of rivers interweaving the area, providing a rich and plentiful supply of alluvium in the estuarine regions. The soil that has been formed in Can Gio has been created by a combination of clay alluvial deposition, vitriolic processes and a brackish water table. Four main soil types can be found here: Saline soil; Saline soil, with low alum content; Saline soil, with high alum content and soft sandy soil, with mud deposits at the seashore

The Can Gio soil types are somewhat limiting for human use. The deeper soil layers are as yet highly un-compacted thus unable to provide solid foundation; they have high content of various sulfur oxides, which are detrimental to agriculture, and a high NaCl salt content.

2.1.4. Climate

High humidity and temperatures, in general, characterize the climate of Can Gio mangrove forest. There are two seasons and the area is affected by equatorial monsoons; rainy season: from May to October and dry season: from November to April.

Precipitation: Precipitation in Can Gio is the lowest in the Ho Chi Minh City area, with an average range of 1300 – 1400 mm per annum.

Temperature: The daily average temperature amplitude is 5^oC – 7^oC, but less than 4^oC over a month. The monthly average temperatures are at their highest from March to May, and at their lowest form December to January. The yearly average temperature is 25.8^oC, measured at the Do Hoa gauging station. There is very slight temperature decrease from north to south, which is barely perceptible.

Radiation: The daily average radiation is always above 300cal/cm^2/day. The maximum monthly average occurs in March, at 14.2 Kcal/cm^2/month. There is a noticeable decline, particularly between the periods from September to December, in the monthly amounts of radiation, from 14 Kcal/cm^2/month to 10 Kcal/cm^2/month.

Wind: There are two main wind directions:

- Between May and October, during the rainy season, there is a south-southwesterly wind, which is at it is strongest during July and August.
- Between November and April during the dry season, a north-northeasterly wind blows, which is at its strongest in February and March.

Humidity and evaporation: The humidity in Can Gio is about 4% - 8% higher than in other areas of Ho Chi Minh City. During the rainy season, humidity ranges from 79% - 83%, with a maximum of 83% in September. In the dry season, humidity ranges from 74%-77%, with a minimum of 74% in April. The average extent of evaporation is 4 mm/day, and 120.4 mm/month. Evaporation is at its highest in June (173.2 mm/month) and at its lowest in September (83.4 mm/month).

2.1.5. Hydrological system

Can Gio District have a complex and convoluted network of rivers (Table 2.2). Freshwater sources originate from the Sai Gon and Dong Nai river, emptying out via the Long Tau and Soai Rap rivers (the main branches) and also via subordinate branches such as the Thi Vai at its estuary, Go Gia. There is a considerable mixing of saline and fresh water at the two main estuaries: Dong Tranh Bay and Ganh Rai Bay. River covers an area of 31.76% of the total area of Can Gio district. Long Tau River is the main shipping waterway, allowing ships of less than 20,000 tonnes carrying capacity to enter Sai Gon port.

Table 2.2: The main rivers of Can Gio

River	Length (km)	Width (km)	Depth (m)
Nha Be	29.50	1.670	10-20
Soai Rap	14.50	3.100	<10
Dong Tranh	67.50	1.800	01-25
Long Tau	32.00	0.550	10-25
Nga Bay	10.00	0.900	10-30
Go Gia	12.00	0.600	10-20

The majority of there rivers flow in a general southeasterly direction; their courses affect the local topography, and a change in vegetation. Long Tau and Soai Rap rivers, the two main terminal branches, effect to the hydrographic regime of other subsidiary branches.

2.1.6. Tidal regime

The Can Gio mangrove forest lies in a zone with a bi-diurnal tidal regime (i.e. two ebb and flow tides per day). Tidal amplitudes range from about 2 m at mean tide to 4 m during spring tides. It has been observed that the two daily high and low tides differ in height. Maximum tidal amplitudes, in the region of 4.0 – 4.2 m are the highest observed in the whole of Viet Nam. Tidal amplitude decreases with distance north (i.e. inland), relating to the proximity of the Bien Dong Sea (South China Sea). High tides reach their maximum between September and January, at 3.6 - 4.1 m in the southern and 2.8 - 3.3 m in the northern regions of Can Gio. In Can Gio, the maximum high tide occurs in October or November, and the minimum in April or May. Between the 29^{th} and 3^{rd} day of the month (lunar calendar) and between the 14^{th} and 18^{th} day of the month, the whole of the Can Gio mangrove forest is flooded at high tide (twice a day). On the 8^{th} and 25^{th} day of the month the low tide is at its minimum.

2.1.7. Salinity

According to data collected to between 1977 - 2000, river and coastal water is most saline during high tide and least saline during low tide. Fluctuation in salinity correlates directly with the combined effects of the tidal regime and the currents of the Sai Gon and Dong Nai rivers. Around the month of April marine waters are more dominant in sea-river interaction such that the marine waters penetrate further inland, thereby increasing salinity levels in the forest. The converse is true during the months of September and October, when the rivers play a more dominant role in sea-river interaction, depressing salinity levels as marine waters are washed out to sea.

The introduction of the Tri An hydroelectric enterprise has affected the salinity of the Can Gio region considerable. In the dry season, salinity has decreased compared to level measured in April prior to 1993. At Nha Be (inland), whereas before 1993 salinity was 4-6 ppt. in April, today it is only 4ppt; and further south, at Tam Thon Hiep (near the sea), only 18 ‰.

In the rainy season, however, salinity has increased, due to the controlled outlet of water from Tri An. The forms of the Soai Rap and Long Bau rivers differ, thus the rivers are affected to different extents by the tidal regime. As the Soai Rap river has a shallow cross-section, the tidal impact of the South China Sea is less than on the deeper Long Tau river, hence its salinity is lower.

2.2. Mangrove Forests in Can Gio District

2.2.1. Can Gio mangrove before the onset of chemical warfare

Prior to April 30th 1975, Can Gio mangrove forest covered an area of 40.000 ha; the canopy was dense, with trees over 25 m tall and 25 – 40 cm diameter. *Rhizophora apiculata* constituted the main part of the flora, together with other assemblages of *Sonneratia alba, Avicennia alba, Rhizophora mucronata, Bruguiera* spp., *Xylocarpus* spp., *Lumnitzera* spp., *Phoenix paludosa, Excoecaria agallocha,* etc.

The Can Gio mangrove forest includes several basaltic hills such as Pagoda Hill (Gong Chua), Pond Hill (Giong Ao), etc. The flora on these formations was the same as that found further inland in the mangrove forest, but also included tropical rainforest tree species.

From 1911, French colonist planned 4000 ha of Can Gio mangrove to protect the air quality around Sai Gon and 500 ha surrounding commune's areas to protect against typhoons and prevent soil erosion; the remaining area was considered as reserve exploitation forest to provide timber and firewood for the region. In 1917, forest regulations were such that land exploitation was issued. Because of desperate circumstances of unemployment and poor transportation, exploitation was rampant due to market demand for *Rhizophora apiculata, R. mucronata* & *Ceriops* spp., the forest became exhausted, the structure and the nature of the indigenous tree assemblages changed until they were quite different from those of the original forest.

Under Sai Gon regime, Sai Gon – Gia Dinh Hydraulic Forestry Department managed 31,910.46 ha of mangrove, of which only 28,096 ha belong to Can Gio district today, including the interdict forest of Quang Xuyen and Can Gio district.

2.2.2 Influence of Chemical Warfare and Status of the Can Gio Mangrove Forest until April 30th 1975

In 1964, during initial acts of chemical warfare, herbicides were sprayed by US army along an axis formed by the Long Tau river, to width of 200 m on either side of the river. From 1965 to 1970 the area was repeatedly sprayed from the air. The consequence was the almost complete destruction of the Can Gio mangrove forest.

Although trees remained standing following spraying, they were not merely defoliated but were actually dead. Different from Ca Mau herbicides affected areas, the dead tree was remained in Can Gio after a short duration; local people collected the dead tree and left the barren soil. During the 1970s, the Can Gio mangrove forests suffered almost complete destruction. The species *Rhizophora apiculata, Rhizophora mucronata,* virtually disappeared. The trees the remaining were small groups of *Ceriops tagal* and *Excoecaria agallocha* in a state of regeneration along the waterways; in tidal flooded areas *Avicenniaceae;* on highter land *Phoenix paludosa, Acrostichum aureum, Gymnanthera nitida, Derris trifoliata, Azima sarmentosa, Pluchea indian,* and *Clerodendrum inerme.* Due to their rapid regeneration soon densely covered the barren land surfaces, hindering a blanced process of forest regeneration.

After 1975, Ho Chi Minh City (HCMC) planted more than 20,000 ha of *Rhizophora apiculata* in Can Gio District to restore the mangrove ecosystem and ensure that the mangrove forest would serve its dual functions of protecting the environment and providing wood fuels, construction materials and other products By declaring this area an environmental protection forest the protective function has now been given the highest priority. However, because no privately owned forests exist, the large demand for wood fuels still exerts great pressure on state forest resources, including mangroves. Furthermore, the establishment of shrimp ponds in mangrove areas has increased rapidly, often causing considerable damage to the mangrove forest ecosystem. The aims of this study are therefore:

a) To bring about an improved understanding of the mangrove forest ecosystem in Can Gio;

b) To identify a suitable way of managing mangrove forests in order to satisfy their multiple functions. Protection of the coastline against tidal waves and storms, production of wood and non-wood products for employment and income generation, as well as maintenance of the ecological balance in the estuaries, thereby protecting the breeding grounds and ensuring a sustainable catch of economically important offshore fish and shrimps;

c) To identify and propose a salvo-fishery plan for the Can Gio mangrove forest which will control the maximum surface area used for shrimp ponds and avoid damaging the environment;

d) To contribute to reducing the fuel wood deficit for Can Gio in habitants by introducing a portable improved cook stove to replace the common traditional "three stone fire". This should help reduce the illegal exploitation of mangrove forest and improve the economy of the mangrove residents;

e) To explore in further detail the socio-economic conditions of mangrove dwellers, with specific attention to gender issues.

2.3. The Can Gio mangrove Biosphere Reserve

After 22 years of rehabilitation and development by the hard efforts of Ho Chi Minh city commitee and people, Can Gio forest become the largest replanted mangrove area in Viet Nam with a beautiful natural landscape and diversity of both flora and fauna. This significant fact led to it is recognition by MAB/UNESCO Committee on January 21, 2000, as an International Mangrove Biosphere Reserve. This is the first biosphere reserve in Viet Nam. Like other biosphere reserves in internation biosphere reserve network, Can Gio Mangrove Biosphere Reserve combines three funtions:

- ♦ ***Conservation:*** Contributes to the diversity of landscapes, ecosystems, species and genes.
- ♦ ***Development:*** Stimulates economic development based on sustainable environment and culture.
- ♦ ***Assistance:*** Enables research, monitoring, training and education about sustainable conservation and development at local, national, regional and international levels.

- **Flora and Fauna**

About 105 plant species, belonging to 48 genera (Nam et al. 1990) are found in Can Gio mangrove forest, including *Rhizophora apiculata, Bruguiera gymnorrhiza, Bruguiera parviflora, Ceriops sp, Kandelia candel, Rhizophora mucronata, Sonneratia alba, Sonneratia ovata, Sonneratia casedar, Avicennia alba, A. officinalis, A. lanata* (stunted trees in abandoned salt fields), *Aegiceras majus, Thespesia populnea, Hibiscus tiliaceus, Lumnitzera racemose, Xylocarpus granatum,* and *Excoecaria agallocha.*

There are about 150 known species of aquatic fauna. The fish fauna is very abundant since mangrove forests serve as nurseries as well as sources of foods for many species of fish like *Lates calcarifer* and *Mugil affinis*, prawns such as *Pangasius* spp, *Penaeus* spp., *Metapenaeus* spp., and *Mudcrabs: Scylla serrata.*

Within the area, there is a variety of wildlife such as wild pig (*Sus scrofa*), monkey (*Macaca fascicularis*), otter (*Lutra lutra*), saltwater crocodile (*Crocodylus porosus*), and many species of snakes etc., which are now endangered or have disappeared due to human interference. There are also many birds, including migratory species, some of which are very rare and should be protected.

2.4. Social - Economics condition

One of the main advantages of Can Gio is that it provides the opportunity to work on environmental protection on a continuum of habitats, ranging from the sea to the boundary of Ho Chi Minh City, the biggest industrial city in Vietnam. The mangrove forest is regarded as the "green lungs" of the city. There are some 58,000 people living within the biosphere reserve boundaries, 54,000 of which live in the transition area. The local people are of different origins and there is a mixture of cultures and ways of life. The main economic activities are agriculture, fisheries, aquaculture and salt production. Some families have been allocated with forests for protection for 30 years and they use a small portion of the land for aquaculture and salt production. Other families, engaged in miscellaneous occupations, have no land and must earn their living by catching crabs and molluscs and collecting firewood.

Can Gio is the poorest district of Ho Chi Minh City. It is expected that the Can Gio Mangrove Biosphere Reserve could be a site where sustainable development, conservation and cultural socio-economic activities in sylvo-forestry and fishery management systems can be tested, refined, demonstrated and implemented

CHAPTER III

PROJECT OBJECTIVES METHODOLOGY

3.1. Project objectives

- Land cover type mapping using multi-remote sensing data
- Change detection of land cover in mangrove forest using multi-remote sensing data
- Investigation, evaluation and monitoring of criterions to production and quality of mangrove forest
- Interpretation key of satellite imagery for mangroves forest
- Methodology provide the application of Remote Sensing & GIS technology in mangrove forest study
- Provide recommendations for the use of RS & GIS technology in mangrove forest
- Provide technical training for CGBR's staff on using remote sensing &GIS technology.
- Propose measure to management, conservation, rehabilitation and development of mangrove ecosystem in Can Gio Biosphere Reserve.

3.2. Methodology

3.2.1. Satellite Data and Instruments

3.2.1.1. Satellite data

The change detection technique requires at least two time data. In this project, three data times data use are SPOT 1999, SPOT 2004 and 2009. The details of satellite data used in the present study are given in the (Table 3.1).

Table 3.1 Details of satellite data used in the study

No.	Satellite	Sensor	Date of pass	Total bands	Spectral bands used	Spatial resolution (m)
1	Spot 4	HRV	March 1999	3	1, 2, 3	10
2	Spot 5	HRV	April 2004	3	1, 2, 3	10
3	Spot 5	HRV	March 2009	3	1, 2, 3	10

3.2.1.2. Instruments

The following instruments, software and hardware are used (Table 3.2)

Table 3.2. The instrument and software used

No.	Type	Name	Utility
1	Instrument	GPS: Garmin 12 channel	Collecting ground truth coordinates
2	Hardware	4-MCPU 2.00 GHz, 1.99 GHz, 256 of RAM	Data storage
3	Software	EARDAS IMAGINE 9.0	Image processing and data analysis
3.1		Arc GIS 9.2	Spatial analysis Principal Component Analysis
3.2		MS word	For documental
3.3		MS excel	Data analysis

3.2.1.3. Ancillary data

The survey of Vietnam topographical maps and the scale 1: 250,000/scale 1: 50,000. Can Gio terrain maps sheep on scale 1: 250,000; FCC maps***;*** Population/livestock data and Management plans map.

Image acquisition involves the conversion of a scene into digital representation that can processed by computer. The appropriate selection of image acquisition date is as crucial to the changes detection method as is the choice of the sensors, change category and change detection techniques. The problem has two dimensions: a) season of acquisition and b) temporal resolution of the data involved.

As tree leaves reflect differently at the beginning and the end of the growing season due to phenological and temperatures disparities, their reflectance varies from season to another season or season to season. That is why ideally, change detection procedures should involve data acquired in the same season, same sensor, same time of the day, preferably etc. Unfortunately, because of one or another reason these conditions cannot be adhered to most of change detection studies, and instead, the selection of data acquisition has been determined according to the availability of satellite data of acceptable quality. This study has used the data as; SPOT in 1999, 2004 and 2009.

3.3. Pre-Processing

3.3.1. Radiometric Correction

Radiometric correction addresses variations in the pixel intensities (DNs) that are not cause by the object or scene being scanned. These variations include differing sensitivities or malfunctioning of the detectors, topographic effects and atmospheric effects. First order corrections had done by dark pixel subtraction technique (Lillesand and Kiefer 1999). This technique assumes that there is a high probability that there are at least a few pixels within an image, which should be black (0% reflectance). However, because of atmospheric scattering, the image system records a non-zero DN value at the supposedly dark-shadowed pixel location. This represents the DN value that must subtract from the particular spectral band to remove the first order scattering component (Fig.3.1, Fig.3.2 and Fig.3.3).

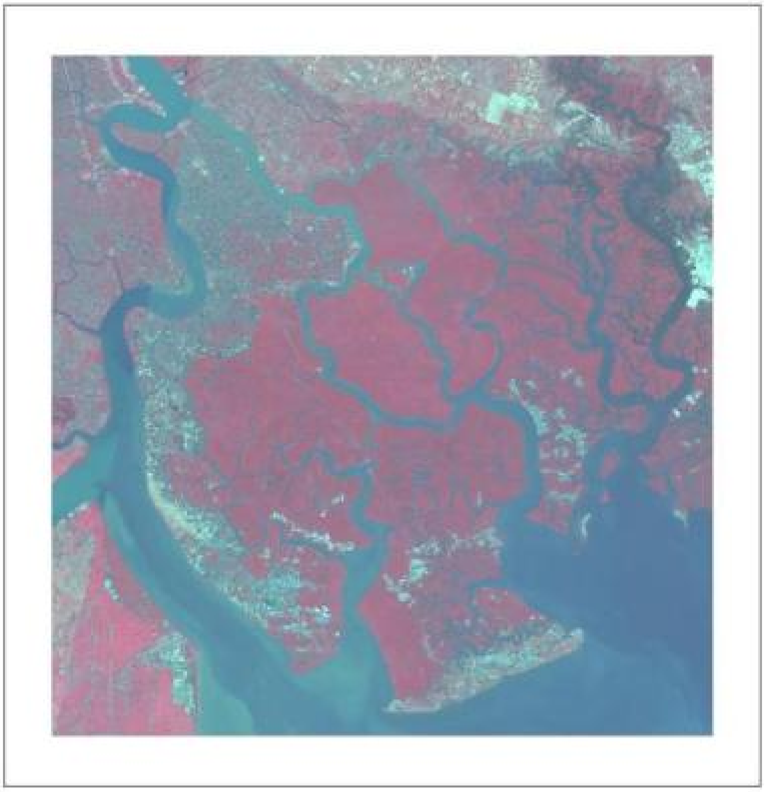


Fig.3.1 False Colour composite of SPOT 1999

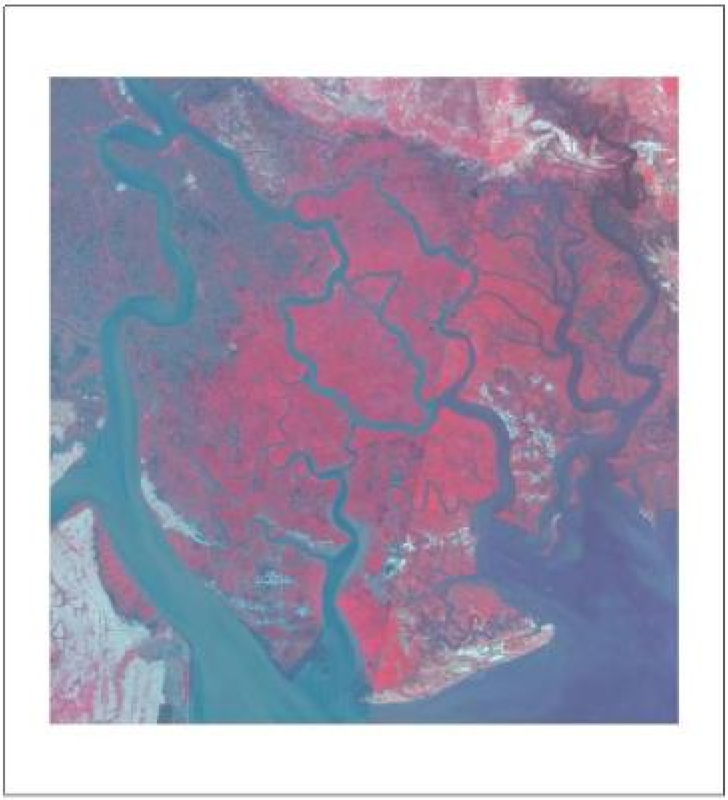


Fig.3.2. False Colour composite of SPOT 2004

Fig.3.3. False Colour composite of SPOT 2009

3.3.2. Geometric Correction

Geometric correction addresses errors in the relative positions of pixels. These errors are inducing by sensor viewing geometry or terrain variations. The common uniformly distributed Ground Control Points (GCPs) were marked with root mean square error of one pixel and the image was re-sampled using nearest neighborhood interpolation method. Both the data sets were then co-registered for further analysis.

3.3.3. Pre - processing

The rectification operation aims to correct distorted images to create a more faithful representation of the original scene. It typically involves the initial processing of raw image data to correct for geometric distortions. The process involves relating GCP coordinate with their map coordinates. This is the most important for geometric correction since each pixel can be represent only by its row and column in a matrix. After rectification completed but it is also rigorously correct in degrees or meters units in a standard map projection. The two basic operations war performed in order to geometrically rectify a remotely sensed image to a map coordinate system:

- The geometric relationship between the input pixel location, and the associated map coordinates of the same point (X, Y) were identified.
- Pixel brightness value must interpolate for rectification.

Identifying GCP in the images and on the reference map and then mathematically modeling the geometric distortion achieve the former. This procedure requires polynomial equations to fit the control point data using least squares criteria to model the correction directly in the image domain without explicitly identifying the source of the distortion.

In each image, 25 GCPs were chosen for rectification and using polynomial equation of first order model and nearest neighbor’s interpolation performed the rectification. Map of the study area was obtained from Forest department. This map was scanned and geo-rectified by identifying well distribute point and x, y coordinate value were fed manually. Resampling was performed. This was again co-registered with available satellite data.

3.3.4. Normalization of the images

Ideally, each material would reflect tremendous amount of energy in certain wavelengths, while other material would reflect differently in the same wavelengths. It could result in contrast between two types of materials when recoded by multi-spectral remote sensing system. However, many land covers have similar spectral response in different part of EMR resulting in a relatively low contrast image. In addition, there are other factors at work. For example, natural building materials as wood, soil, etc. used in urban areas, result in much lower contrast on remotely sensed imagery for such area, where concrete, asphalt and fertilized green vegetation may by more prevalent. Thus, biophysical materials themselves are an important factor and may further confuse the issues by bringing the materials together in diverse ways.

The imaging multi-spectral scanners are designed to accommodate a wide range of scene illumination conditions (e.g. from 0 to 255). Unfortunately, as written above, most of the scenes occupy only a small portion of contrast display, in which similar features are indistinguishable. To produce an image with optimum contrast ratio, it is necessary to use the entire range of brightness display medium. For this purpose, preliminary step is to examine the image histogram, which describes the statistical distribution of grey level in the image in terms of number of pixels having each grey level. Histogram matching was performed among the dataset for normalizing the images. Images were subjected to contrast enhancement procedures before interpretation.

3.3.5. Image Analysis

The accurate image-to-image registration of data is very important before analysis. The accurate spatial registration of the images involved is essential for digital change detection ensuring that identical locations in each scene were compare between two images. As images used for digital change detection are raw remotely sensed data acquired at two different times by two different sensors it is necessary to use geometric rectification algorithm to register the image to each other with the same pixel size and error should be less than 0.5 pixels.

3.3.5.1. Land Cover Classification

From three datasets: SPOT 1999, SPOT 2004 and SPOT 2009. This data chose not so different time, it is advantage and accurate for the change detection methods between two time. This classification makes easily use to mangrove forest manager, it is also conformity with criteria classification in Viet Nam. Classification scheme land covers as:

- Level 1 has six classes: Dense mangrove forest (dense forest), Open mangrove forest (opend forest), Young forest&scrub (young forest and scrub mixed), Agriculture land, Water body, and Barren land.
- Level 2 has three classes:

  - Non-change (the area not change)

- Negative areas change as; *dense forest to open forest, dense forest to scrub, dense forest to agriculture land, dense forest to barren soil, dense forest to water bodies, open forest to scrub, open forest to agriculture land, open forest to barren soil, open forest to water bodies, scrub to agriculture land, scrub to barren soil, scrub to water bodies, agriculture land to water bodies.*

- Positive areas change as; *open forest to dense forest, scrub to dense forest agriculture land to dense forest, water body to dense forest, barren soil to dense forest, scrub to dense forest, scrub to open forest, agriculture land to open forest, scrub, water bodies to dense forest, water bodies to open forest, barren soil to open forest, barren soil to dense forest, barren soil to open forest, barren soil to scrub, barren soil to water body.*

3.3.5.2. Supervised classification approach for Land Cover classification

Supervised classification can defined normally as the process of sample of known identity to classify pixels of unknown identity. Samples of known identity are those pixels located within training areas. Pixels located within these areas term the training samples used to guide the classification algorithm to assigning specific spectral values to appropriate information class. The basic steps involved to typical supervised classification procedure as; Define signatures, Evaluate signatures and Process a supervised classification

3.3.5.2.1. Land Cover classification for 1999

Land Cover classifications for 1999 have six classes: Dense forest, Open forest, Young forest &Scrub, Agriculture land, Water body, and Barren land.

3.3.5.1.2. Land Cover classification for 2004

Land Cover classifications for 2004 have six classes: Dense forest, Open forest, Young forest &Scrub, Agriculture land, Water body, and Barren land.

3.3.5.1.3. Land Cover classification for 2009

Land Cover classifications for 2009 have six classes: Dense forest, Open forest, Young forest &Scrub, Agriculture land, Water body, and Barren land.

3.4. Change detection analysis

The recognition of the changes in area or the region was affected by spatial, spectral, temporal and thematic constraints. One of the positive changes is increase in vegetation, which would result in increase area of Infrared and red reflectance. The method implemented can profoundly affect the qualitative and quantitative estimates of the changes or disturbance. The selection of the appropriate method therefore has considerable significance. Ideally, the change detection procedures should involve data acquired by the same sensor, the same season, having same spatial resolution, viewing geometry, spectral bands and time of the days. Thus, the change detection techniques used for the present study take into account the fact that the study area is a reserve forest and densely populated.

While mapping, earlier scientists and researchers have attempted to use digital satellite data to find changes in land cover (Coppin and Bauer 1994; Howarth and Wickware 1981). They have proposed several procedures for and cover change detection. These procedures could aid in updating resource inventory. Currently, there are many change detection methods that had been implemented and their uses depend on the application. These methods may broadly categorize in to six general classes. In this study three approaches was the Post classification comparison method (based supervised classification).

This procedure is post-classification comparison, based supervised classification temporal dataset. Post classification alternative identifies change by comparing two independently produced classification map (Jakubauskas, 1989). Spectral/temporal change classifications were performed on a single classification on a multiple date dataset. For example, in a two-time dataset with four bands is produce and then was analyze at one time by unsupervised mode. In the supervised method, training sets pertaining to change and no change areas used to derive statistics. In either case, change classes should have significantly different statistics from no change classes. The principal advantage of post classification comparison lies in the fact that the two dates of imagery were separately classified, thereby minimizing the problem of radiometric calibration of two data.

3.5. Field work

Fieldwork is a very important part of the project. Fieldwork helps to check and collect most of the ground information require for mapping (Fig.3.4).

The reconnaissance field survey had undertaken to get acquainted with the general patterns of vegetation of the area. Major vegetation types and few prime localities of characteristic types were record. The variation and tonal patterns had observed on existing images. Traverses along all main roads, trail roads inside forest, dry rivers had made for collecting ground truth between maps/images and on the ground. Various features had identified and correlation with image element was established and noted on forest image (2009) and survey maps on 1:50,000 scales used GPS observations had obtained for various land cover and land uses. It had done two times.

First time; for and overview field work and the total number ground control point take are 32 points; Establish sample plots network, at each sample point, the circumference at breast height (cbh) of all tree species is recorded (the individual woody tree with height > 6 m, and cbh > 5 cm, and shrub with height >1m). Total number of seedling of various species is counte and average girth of each species is record. The plot for woody forest is 25 m x 20 m ($500m^2$). For shrubs, total number of small trees for each species had counted (cbh) and for each species and average circumference at ground, height level is estimate. For shrubs, a plot is 10 m x 10 m. For regenerated seedling layer or ground flora, the nested quadrate method with 2m x 2 m plot size ($4m^2$) has taken in four corners (Fig.3.5). Total inform from the sample plot fill in the field forms (Table 1-Calculate of the wood trees), (Table 2-Calculated of the regenerated seedling).

Second time; total number of ground control points taken are 54 as a part of ground check, and used for accuracy check analysis.

- **The dign of sampling plot**

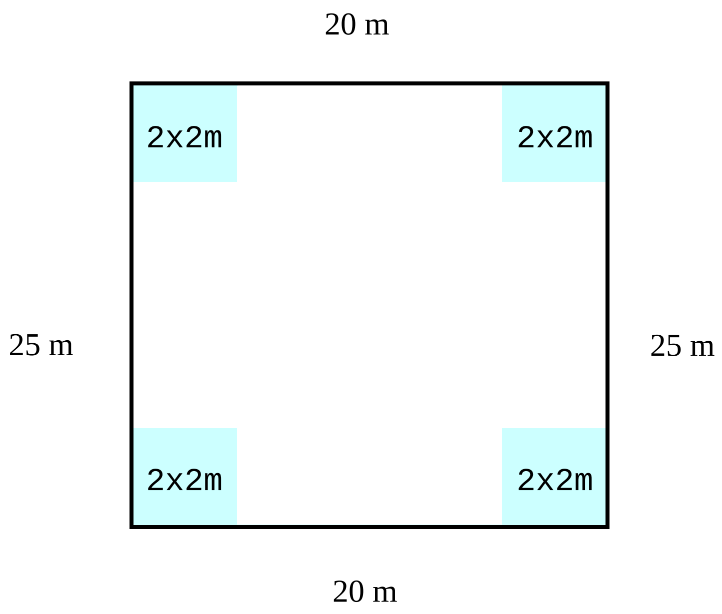


Fig.3.5. Size of sampling plot in the field

A. Measure of wood tree

No.	**Name of species**		**Circumference (Cbh.) (cm)**	**Tree height (m)**		**Tree canopy diameter (m)**		**Quality of trees**
	Viet Nam	Science		bottom to top of tree	under branch	East - West	South-North	
1								a
2								b
...								
n								c

B. Measure of regenerated seedling

No.	**Name of species**		**Quantity of tree**	**Height of tree > 1m**	**Note**
	Viet Nam	Science			
¤ 1					
¤ 2					
¤ 3					
¤4					

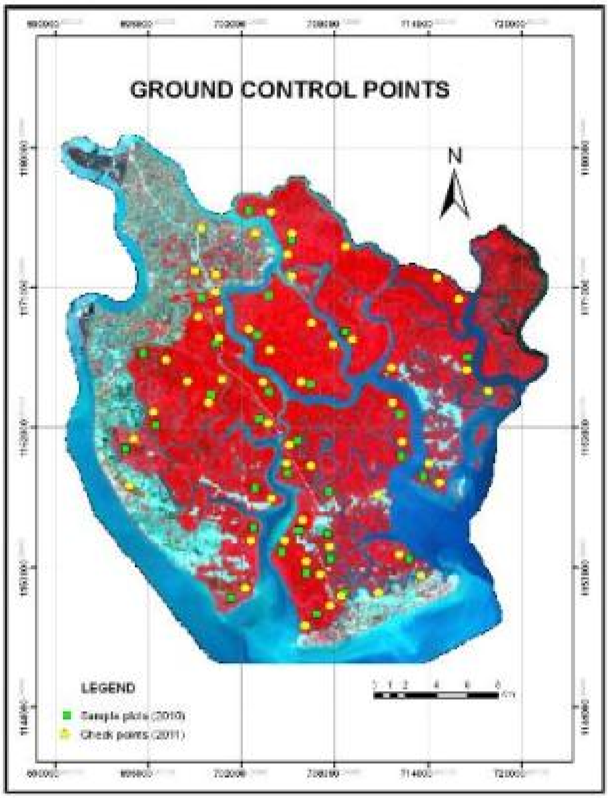


Fig.3.4: Ground control points overlaid on False Color Composite

Some photo from fieldwork:

Fig.3.6. Dense mangrove forest

Fig.3.7. Dense mangrove forest

Fig.3.8. Open mangrove forest

Fig.3.9. Young forest and Scrub

Fig.3.7. Barrens land

Fig.3.8. Agriculture field

CHAPTER IV

RESULTS

The results of the land cover change in Can Gio Biosphere Reserve, Ho Chi Minh City had discussed in this chapter. The area statistics of the mapping and changes had given to compare changes between three times data (1999, 2004 and 2009). The results are as follows:

4.1. The survey results from the sample plots in the field

From 32 sample plots, the indicators of biodiversity of each forest status as; value of timber, timber quality, density of wood tree, density of regenerated tree, the component of wood trees, the component of the regenerated trees was calculated according to the mean as follows;

Note:

$D_{.1.3}$: Breast height diameter at 1.3 m position, ($D_{1.3}$ >5 cm).
H_{dc}: Height of wood tree under branch
N/ha: Density of wood tree/ha
M/ha: Timber volume of wood tree/ha (m^3)
Htstb: Height of regenerated seedling
H_{vn}: From bottom to top of wood tree
H_{dc}: Height of wood tree under branch
ΣG/ha: Basal area average/ha
N_{ts}/ha: Density of regenerated seedling/ha

Quality of wood trees: There have three level a, level b, level c:

a - Strongly trees, not curved of tree, not disease

b - Curved tree, many branches, low under branch of tree, canopy of leaves is not equilateral

c - Curved tree, disease, have lost top of tree.

4.1.1. Dense mangrove forest (dense forest)

The indicators of biodiversity of the structure of dense forest had shown below;

Results:

$D_{1.3tb}$ = 11.76 cm, H_{vntb} = 13.66 m, H_{dctb} = 7.51, N/ha = 1609 (tree/ha), G/ha = 20.31 (m^2/ha), M/ha = 153 (m^3/ha), N_{ts}/ha = 2513 (tree/ha) and H_{tstb} = 2.52 m.

+ Stand formula of wood tree:

Scientist name	Vietnamese name	Abbreviation name	Number of trees measured	Ratio 1/10
Rhizophora apiculata	Đước	Rha	1214	7.93
Exceocacia agallocha	Giá	Exa	146	0.95
Avicennia alba	Mắm	Ava	131	0.86
Sonneratia alba	Bần	Soa	38	0.25
Aegyceras corniculatum	Sú	Aec	1	0.01
			1530	**10**

7.93Rha + 0.95Exa + 0.86Ava + 0.25Soa +0.01 Aec

+ Quality of wood tree:

a = 72.11%, b = 6.58% and c = 1.84%

+ Stand formula of regenerated seedling:

Scientist name	Vietnamese name	Abbreviation name	Number of trees measured	Ratio 1/10
Rhizophora apiculata	Rha	Rha	65	7.14
Ceriops spp.	Ces	Cesp.	15	1.65
Exceocacia agallocha	Exa	Exa	8	0.88
Avicennia alba	Ava	Ava	2	0.22
Lumnitzera racemosa	Lur	Lur	1	0.11
			91	**10**

7.14Rha +1.65Cesp. + 0.88Exa + 0.22Ava + 0.1Lur

4.1.2. Open mangrove forest (open forest)

The indicators of biodiversity of the structure of open forest had shown below;

<u>Results:</u>

$D_{1.3tb}$ = 8.14 cm, H_{vntb} = 9.14 m, H_{dctb} = 4.36, N/ha = 785 (tree/ha), G/ha = 2.72 (m^2/ha), M/ha = 10.89 (m^3/ha), N_{ts}/ha = 14107 (tree/ha) and H_{tstb} = 2.35 m.

+ Stand formula of wood tree:

Scientist name	Vietnamese name	Abbreviation name	Number of trees measured	Ratio 1/10
Rhizophora apiculata	Đước	Rha	81	2.91
Avicennia alba	Mắm	Ava	75	2.70
Ceriops spp.	Dà	Cesp.	44	1.58
Lumnitzera racemonsa	Cóc vàng	Lur	40	1.44
Excoecacia agallocha	Giá	Exa	23	0.83
Sonneratia alba	Bần	Soa	12	0.43
Lumnitzera littorea	Cóc đỏ	Lul	3	0.11
			278	**10**

2.91Rha + 2.7Ava + 1.58Cepp. + 1.44Lur + 0.83Exa + 0.43Soa + 0.11Lul

+ Quality of wood tree:

a = 79.27%; b = 15.64% and c = 5.09%

+ Stand formula of regenerated seedling:

Scientist name	Vietnamese name	Abbreviation name	Number of trees measured	Ratio 1/10
Ceriops spp.	Dà	Cesp.	81	2.91
Rhizophora apiculata	Đước	Rha	75	2.70
Excoecacia agallocha	Giá	Exa	44	1.58
Lumnitzera racemonsa	Cóc vàng	Lur	40	1.44
Hibiscus tiliaceus	Tra bụp	Hit	23	0.83
Avicennia alba	Mắm trắng	Ava	12	0.43
Avicennia lanata	Mắm quăn	Avl	3	0.11
			278	**10**

2.91Cesp + 2.70Rha + 1.58Exa + 1.44Lur + 0.83Hit + 0.43Ava + 0.11Avl

4.1.3. Young mangrove forest&scrub (young forest&scrub)

The indicators of biodiversity of the structure of young forest and scrub had shown below;

Results:

N/ha = 103692 (tree/ha); H_{tstb} = 1.73 m

+ Stand formula of young tree and scrub:

Scientist name	Vietnamese name	Abbreviation name	Number of trees measured	Ratio 1/10
Ceriops spp.	Dà	Cesp.	835	8.55
Lumnitzera racemosa	Cóc vàng	Lur	68	0.70
Avicennia alba	Mắm	Ava	68	0.70
Rhizophora apiculata	Đước	Rha	6	0.06
Total			**977**	**10**

8.55Cesp. + 0.70Lur + 0.70Ava + 0.06Rha

4.2. Land Cover Mapping

The building of the land cover maps of the study area in 1999, 2004 and 2009 from satellite images SPOT of 1999, 2004 and 2009. In this project, using supervised classification method.

4.2.1. Land cover map in 1999

The land cover map based on supervised classification of SPOT 1999 had given in Fig.4.1 and the area analysis of land cover had given in Table 4.1.

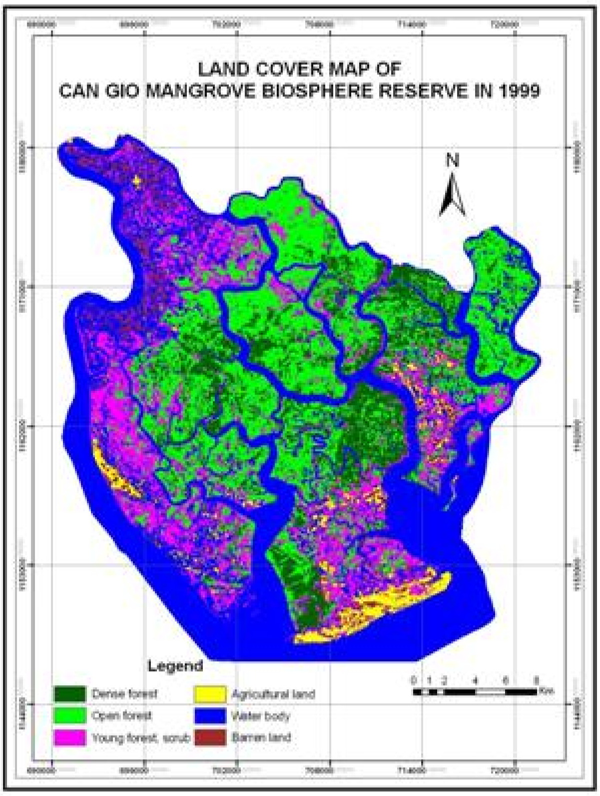


Fig.4.1 Land covers map in 1999

The dense forest area is 12.89%, open forest is 23.73%, young forest and scrub are 15.83%, agriculture land is 2.76%, water body is 41.67% and barren land is 3.11%.

Table 4.1: Area statistics of land cover map

No.	Class	Area (ha)	Percent (%)
1	Dense forest	9546.93	12.89
2	Open forest	17570.80	23.73
3	Young forest, scrub	11724.88	15.83
4	Agriculture land	2045.64	2.76
5	Water body	30855.51	41.67
6	Barren land	2304.99	3.11
	Total	**74048.75**	**100**

Classification accuracy assessment based on confusion matrix had given in Table 4.2. The overall accuracy is 83.89% and average accuracy of 81.95%. Kappa statistics ($\hat{K}$) is 0.7894.

Table 4.2: Classification accuracy assessment report

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Dense forest	29	36	29	100.00%	80.56%
Open forest	35	34	28	80.00%	82.35%
Young forest, scrub	52	36	35	67.31%	97.22%
Agriculture land	6	8	6	100.00%	75.00%
Water body	54	64	51	94.44%	79.69%
Barren land	4	2	2	50.00%	100.00%
Totals	**180**	**180**	**151**		
Overall Classification Accuracy = 83.89%					
KAPPA (K^) STATISTICS					
Overall Kappa Statistics = 0.7894					

4.1.2 Land cover map in 2004

The land cover map based on supervised classification for the year 2004 had given in Fig.4.2. The area statistics for land cover of 2004 had given in Table 4.3 and it indicates that dense forest is 27.01%, open forest 14.38%, young forest and scrub 14.53%, agriculture land is 1.26%, water body 39.65% and barrens land is 3.16%.

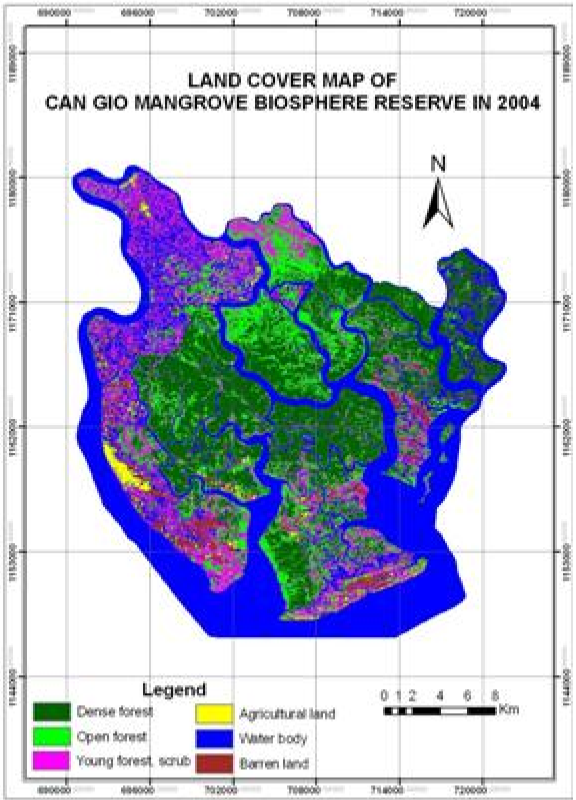


Fig. 4.2 Land Cover map in 2004

Table 4.3 Area statistics of land cover map in 2004

No.	Class	Area (ha)	Percent (%)
1	Dense forest	20003.06	27.01
2	Open forest	10649.23	14.38
3	Young forest, scrub	10758.08	14.53
4	Agriculture land	936.06	1.26
5	Water body	29361.03	39.65
6	Barren land	2341.29	3.16
	Total	**74048.75**	**100**

The classification accuracy based on confusion matrix had estimated (Table 4.4). The overall accuracy of mapping is 87.78% and average accuracy of 82.90%. Kappa statistics (K^) is 0.82%.

Table 4.4 Classification accuracy assessment report

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Dense forest	19	26	19	100.00%	73.08%
Open forest	22	19	13	59.09%	68.42%
Young forest, scrub	36	32	27	75.00%	84.38%
Agriculture land	10	10	10	100.00%	100.00%
Water body	90	90	87	96.67%	96.67%
Barren land	3	3	2	66.67%	66.67%
Totals	**180**	**180**	**158**		
Overall Classification Accuracy = 87.78%					
KAPPA (K^) STATISTICS					
Overall Kappa Statistics = 0.8210					

4.1.2 Land cover map in 2009

The land cover map based on supervised classification for the year 2009 had given in Fig.4.3. The area statistics for land cover of 2009 had given in Table 4.3 and it indicates that dense forest is 32.62%, open forest 16.90%, young forest and scrub are 10.84%, agriculture land is 1.48%, water body 36.45% and barren land is 1.71%.

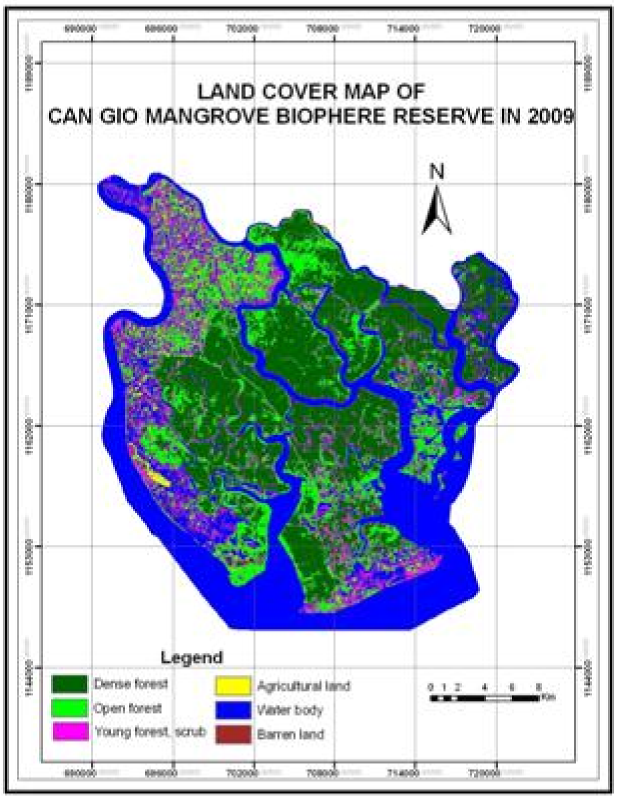


Fig.4.3 Land Cover map in 2009

Table 4.3 Area statistics of land cover map in 2009

No.	Class	Area (ha)	Percent (%)
1	Dense forest	24153.62	32.62
2	Open forest	12513.72	16.90
3	Young forest, scrub	8028.78	10.84
4	Agriculture land	1095.22	1.48
5	Water body	26992.28	36.45
6	Barren land	1265.13	1.71
	Total	**74048.75**	**100**

The accuracy assessment based on confusion matrix had given in Table.4.5. The overall classification accuracy based on confusion matrix is 82.78% and average accuracy of 70.00%. Kappa statistics (K^) is 76.09%.

Table 4.5. Classification accuracy assessment report

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Dense forest	26	31	21	80.77%	67.74%
Open forest	30	25	20	66.67%	80.00%
Scrub	43	40	35	81.40%	87.50%
Agriculture land	2	1	1	50.00%	100.00%
Water bodies	72	80	69	95.83%	86.25%
Barren soil	7	3	3	42.86%	100.00%
Totals	**180**	**180**	**149**		
Overall Classification Accuracy = 82.78%					
KAPPA (K^) STATISTICS					
Overall Kappa Statistics = 0.7609					

4.2 Change detection Analysis

The analysis of coverage changes of mangrove forest in Can Gio with two periods are from 1999 to 2004 and from 2004 to 2009. In this study, using methods of supervised classification. The results of the analysis of land cover changes in each period as follows;

4.2.1. From 1999 to 2004

The result of the change map from 1999 to 2004 based on post classification comparison of supervised classification method had given Fig.4.4. The analysis indicates that; no change areas is 56.02%, while with negative change is 31.52% and positive change area is 12.46%. In the past 5 years (1999-2004); the dense mangrove forest area increased is 10456.13 ha. While the open forest area reduction is 6921.57 ha, young forest area reduction is 966.80 ha, agriculture land area reduced 1109.58 ha and water body area reduced 1494.48 ha, but barren land area increased 36.30 ha (see Table 4.7 and more than detailed see table 4.8. Area change matrix based on supervised classification).

Table 4.7. Area change matrix based on supervised classification (units: ha)

1999 \ 2004	Dense forest	Open forest	Young forest, scrub	Agriculture land	Water body	Barren land	Total
Dense forest	8313.65	760.08	288.59	2.07	180.78	1.76	**9546.93**
Open forest	9729.94	4831.00	2120.74	37.34	779.49	72.29	**17570.80**
Young forest, scrub	1401.37	3054.48	3905.14	177.11	2683.49	503.29	**11724.88**
Agricultural land	10.92	420.98	501.41	347.33	217.71	547.29	**2045.64**
Water body	522.81	1352.04	3186.22	220.68	24719.62	854.14	**30855.51**
Barren land	24.37	230.64	755.96	151.53	780.21	362.28	**2304.99**
Total	**20003.06**	**10649.22**	**10758.06**	**936.06**	**29361.30**	**2341.05**	**74048.75**

In there, our temporary regulations for the criteria of positive and negative mangrove forest changes such as;

- Non-change (the area unchanged)

- Negative area changes including; *dense forest to open forest, dense forest to young forest and scrub, dense forest to agriculture land, dense forest to water body, dense forest to barren land; open forest to young forest and scrub, open forest to agriculture land, open forest to water body, open forest to barren land; young forest and scrub to agriculture land, young forest and scrub to water body, young forest and scrub to barren land; agriculture land to water body and agriculture land to barren land;*

- Positive area change including; *open forest to dense forest, young forest and scrub to open to dense forest; young forest and scrub to open forest; agriculture land to dense forest, agriculture land to open forest, agriculture land to young forest and scrub; water body to dense forest, water body to open forest, water body young forest and scrub; barren land to dense forest, barren land to open forest, barren land to young forest and scrub, barren land to water body.* (Table 4.9)

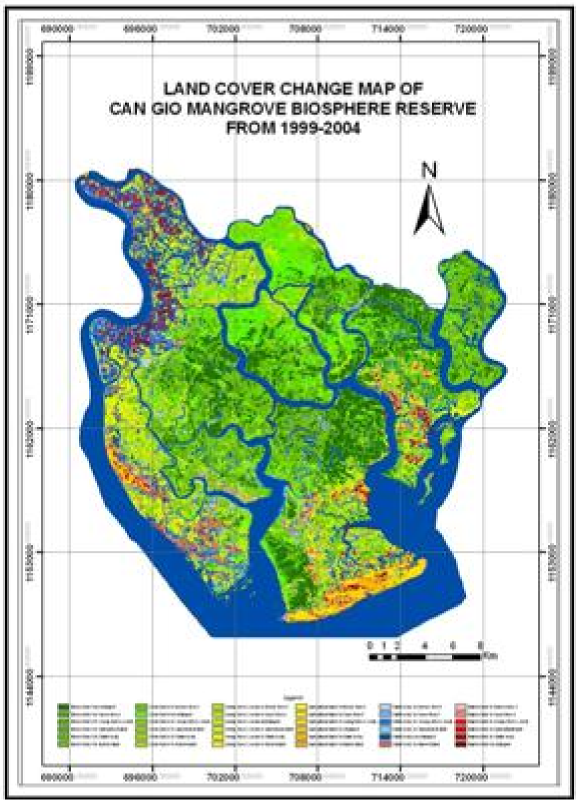


Fig.4.4. Land cover change map from 1999 to 2004

Table 4.8. Change Land covers of mangrove forest in 1996 and 2004

No.	Class	Area (ha)		Area Change (ha)
		1999	2004	
1	Dense forest	9546.93	20003.06	10456.13
2	Open forest	17570.80	10649.23	-6921.57
3	Young forest, scrub	11724.88	10758.08	-966.80
4	Agriculture land	2045.64	936.06	-1109.58
5	Water body	30855.51	29361.03	-1494.48
6	Barren land	2304.99	2341.29	36.30
Totals		**74048.75**	**74048.75**	

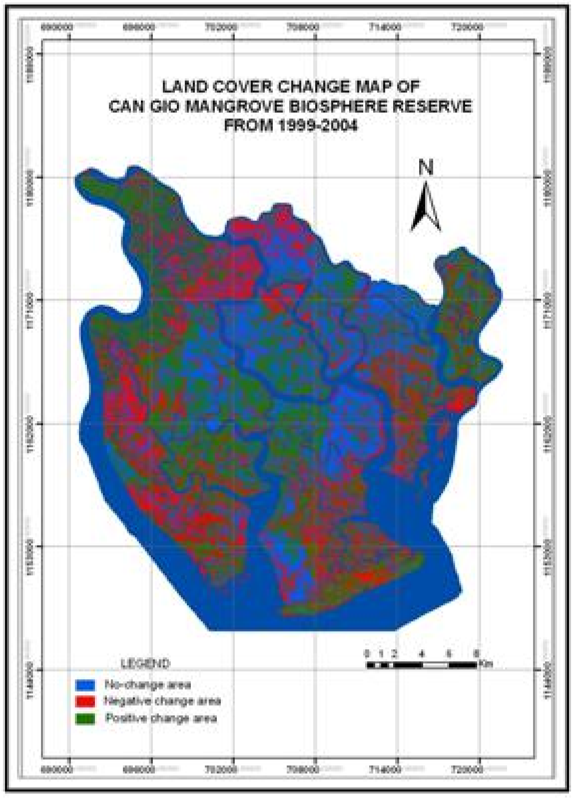


Fig. 4.5. Land cover change map

Table 4.9 Area change distribution from 1999 to 2004

No.	Class	Area (ha)	Percent (%)
1	No change	41479.02	56.02
2	Negative change	23343.56	31.52
3	Positive change	9226.17	12.46
	Total	**74048.75**	**100**

4.2.2. From 2004 to 2009

The result of change maps from 2004 to 2009 based on post classification comparison of supervised classification method had given Fig.4.6, Fig.4.7. The analysis indicates that the no change area is 58867.88 ha (65.99%), the negative change area is 18495.51 ha (24.98%) and the positive change area is 6685.36 ha (9.03%).

In the past 5 years (2004-2009); the dense forest area increased 4150.56 ha (from 20003.06 ha to 24153.62 ha), the open forest area increased 1864.48 ha (from 10649.23 ha to 12513.72 ha). While the young forest and scrub areas reduced 2729.30 ha, the water area reduced 2368.75 ha and barren land area reduced 1076.16 ha. Nevertheless, agriculture land area increased 159.16 ha. (See Table.4.10 and more than detailed see Table 4.11. Area change matrix based on supervised classification).

Table 4.10 Area change matrix based on supervised classification (units: ha)

2004 \ 2009	Dense forest	Open forest	Young forest, Scrub	Agricultural land	Water body	Barren land	Total
Dense forest	18391.66	823.11	668.75	28.54	86.01	4.99	**20003.06**
Open forest	4181.21	4449.78	1241.64	167.30	503.25	106.05	**10649.23**
Young forest, scrub	1378.21	4883.08	2390.10	521.30	1266.60	318.79	**10758.08**
Agricultural land	2.77	169.86	333.62	103.85	255.48	70.48	**936.06**
Water body	198.00	2018.88	2875.00	255.34	23390.74	623.07	**29361.03**
Barren land	1.77	169.01	519.67	18.89	1490.20	141.75	**2341.29**
Total	**24153.62**	**12513.72**	**8028.78**	**1095.22**	**26992.28**	**1265.13**	**74048.75**

In there, our temporary regulations for the criteria of positive and negative mangrove forest changes such as;

- Non-change (the area unchanged)

- Negative area changes including; *dense forest to open forest, dense forest to young forest and scrub, dense forest to agriculture land, dense forest to water body, dense forest to* *barren land; open forest to young forest and scrub, open forest to agriculture land, open forest to water body, open forest to barren land; young forest and scrub to agriculture land, young forest and scrub to water body, young forest and scrub to barren land; agriculture land to water body and agriculture land to barren land;*

- Positive area change including; *open forest to dense forest, young forest and scrub to open to dense forest; young forest and scrub to open forest*; *agriculture land to dense forest, agriculture land to open forest, agriculture land to young forest and scrub; water body to dense forest, water body to open forest, water body young forest and scrub; barren land to dense forest, barren land to open forest, barren land to young forest and scrub, barren land to water body.* (Table 4.12).

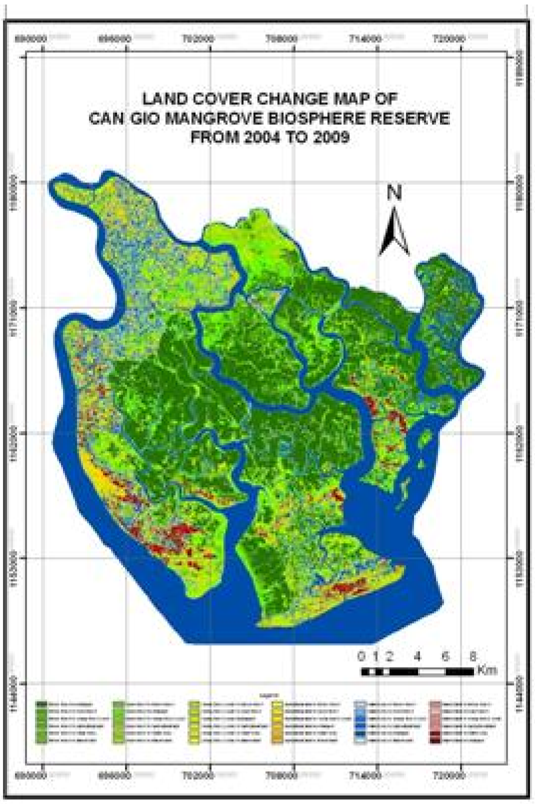


Fig.4.6. Land cover change map from 2004 to 2009

Table 4.11 Change land cover of mangrove forest in 2004 and 2009

No.	Class	Area (ha)		Change
		2004	**2009**	
1	Dense forest	20003.06	24153.62	4150.56
2	Open forest	10649.23	12513.72	1864.49
3	Young forest, scrub	10758.08	8028.78	-2729.30
4	Agriculture land	936.06	1095.22	159.16
5	Water body	29361.03	26992.28	-2368.75
6	Barren land	2341.29	1265.13	-1076.16
	Total	**74048.75**	**74048.75**	

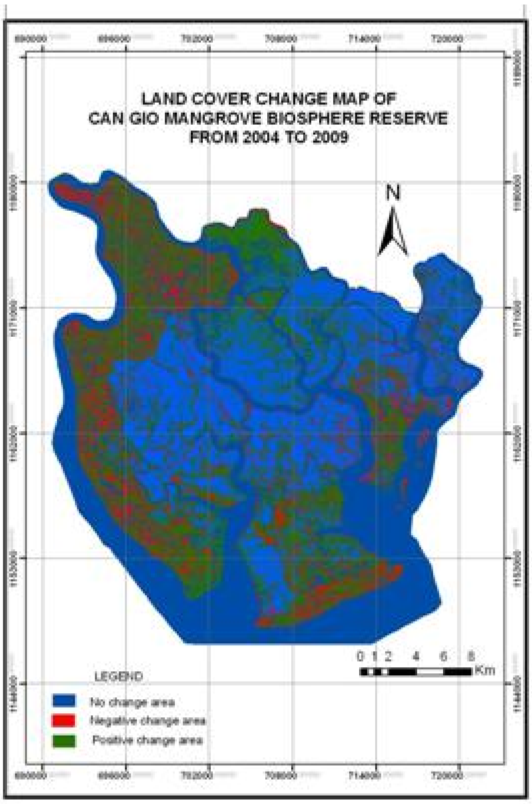


Fig.4.7. Land cover change map

Table 4.12 Area change distribution from 2004 to 2009

No.	Class	Area (ha)	Percent (%)
1	No change	48867.88	65.99
2	Negative change	18495.51	24.98
3	Positive change	6685.36	9.03
	Total	**74048.75**	**100**

4.3. Conclusion

From satellite images (SPOT 1999, SPOT 2004 and SPOT 2009) with a resolution of 10 m x 10 m, had built the land cover maps of 1999, 2004 and 2009 with overall classification accuracy from 82,78% to 87.78% and also has built the land cover changed maps of the periods of 1999 to 2004 and 2004 to 2009. ***About area of mangrove forest:*** The total area considered in this study is 74048.75 ha. From 1999 to 2009, the dense mangrove forest always increases, from 1999 to 2004 increased 10456.13 ha, from 2004 to 2009 increased 4150.56 ha. However, from 1999 to 2004, the open mangrove forest reduced 6912.57 ha. Because, much of the open mangrove forest converted to dense forest, but from 2004 to 2009 the open mangrove forest increased 1755.64 ha. However, from 1999 to 2004 and 2004 to 2009, most of young forest and scrub area were reduced, respectively; 6921.57 ha and 2620.45 ha. Over the years, from 1999 to 2009, most of the agricultural land area decreased, and decreased the most in the period from 2004 to 2009. The water body area of little changed, because the shrimp ponds area did not expanded. From 1999 to 2004, the barren land area of little changed, however, from 2004 to 2009, but the barren land has greatly decreased 1076.16 ha (see Table 14). ***About structure of mangrove forest:*** research has focused on the structure of the three main forest condition that are dense mangrove forest, open mangrove forest and young mangrove forest&scrub with indicators such as; value of timber, timber quality, density of wood tree, density of regenerated tree, the component of wood trees and the component of the regenerated trees. The dense forest has $D_{1.3tb}$ = 11.76m, H_{vntb} = 13.66m, N/ha = 1609 tree/ha, N_{ts} = 2513 tree/ha and M/ha = 153 m^3/ha with the domination is *Rhizophora apiculata* species (7.93/10). The open forest has $D_{1.3}$ = 8.14m, H_{vn} = 9.14m, N/ha = 785 tree/ha, M/ha = 10.98 m^3/ha and N_{ts}/ha = 14107 tree/ha, with the domination are *Rhizophora apiculata* (2.91/10) and *Avicennia alba* species (2.7/10). The dense young forest is dense 103692 tree/ha with H_{tstb} = 1.73 m, with the domination is *Ceriops spp* species (8.55/10) and then are *Avicenia alba* species (0.7/10) and *Lumnitzera racemosa* species (0.7/10), more than detailed results show in the Table 13;

Table 13. Interpretation key of satellite imagery and structural indicators of the mangrove forests status

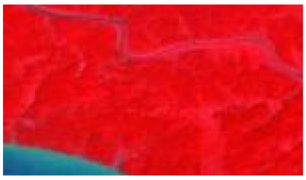
No.	Class	Sample images and identification on the satellite image	Photo and structural characteristics of mangrove forests
1	Dense mangrove forest		
		Dark red and fine structure	+ $D_{1.3tb}$ = 11.76 cm, H_{vntb} = 13.66 m, H_{dctb} = 7.51, N/ha = 1609 (tree/ha), G/ha = 20.31 (m^2/ha), M/ha = 153 (m^3/ha), N_{ts}/ha = 2513 (tree/ha) and H_{tstb} = 2.52 m + Quality of wood tree: a = 72.11%, b = 6.58% and c = 1.84% + 7.93Rha + 0.95Exa + 0.86Ava + 0.25Soa +0.01 Aec (wood tree) + 7.14Rha + 1.65Cesp. + 0.88Exa + 0.22Ava + 0.1Lur (regenerated seedling)
2	Open mangrove forest		
		Red and fine structure	+ $D_{1.3tb}$ = 8.14 cm, H_{vntb} = 9.14 m,H_{dctb} = 4.36, N/ha = 785(tree/ha), G/ha =2.72 (m^2/ha), M/ha = 10.89 (m^3/ha), N_{ts}/ha = 14107 (tree/ha) and H_{tstb} = 2.35 m. + Quality of wood tree: a = 79.27%, b = 15.67% and c = 5.09% + 2.91Rha + 2.7Ava + 1.58Cepp. + 1.44Lur + 0.83Exa + 0.43Soa + 0.11L (wood tree). + 2.91Cesp. + 2.70Rha + 1.58Exa + 1.44Lur + 0.83Hit+ 0.43Ava + 0.11Avl (regenerated seedling)
3	Young mangrove forest and scrub		
		Light red, fine to very fine structure. Shape is not clear	+ N/ha = 103692 (tree/ha); H_{tstb} = 1.73 m + 8.55Cesp. + 0.70Lur + 0.70Ava + 0.06Rha

Table 14. Area statistics of land cover in 1999, 2004 and 2009

No.	Class	Area (ha)		
		1999	2004	2009
1	Dense forest	9546.93	20003.06	24153.62
2	Open forest	17570.80	10649.23	12513.72
3	Young forest, scrub	11724.88	10758.08	8028.78
4	Agriculture land	2045.64	936.06	1095.22
5	Water body	30855.51	29361.03	26992.28
6	Barren land	2304.99	2341.29	1265.13
	Totals	**74048.75**	**74048.75**	**74048.75**

4.4. Recommendation

- Management of mangrove forest may use satellite data for monitoring the mangrove forest every two years, preferable with high resolution.
- Management skills of the manger and ranger officers should improved by imparting better training.
- The dense mangrove forest area should to thinning. The barren land area needs to replant. The open mangrove forest and young mangrove forest area need to restoration-oriented protection.
- Promotion and continue policy to reforest which could be useful on wasteland in this areas.
- Research to build an economic, ecological and tourism model with sustainable development of mangrove ecosystems.
- Studies evaluating/assessment the CO_2 absorption by mangrove ecosystems, it is the basis for the calculation and implementation of payment environmental service.
- The build scenarios for adaptation and mitigation to climate change
- Development oriented tourism may be developed and encouraged.
- Awareness should generate among local people about the advantage of forest in our surrounding.

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