The analysis of mangrove forest changes period of 20 years in Can Gio Biosphere Reserve, Viet Nam using remote sensing and GIS technology

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Abstract

On January 21, 2000, the MAB/UNESCO Committee recognized the Can Gio mangrove forest as an International Biosphere Reserve. The MAB/UNESCO committee requires every potential biosphere reserve to be assessed for a period of 10 years. During this time, the ecology of the area is closely reviewed, including the vegetation cover. This study used 45 sample plots in the field and utilized Remote Sensing and Geographic Information Systems (RS & GIS) technology for mapping, allowing for the close observation of changes in the mangrove forest during a 20 year period (1996-2016). The results show that, from the SPOT, Landsat 8 OLI satellite imagery, we can categorize the land cover maps in Can Gio Mangrove Biosphere Reserve, including periods of 1996, 1999, 2004, 2009 and 2016, into six classes: dense mangrove forest,

open mangrove forest, young mangrove forest and scrub, agriculture land, water body, and barren land. The accuracy of the land cover maps for 1996, 1999, 2004, 2009 and 2016 was high, with scores of 84.89 percent, 83.89 percent, 87.78 percent, 82.78 percent, and 84.44 percent, respectively.

Keywords: Mangrove forest, monitoring, remote sensing, GIS

Introduction

Vietnam is located on the Indochinese Peninsula, and has a 3,260 km long coastline. Of the eight International Biosphere Reserves (IBRs) in Vietnam, seven IBRs are positioned along the coast and including rich natural resources, such as mangroves (Hong et al., 1997). Vietnam is one of the countries most affected by climate change. In recent years, we have seen an increase in irregular weather and natural disasters, especially in the form of storms and floods. Droughts and floods have caused widespread damages to the country in 2006, 2007, 2009, and 2015. In areas of southern Vietnam, such as Ho Chi Minh city and Can Tho Ca Mau, provinces that had never suffered from floods in the past, are now regularly hit. In June 2009, the Ministry of Natural Resources and Environment conveyed concerns regarding climate change, and asked the departments to develop an action plan addressing the threat of rising of sea levels. According to the Ministry's calculations, the temperature in Vietnam will have increased by 2.3^{o}C, and most of the area in the southern provinces (agricultural land, residential land, mangrove forest, etc.) will be flooded by the end of the 21st century (Tran Thuc et al., 2016). The Can Gio Biosphere Reserve, lying entirely within the Can Gio district in southern Vietnam, is an important mangrove forest ecosystem, and is regarded as the "green lungs" of the region (Nguyen Hoang Tri et al., 2000). Due to its international significance, it was recognized as the first International Biosphere Reserve in Vietnam by the MAB/UNESCO committee in 2000 (UNESCO, 2000). After serious damage suffered during the Vietnamese war, the reserve is now under threat of global

climate change and rising sea levels along the Mekong river. There are around 58,000 people living within the boundaries of this reserve, and approximately 54,000 people living in the transition area (Tuan et al., 2002). The local people are of various origins and ethnical groups; Consequently, a mixture of culture and social systems is inherent to this region. The main economic activities are agriculture, fisheries, aquaculture, and salt production. Most of the families in this region must earn their livings by catching crabs and mollusks, and by collecting firewood. The livelihood of the local people depends on mangrove forests, either directly or indirectly. The scientific management of the mangrove forests is extremely important, not only for the conservation of natural coastal environments, but also for safeguarding the livelihood of thousands of local people.

The purpose of this study is to monitor the mangrove forests of the Can Gio Biosphere using remote sensing data and geographical information system (GIS) technology, and help protect an important biosphere reserve of both Vietnam and the world.

STUDY AREA

Can Gio mangrove forest lies entirely within the district of Ho Chi Minh City, on the geographic co-ordinates of are $10^{o}22'14$N to $10^{o}40'09''$N latitude and $106^{o}46'12''$E to 107^{o} 00' 59'' E longitude. The reserve is located south of Nha Be district, and north of Dong Nai and Ba Ria – Vung Tau and Long An sit to the east and west, respectively. The area measures 35 km from North to South and 30 km from East to West (Tuan et al., 2002; Hirose et al., 2004) (Figure No. 1).

Figure No. 1. Local map of study area (Can Gio Biosphere Reserve)

DATA AND METHODOLOGY

In this study, we used five optical satellite images: SPOT 4 of 1996, 1999, SPOT 5 of 2004 and 2009, and Landsat 8 OLI 2016. Data for 1999, 2004, and 2009 was acquired from the works of Luong and Singh (Luong., 2009, 2011; Singh and Luong 2013). The optical satellite used in the present study are shown in Figure No. 2.

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(a.)

(b.)

(c.)

(d.)

(e.)

Figure No. 2. False colour composite of (a.) SPOT HRV in 1996, (b.) 1999, (c.) 2004, (d.) 2009, (e.) Landsat 8 OLI in 2016.

FIELD WORK

In total, 45 sample plots were used in this study. The diameter of all the trees larger than 5 cm in diameter were measured at breast height (D) and full height (H). The tree diameter and height were measured by using laser instruments, and the central geo-location (latitude and longitude) of each sample plot was recorded with a GPS device. The average forest parameters (units per hectare) in each plot were calculated according to the guidelines provided by Hong et al., 2006. The summary of results from filed work are shown in Table No. 1.

Table No. 1. Summary of forest inventory parameters in Can Gio Mangrove Reserve

Parameter	**Forest inventory parameters**			
	Minimum	Maxmum	Mean	Standard Deviation
Diameter (m)	5.83	17.60	11.10	3.25
Height (m)	6.34	17.04	13.84	2.85

Parameter	Forest inventory parameters			
	Minimum	Maxmum	Mean	Standard Deviation
Woody volume ($m^3.ha^{-1}$)	8.27	206.03	136.56	64.26

(a)

(b.)

(c.)

(d.)

(e.)

(f.)

Figure No. 3. Photo from field work: (a.) Dense mangrove forest, (b.) Open mangrove forest, (c.) Young mangrove forest, (d.) Scrub, (e.) Agriculture land, (f.) Barren land

LAND COVER CLASSIFICATION

The classification scheme is based on the objectives or requirement of the user. In this study, we used five satellite images, four of the five from SPOT satellites including SPOT in 1996, 1999, 2004, 2009 and one of them from Landsat 8 satellite in 2016. The selected satellite images did not differ much about time observed per the years, it is an advantage to accurately detect changes in mangrove forest over time. The classification makes easily use to mangrove forest manager, and also conformity with criteria for the classification by Vietnam (MARD, 2009), and was adopted classification criteria of the UNESCO (1973) and Thai Van Trung (1998) systems. The classification scheme land covers in this study are described following:

- Level 1 (main classes) has two classes: Forest land and Other land (none forest).
- Level 2 (Sub-classes) has six classes: Dense mangrove forest (dense forest), Open mangrove forest (open forest), Young forest&scrub (young forest and scrub mixed), Agriculture land, Water body, and Barren land.

PROCESSING OF SATELLITE DATA

The processing of satellite data in this study included geometric correction, image to map rectification, image registration, image fusion, and change analysis (Laben et al., 2000; Luong et al., 2015). Supervised classification method was used. The supervised classification is the process of sampling a known identity, in order to classify pixels of unknown identity. Samples of known identities are pixels located within training areas. Pixels located within these areas are used to guide the classification algorithm, assigning specific spectral values to appropriate information classes. There are three basic steps to the supervised classification procedure: define signatures, evaluate signatures, and process a supervised classification.

RESULTS

Land cover mapping

Land cover map in 1996

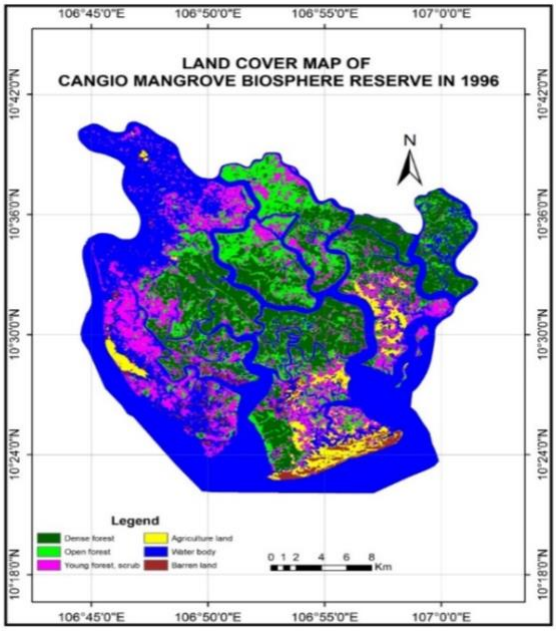


Figure No. 4. Land cover map in 1996

The statistical results from the land cover map in 1996 were comprised of 20.22 dense forest area, 12.12 percent open forest, and 15.82 percent young forest and scrub. Water accounted for 46.29 percent, while both agricultural and barren land made up 3.56 percent, see at Table No. 2 and Figure No. 4.

The overall accuracy of this data is 84.89

percent, with an average accuracy of 82.95 percent (Kappa statistics (K) is 0.7994).

Table No. 2. Area statistics of land cover in Can Gio Biosphere Reserve in 1996

Main classes	Sub-classes	Pixel count	Area	
			Hectare (ha)	Percent (%)
Forest land	Dense forest	1496933	14969.33	20.22
	Open forest	897561	8975.61	12.12
	Young&scrup	1171464	11714.64	15.82
	Sub-total		***35659.58***	***48.16***
Other land	Agriculture land	263693	2636.93	3.56
	Water body	3428002	34280.02	46.29
	Barren land	147222	1472.22	1.99
	Sub-total		***38389.17***	***51.84***
Total			**74048.75**	**100.00**

Land cover map in 1999

The land cover map based on the supervised classification of SPOT 1999 had given in Figure No. 5 and the statistical results of land cover had given in Table No. 3.

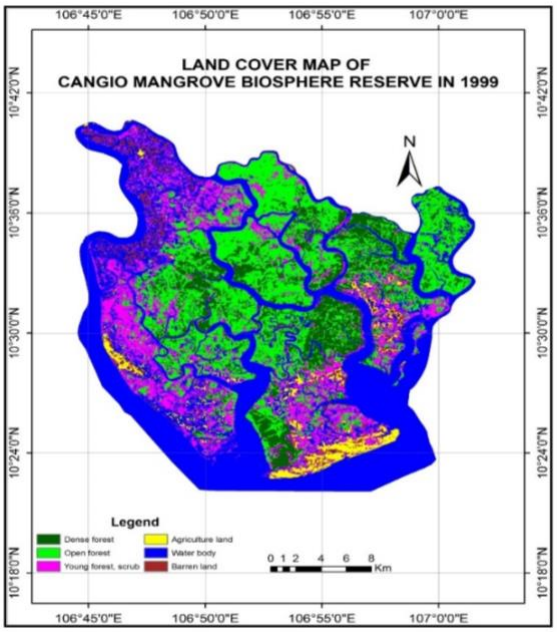


Figure No. 5. Land cover map in 1999

The dense forest area is 13.89%, 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 No. 3. Area statistics of land cover in Can Gio Biosphere Reserve in 1999

Main classes	Sub-classes	Pixel count	Area	
			Hectare (ha)	Percent (%)
Forest land	Dense forest	954698	9546.98	12.89
	Open forest	1757084	17570.84	23.73
	Young&scrup	1172494	11724.94	15.83
	Sub-total		***38842.76***	***52.46***
Other land	Agriculture land	204564	2045.64	2.76

	Water body	3085532	30855.32	41.67
	Barren land	230503	2305.03	3.11
	Sub-total		***35205.99***	***47.54***
Total			**74048.75**	**100.00**

Classification accuracy assessment based on confusion matrix. The results of the overall accuracy is 83.89% and average accuracy of 81.95%. Kappa statistics (K^) is 0.7894.

Land cover map in 2004

The land cover map based on supervised classification of SPOT 2004 had given in Figure No. 6 and the area analysis of land cover had given in Table No. 4.

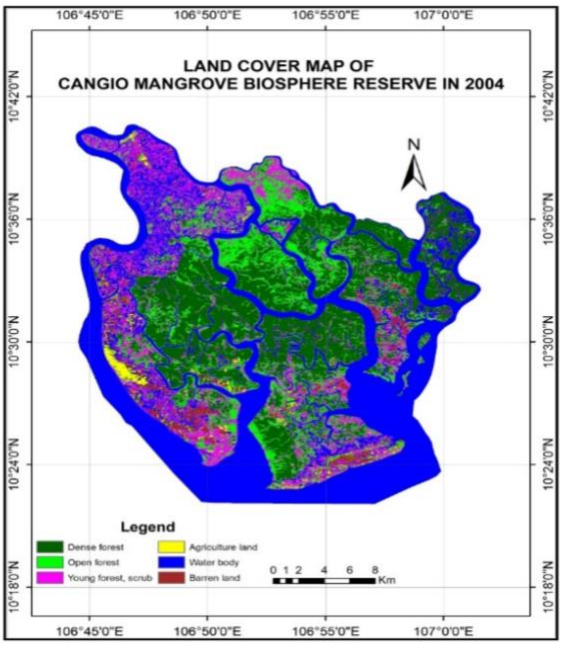


Figure No. 6. Land cover map in 2004

The dense forest area is 27.01%, open forest is 14.38%, young forest and scrub are 14.53%, agriculture land is 1.26%, water body is 39.65% and barren land is 3.16%.

Table No. 4. Area statistics of land cover in Can Gio Biosphere Reserve in 2004

Main classes	**Sub-classes**	**Pixel count**	**Area**	
			Hectare (ha)	**Percent (%)**
Forest land	Dense forest	2000306	20003.06	27.01
	Open forest	1064922	10649.23	14.38
	Young&scrup	1075806	10758.08	14.53
	Sub-total		***41410.37***	***55.92***

Main classes	Sub-classes	Pixel count	Area	
			Hectare (ha)	Percent (%)
Other land	Agriculture land	93606	936.06	1.26
	Water body	2936131	29361.03	39.65
	Barren land	234105	2341.29	3.16
	Sub-total		***32638.38***	44.08
Total			**74048.75**	**100.00**

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

Land cover map in 2009

The land cover map based on supervised classification of SPOT 2009 had given in Figure 7 and the area analysis of land cover had given in Table No. 5.

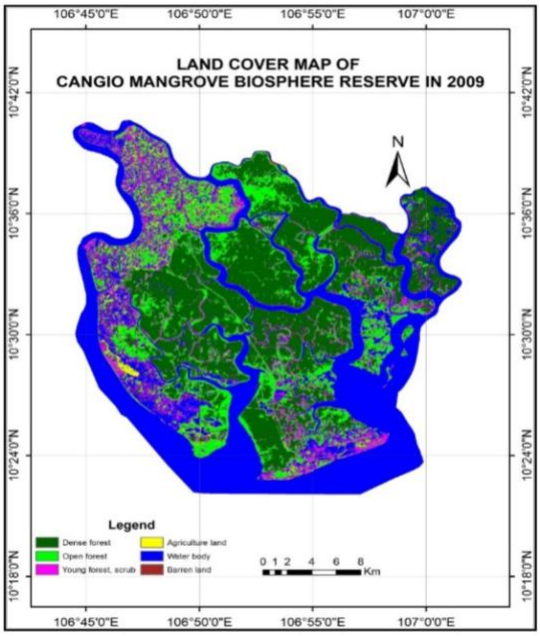


Figure No. 7. Land cover map in 2009

The dense forest area is 32.62%, open forest is 16.38%, young forest and scrub are 14.53%, agriculture land is 1.26%, water body is 39.65% and barren land is 3.16%.

Table No. 5. Area statistics of land cover in Can Gio Biosphere Reserve in 2009

Main classes	Sub-classes	Pixel count	Area	
			Hectare (ha)	Percent (%)
Forest land	Dense forest	2415361	24153.61	32.62
	Open forest	1251370	12513.70	16.90
	Young&scrup	802878	*8028.78*	10.84
	Sub-total		***44696.09***	***60.36***
Other land	Agriculture land	109498	1094.98	1.48

Main classes	Sub-classes	Pixel count	Area	
			Hectare (ha)	Percent (%)
	Water body	2699259	26992.59	36.45
	Barren land	126509	1265.09	1.71
	Sub-total		***29352.66***	***39.64***
Total			**74048.75**	**100.00**

The accuracy assessment based on confusion matrix. The results of the overall classification accuracy based on confusion matrix is 82.78% and average accuracy of 70.00%. Kappa statistics (K^) is 76.09%.

Land cover map in 2016

The land cover map based on supervised classification of Landsat OLI 2016 had given in Figure 8 and the area analysis of land cover had given in Table No. 6.

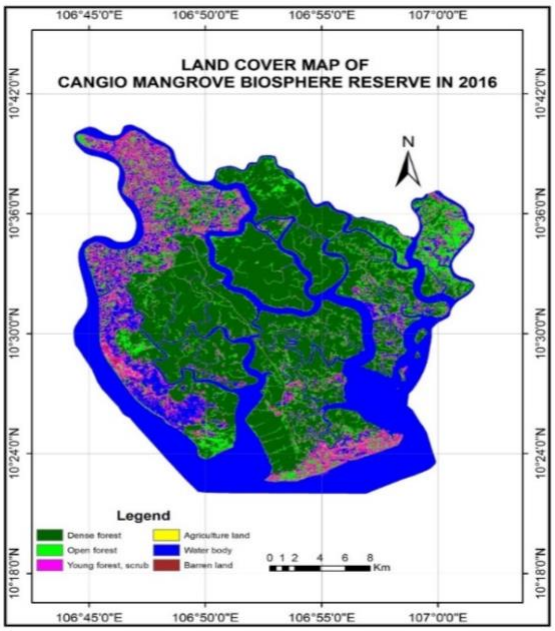


Figure No. 8. Land cover map in 2016

The dense forest area is 38.53%, open forest is 11.17%, young forest and scrub are 9.79%, agriculture land is 2.76%, water body is 34.07% and barren land is 3.69%.

Table No. 6. Area statistics of land cover in Can Gio Biosphere Reserve in 2016

Main classes	Sub-classes	Pixel count	Area	
			Hectare (ha)	Percent (%)
Forest land	Dense forest	1268111	28532.50	38.53
	Open forest	367447	8267.56	11.17
	Young&scrup	322096	*7247.15*	9.79
	Sub-total		***44047.21***	***59.48***

Other land	Agriculture land	90737	2041.58	2.76
	Water body	1165704	25228.34	34.07
	Barren land	76961	2731.62	3.69
	Sub-total		***30001.55***	***40.52***
Total			**74048.75**	**100.00**

The accuracy assessment based on confusion matrix. The overall classification accuracy based on confusion matrix is 84.44% and average accuracy of 70.00%. Kappa statistics (K^) is 76.09%.

Analyze the change of mangrove forests

The analysis of land cover changes of mangrove forest in Can Gio Biosphere Reserve over of 20 years (1996-2016), and divided into four periods are from 1996 to 1999, from 1999 to 2004, from 2004 to 2009 and from 2009 to 2016. In there are (+) Increase and (-) decrease. The detailed results of the analysis of land cover changes in study area in each period as follows;

Period from 1996 to 1999

The total area of forest land area has changed to 3,183.18 ha, there include rich forest (-5,422.35 ha), open forest (8,595.23 ha) and young forest and scrub (10.30 ha). Other land area has changed by 3,183.18 ha, there include agriculture land (-591.29ha), water body (-3,424.70 ha) and barren land (-3,183.18ha). The result are shown in Table No. 7.

Table No. 7. Land cover changed during 1996 to 1999; (+) Increase and (-) decrease

Sub-classes	**Area 1996**		**Area 1999**		**Changed area 1996-1999**	
	ha	%	ha	%	ha	%
Dense forest	14969.33	20.22	9546.98	12.89	-5422.35	-7.32
Open forest	8975.61	12.12	17570.84	23.73	+8595.23	+11.61
Young forest & scrub	11714.64	15.82	11724.94	15.83	+10.30	+0.01
Sub-total	***35659.58***	***48.16***	***38842.76***	***52.46***	***+3183.18***	***+4.30***
Agriculture land	2636.93	3.56	2045.64	2.76	-591.29	-0.80
Water body	34280.02	46.29	*30855.32*	*41.67*	-3424.70	-4.62

Sub-classes	Area 1996		Area 1999		Changed area 1996-1999	
	ha	%	ha	%	ha	%
Barren land	1472.22	1.99	2305.03	3.11	+832.81	+1.12
Sub-total	***38389.17***	***51.84***	***35205.99***	***47.54***	***-3183.18***	***-4.30***
Total	**74048.75**		**74048.75**	**100.00**		

Period from 1999 to 2004

The total area of forest land area has changed to 2,567.61 ha, there include rich forest (-1,0456.08 ha), open forest (-6,921.61 ha) and young forest and scrub (-966.86 ha). Other land area has changed by (-2,567.61 ha), there include agriculture land (-1,109.58 ha), water body (-1494.58 ha) and barren land 36.26 ha. The results are shown in Table No. 8.

Table No. 8. Land cover changed during 1999 to 2004; (+) Increase and (-) decrease

Sub-classes	Area 1999		Area 2004		Changed area 1999-2004	
	ha	%	ha	%	ha	%
Dense forest	9546.98	12.89	20003.06	27.01	+10456.08	+14.12
Open forest	17570.84	23.73	10649.23	14.38	-6921.61	-9.35
Young forest& scrub	11724.94	15.83	10758.08	14.53	-966.86	-1.31
Sub-total	***38842.76***	***52.46***	***41410.37***	***55.92***	***+2567.61***	***+3.47***
Agriculture land	2045.64	2.76	936.06	1.26	-1109.58	-1.50
Water body	30855.32	41.67	*29361.03*	*39.65*	-1494.29	-2.02
Barren land	2305.03	3.11	2341.29	3.16	+36.26	+0.05
Sub-total	***35205.99***	***47.54***	***32638.38***	***44.08***	***-2567.61***	***-3.47***
Total	**74048.75**	**100.00**	**74048.75**	**100.00**		

Period from 2004 to 2009

The total area of forest land area has changed to 3,285.72 ha, there include rich forest 4,150.55 ha, open forest 1,864.47 ha and young forest and scrub (-2,729.30 ha). Other land area has changed by (-3,285.72 ha), there include agriculture land 158.92 ha, water body (-2,368.44 ha) and barren land (-1,076.20 ha). The results are shown in Table No. 9.

Table No. 9. Land cover changed from 2004 to 2009; (+) Increase and (-) decrease

Sub-classes	**Area 2004**		**Area 2009**		**Changed area 2004-2009**	
	ha	%	ha	%	ha	%
Dense forest	20003.06	27.01	24153.61	32.62	+4150.55	+5.61
Open forest	10649.23	14.38	12513.70	16.90	+1864.47	+2.52
Young forest&scrub	10758.08	14.53	8028.78	10.84	-2729.30	-3.69
Sub-total	***41410.37***	***55.92***	***44696.09***	***60.36***	***+3285.72***	***+4.44***
Agriculture land	936.06	1.26	1094.98	1.48	+158.92	+0.21
Water body	29361.03	39.65	*26992.59*	*36.45*	-2368.44	-3.20
Barren land	2341.29	3.16	1265.09	1.71	-1076.20	-1.45
Sub-total	***32638.38***	***44.08***	***29352.66***	***39.64***	***-3285.72***	***-4.44***
Total	**74048.75**	**100.00**	**74048.75**	**100.00**		

Period from 2009 to 2016

The total area of forest land area has changed to 3,285.72 ha, there include rich forest (-648.88 ha), open forest (-4,246.14 ha) and young forest and scrub (-781.63 ha). Other land area has changed by 648.89 ha, there include agriculture land 946.60 ha, water body (-1,764.25 ha) and barren land 1,466.53 ha. The results are shown in Table No. 10.

Table 10. Land cover changed from 2009 to 2016; (+) Increase and (-) decrease

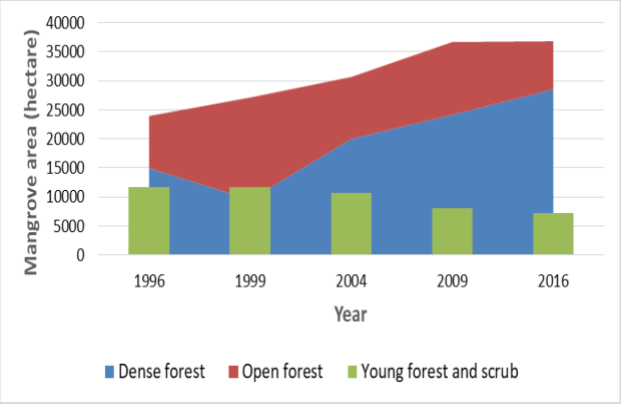
Sub-classes	**Area 2009**		**Area 2016**		**Changed area 2009-2016**	
	ha	%	ha	%	ha	%
Dense forest	24153.61	32.62	28532.50	38.53	+4378.89	+5.91
Open forest	12513.70	16.90	8267.56	11.17	-4246.14	-5.73
Young forest & scrub	8028.78	10.84	7247.15	9.79	-781.63	-1.06
Sub-total	***44696.09***	***60.36***	***44047.21***	***59.48***	***-648.88***	***-0.88***
Agriculture land	1094.98	1.48	2041.58	2.76	+946.60	+1.28
Water body	26992.59	36.45	*25228.34*	*34.07*	-1764.25	-2.38
Barren land	1265.09	1.71	2731.62	3.69	+1466.53	+1.98
Sub-total	***29352.66***	***39.64***	***30001.55***	***40.52***	***+648.89***	***+0.88***
Total	**74048.75**	**100.00**	**74048.75**	**100.00**		

CONCLUSIONS AND DISCUSSIONS

In this study, we have used satellite imagery from SPOT, Landsat OLI for

assessing mangrove forest dynamics at Can Gio Biosphere Reserve for 20 years (from 1996 to 2016). The results are summarized are shown in Diagram No. 1: The results show that; young and scrub mangrove forests area in Can Gio Biosphere have always been reduced over the periods from 1996 to 2016; there are in 1996 (11,714.64 ha); in 1999 (11,724.94 ha); in 2004 (10,758.08 ha); in 2009 (8,028.78 ha) and in 2016 (7,247.15 ha). Although according to the annual Can Gio Biosphere Reserve reports, the area of mangroves has been expanded by afforestation or regeneration of natural forests. However, some young forest areas have been converted into open mangrove forest and rich mangrove forest.

Statistical results from satellite images have also shown that; The open mangrove forest area has also increased over the period 1996 to 2009, there are in 1996 (8,975.61 ha); in 1999 (17,570.84 ha); in 2004 (10,649.23 ha) and 2009 (12,513.70 ha), and the area has not changed much in the periods from 2009 (12,513.70 ha) to 2016 (8,267.57 ha). The reasons are that the area of young mangrove forest converted to open mangrove forests, and some open mangrove forest area converted to the rich mangrove forest area are equivalent.



Histogram No. 1: Distribution of mangrove forests area over periods of 1996, 1999, 2004, 2009 and 2016

The study also showed that: The area of rich mangroves has always increased over the periods from 1996 to 2016, there area in 1996 (14,969.33 ha); in 1999 (9,546.98 ha); in 2004 (20,003.06 ha); in 2009 (24,153.61 ha) and in 2016 (28,532.50 ha). These are proven results for the conservation and development of mangroves that have been implemented well in Can Gio Mangrove Reserve, Vietnam.

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