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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

Can Gio mangrove forest is first biosphere reserve in Vietnam, on January 21st 2000, the MAB/UNESCO Committee recognized the Can Gio mangrove like as International Biosphere Reserve. According to the MAB/UNESCO committee, every biosphere reserve should be assessed 10 years one time, the criteria and standard should be reviewed, including information of the vegetation cover. This study used 45 sample plots in the filed and application of Remote Sensing and Geographic Information Systems (RS & GIS) technology for mapping and then analysis of mangrove forest changes in the period of 20-years (1996-2016). The results show that, from the SPOT, Landsat OLI satellite imagery, we can building the land cover maps in Can Gio Mangrove Biosphere Reserve including periods of 1996, 1999, 2004, 2009 and 2016 with six classes area dense mangrove forest, open mangrove forest, young mangrove forest & scrub, agriculture land, water body and barren land. The land cover maps was established accuracy for 1996, 1999, 2004, 2009 and 2016 with 84.89%, 83.89%, 87.78%, 82.78%, 84.44% respectively.

Keyword: Mangrove forest; Monitoring; Remote sensing; GIS

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Introduction

Vietnam is the peninsula (Indochinese Peninsula) with 3260km long coastline. Out of eight International Biosphere Reserves (IBRs) in Vietnam, seven IBRs comprise of long coastal and coastal rich natural resources including mangroves [1]. Vietnam is one of the countries most affected by climate change. In recent times, we have seen increasingly changeable weather, and natural disasters especially storms and floods are more common. Drought and floods caused widespread damages to the country in 2006, 2007, 2009 and 2015. The southern Vietnam such as Ho Chi Minh city, and Can Tho Ca Mau provinces had never suffered from floods in the past, but now they are regularly hit. In June 2009, the Ministry of Natural Resources and Environment projected a possible scenario of climate change, and asked the departments to develop an action plan concerning to the rising of sea levels. According to this scenario, by the end of 21st century the temperature in Vietnam will have increased by 2.3^{o}C compared to 1980-1999; and most of the area (agricultural land, residential land, mangrove forest etc.) will be flooded in the southern provinces [2]. The Can Gio Biosphere Reserve, lying entirely within the Can Gio district in southern Vietnam, is an important mangrove forest ecosystem, and regarded as the "green lungs" of the region [3]. Due to its international significance, it was recognized as the first International IBR in Vietnam by the MAB/UNESCO committee in 2000 [4]. After serious damage suffered during the Vietnamese war, the reserve is currently under threat to global climate change and sea level rise along the downstream of the Mekong river. There are around 58,000 people living within the boundaries of this reserve, whereas around 54,000 people live in the transition area [5]. The local people are mixed of different origins and ethnical groups. Hence, a mixture of culture and social system 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 fire woods. The livelihood of the local people depends on mangrove forests directly or indirectly. The scientific management of the mangrove forests is extremely important not only for the conservation of natural coastal environment but also for safeguarding the livelihood of thousands of local people.

The propose of this study is remote sensing data and geographical information system (GIS)

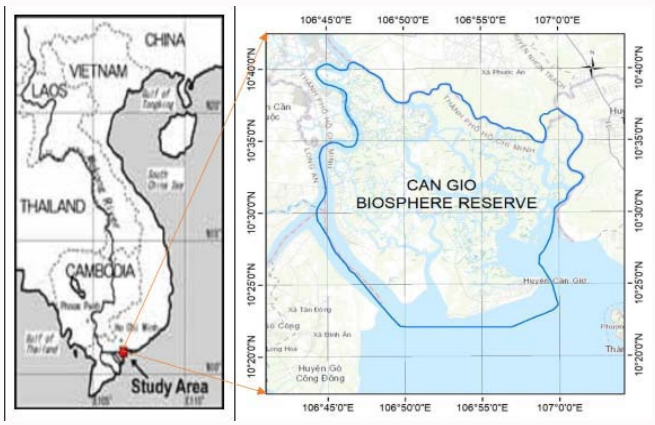


Figure 1: Local map of study area (Can Gio Biosphere Reserve).

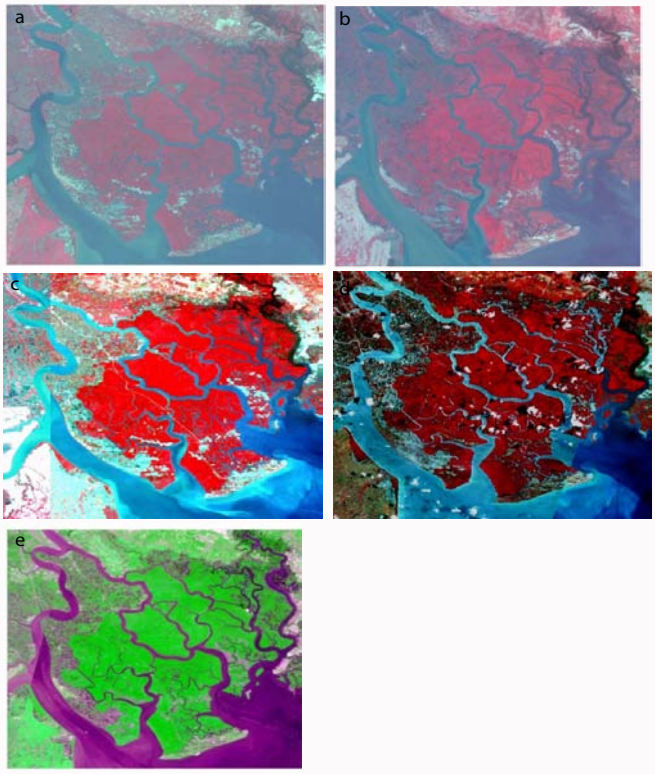


Figure 2: False colour composite of SPOT HRV in 1996 (a), 1999 (b), 2004 (c), 2009 (d), Landsat 8 OLI in 2016 (e).

technology for monitoring of the mangrove forests in Can Gio Biosphere Reserve, an important biosphere reserve of Vietnam and the world.

Study Area

Can Gio mangrove forest lies entirely with the Can Gio district of Ho Chi Minh city, and geographic co-ordinate are latitude 10°22'14N to 10°40'09''N and longitude 106°46'12''E to 107°00' 59''E. Boundaries: adjacence to Nha Be district in the North to East Sea in the South to Dong Nai and Ba Ria – Vung Tau provinces in the East to Long An in the West. The area measures 35km from North to South and 30km from East to West (Figure 1) [5,6].

Data and Methodology

In this study, we used five optical satellite image times are SPOT 4 of 1996, 1999 and SPOT 5 of 2004 and 2009 and Landsat 8 OLI 2016, in which data of 1999, 2004 and 2009 we have inherited from [7-9]. The details of optical satellite data used in the present study are given in Table 1 and Figure 2 the bellow.

Figure 3: Photo from field work: (a) Dense mangrove forest; (b) Open mangrove forest; (c1) Young mangrove forest, (c2) Scrub; (d) Agriculture land; (e) Barren land.

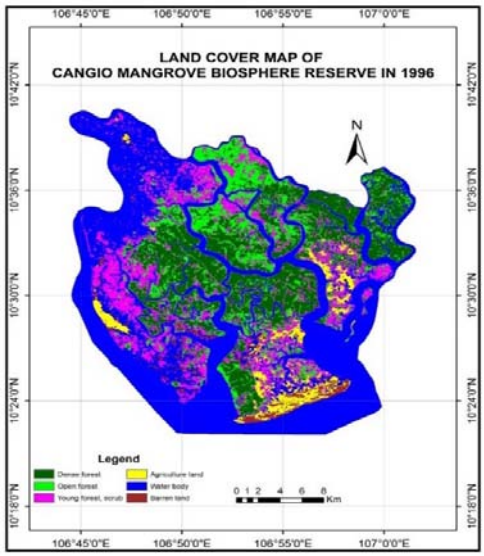


Figure 4: Land cover map in 1996.

Field work

In this study, we used 45 sample plots. The diameter at breast height (D) and total tree height (H) of all the trees larger than 5cm diameter at breast height located inside the sample plots were measured. The tree diameter and height were measured by using

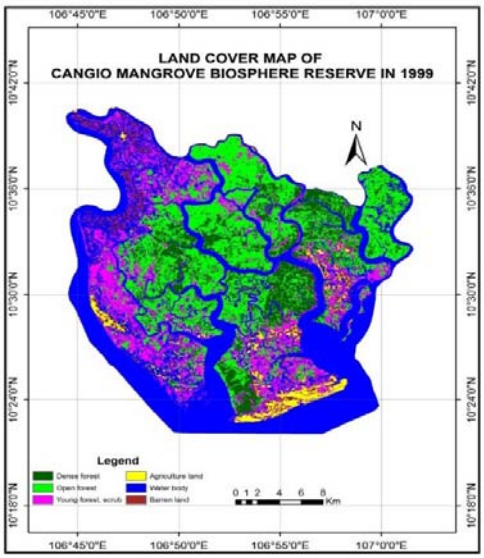


Figure 5: Land cover map in 1999.

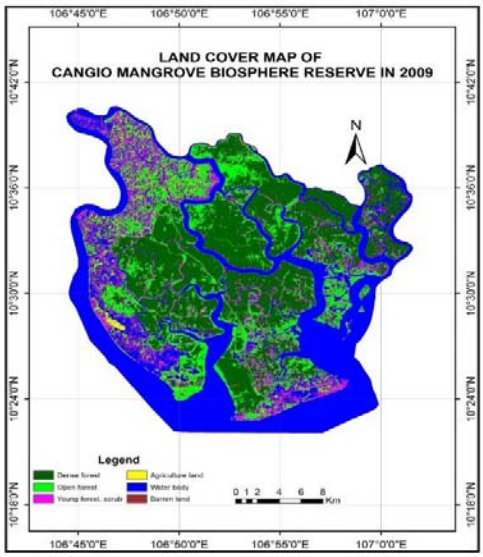


Figure 7: Land cover map in 2009.

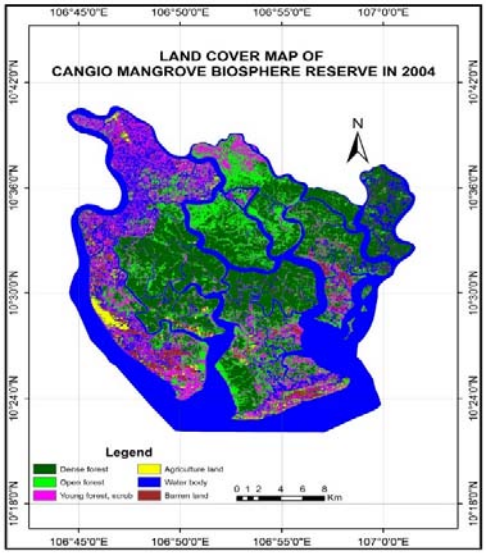


Figure 6: Land cover map in 2004.

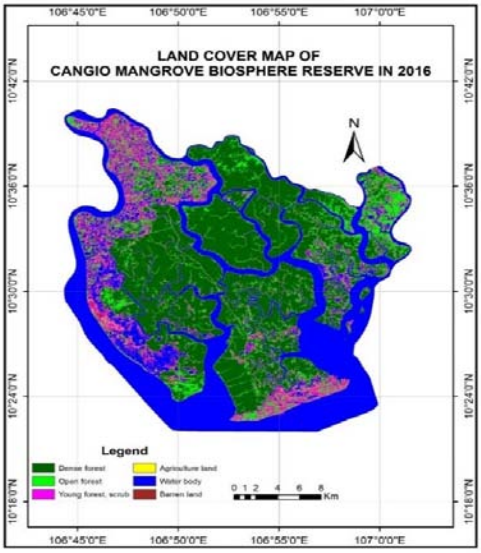
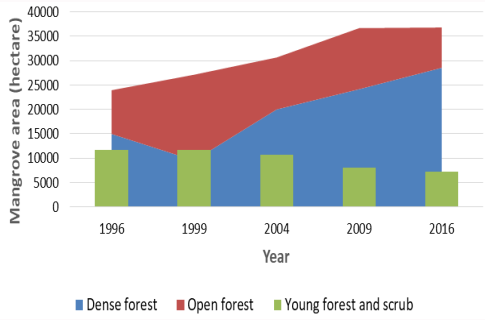


Figure 8: Land cover map in 2016.

laser diameter and laser height instruments respectively. The central geo-location (latitude and longitude) of each sample plot was also recorded by using GPS instrument. The average forest parameters (units per hectare) in each plot were calculated according to the guidelines provided by Hong et al., [10]. The summary of results from filed work is shown in Table 2 (Figure 3).

Land cover classification

From three datasets: SPOT 1996, 1999, 2004, SPOT 2009 and Landsat 8 in 2016. 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 Circular 34/2009/TT-BNNPTNT 'Regulations on the criteria for identifying and classifying forest' [9,11], and was adopted classification criteria of the UNESCO and Thai Van Trung systems. Classification scheme land covers as:



Histogram 1: Distribution of mangrove forests area over periods of 1996, 1999, 2004, 2009 and 2016.

- Level 1 (main classes) have two classes: Forest land and other land (none forest).
- Level 2 (Sub-classes) has six classes: Dense mangrove forest

Table 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	Mar-96	3	1, 2, 3	10
2	Spot 4	HRV	Mar-99	3	1, 2, 3	10
3	Spot 5	HRV	Apr-04	3	1, 2, 3	10
4	Spot 5	HRV	Mar-09	3	1, 2, 3	10
5	Landsat 8	OLI, TIRS	Jan-16	4	3,4,5 (8)	30 (15)

Table 2: Sumarry of forest inventory parameters data in Can Gio Mangrove Reserve.

Parameter	Forest inventory parameters			
	Minimum	Maxmum	Mean	Standard Deviation
Diameter (m)	5.83	17.6	11.1	3.25
Height (m)	6.34	17.04	13.84	2.85
Woody volume ($m^3.ha^{-1}$)	8.27	206.03	136.56	64.26

Table 3: 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**

Table 4: 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**

(dense forest), Open mangrove forest (opened forest), Young forest & scrub (young forest and scrub mixed), Agriculture land, Water body, and Barren land.

Processing of satellite data

Processing of satellite data in this study including: Geometric correction; Image to map rectification; Image to Image registration; Image fussion; Change analysis [12]. In this study using the Post classification comparison method (based supervised 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 [13]. In this study was used GIS software for image processing and data analysis are ENVI 5.3 and ERDAS IMAGINE 2015 with the license was supported from Space Technology Institute, Vietnam.

Results

Land cover mapping

Land cover map in 1996: The land cover map based on supervised classification of SPOT 1996 had given in Figure 4 and the area analysis of land cover had given in Table 3.

The dense forest area is 20.22%, open forest is 12.12%, young forest and scrub are 15.82%, agriculture land is 3.56%, water body is 46.29% and barren land is 3.56% (Table 3).

The overall accuracy is 84.89% and average accuracy of 82.95%. Kappa statistics (K) is 0.7994.

Land cover map in 1999: The land cover map based on supervised classification of SPOT 1999 had given in Figure 5 and the area analysis of land cover had given in Table 4.

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 4).

Classification accuracy assessment based on confusion matrix. The results of the overall accuracy are 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 6 and the area analysis of land cover had given in Table 5.

Table 5: 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**
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**

Table 6: 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	12513.7	16.9
	Young & Scrup	802878	8028.78	10.84
	Sub-total		**44696.09**	**60.36**
Other land	Agriculture land	109498	1094.98	1.48
	Water body	2699259	26992.59	36.45
	Barren land	126509	1265.09	1.71
	Sub-total		**29352.66**	**39.64**
Total			**74048.75**	**100**

Table 7: 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	28532.5	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**

Table 8: 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	10.3	0.01
Sub-total	**35659.58**	**48.16**	**38842.76**	**52.46**	**3183.18**	**4.3**
Agriculture land	2636.93	3.56	2045.64	2.76	-591.29	-0.8
Water body	34280.02	46.29	30855.32	41.67	-3424.7	-4.62
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**	**-4.3**
Total	**74048.75**		**74048.75**	**100**		

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 5).

The classification accuracy based on confusion matrix had estimated. The results of the overall accuracy of mapping are 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 5.

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 6).

Table 9: 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	-1.5
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**	**74048.75**	**100**		

The accuracy assessment based on confusion matrix. The results of the overall classification accuracy based on confusion matrix are 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 7.

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 7).

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 3183.18 ha, there include rich forest (-5422.35 ha), open forest (8595.23 ha) and young forest and scrub (10.30 ha). Other land area has changed by 3183.18 ha, there include agriculture land (-591.29ha), water body (-3424.70 ha) and barren land (-3183.18ha) (Table 8).

Period from 1999 to 2004: The total area of forest land area has changed to 2567.61 ha, there include rich forest (-10456.08 ha), open forest (-6921.61 ha) and young forest and scrub (-966.86 ha). Other land area has changed by (-2567.61 ha), there include agriculture land (-1109.58ha), water body (-1494.58 ha) and barren land 36.26 ha (Table 9).

Period from 2004 to 2009: The total area of forest land area has changed to 3285.72 ha, there include rich forest 4150.55 ha, open forest 1864.47 ha and young forest and scrub (-2729.30 ha). Other land area has changed by (-3285.72 ha), there include agriculture land 158.92 ha, water body (-2368.44 ha) and barren land (-1076.20 ha), (Table 10).

Period from 2009 to 2016: The total area of forest land area has changed to 3285.72 ha, there include rich forest (-648.88 ha), open

Table 10: 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	12513.7	16.9	1864.47	2.52
Young forest & scrub	10758.08	14.53	8028.78	10.84	-2729.3	-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	-3.2
Barren land	2341.29	3.16	1265.09	1.71	-1076.2	-1.45
Sub-total	**32638.38**	**44.08**	**29352.66**	**39.64**	**-3285.72**	**-4.44**
Total	**74048.75**	**100**	**74048.75**	**100**		

Table 11: 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	28532.5	38.53	4378.89	5.91
Open forest	12513.7	16.9	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	946.6	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**	**74048.75**	**100**		

forest (-4246.14 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 (-1764.25 ha) and barren land 1466.53 ha (Table 11, Histogram 1).

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 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 (11714.64 ha); in 1999 (11724.94 ha); in 2004 (10758.08 ha); in 2009 (8028.78 ha) and in 2016 (7247.15 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. This is because 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 (8975.61 ha); in 1999 (17570.84 ha); in 2004 (10649.23 ha) and 2009 (12513.70 ha), and the area has not changed much in the periods from 2009 (12513.70 ha) to 2016 (8267.57 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.

The study also showed that: The area of rich mangroves has always increased over the periods from 1996 to 2016, there area in 1996 (14969.33 ha); in 1999 (9546.98 ha); in 2004 (20003.06 ha); in 2009 (24153.61 ha) and in 2016 (28532.50 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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