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Monitoring Riverbank Erosion in Can Gio Mangroves

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1. Introduction

Four major rivers and their tributaries traverse the Can Gio mangroves before draining into the East Sea. They are Soai Rap, Dong Tranh, Nga Bay and Thi Vai (Figure 1). Together they cover an area of 22,160 ha or ~20% of the Can Gio district. These large rivers together with small ones such as Long Tau are the main shipping lanes, enabling cargo tankers and ships of up to 20,000 tonnes carrying capacity to enter into the port of Ho Chi Minh City (HCMC) (Luong, 2011).

The Steering Committee for Flood and Storms (SCFS) of HCMC has identified 36 areas with high risk of erosion (SCFS, 2010). They included the districts of Binh Thanh, Nha Be and Can Gio. In Can Gio district, vulnerable areas are the riverbanks of Nha Be, Nga Bay, Long Tau and Soai Rap. Passing tankers and ships create water disturbance in the form of primary and secondary waves (also known as wash). These waves would scour the riverbanks causing erosion in the form of bank collapse and toppling of mangrove trees.

In addition to riverbank erosion, coastal areas bordering the East Sea are subjected to severe coastal erosion. With climate change such as sea-level rise and extreme weather conditions such as coastal storms and typhoons, the problem of coastal erosion would be further aggravated.

Erosion in Can Gio mangroves is more extensive than accretion. The problem of riverbank and coastal erosion needs to be addressed as it leads to loss of land and human property. This study on the monitoring of riverbank erosion in Can Gio is aimed at providing information on the severity of erosion along the banks of selected rivers, which will be made available to decision makers, planners and resource managers.

2. Materials and Methods

Satellite imageries and maps from previous years of Can Gio were collected for data analysis. The rivers studied were Dua, Nga Bay, Long Tau and Tac Roi (Figure 1). In the field, bamboo stakes were piled into the ground as markers to monitor the rate of bank erosion along the banks of studied rivers. The distance between stakes was 100 m along the riverbank and at each location, two stakes were piled (Figure 2). The first stake was 2 m and the second stake was 20 m from the riverbank. The total length of the four studied rivers was 78 km with 780 numbered stakes. Using GPS to determine coordinates, the positions of the stakes along the riverbanks were recorded. Monitoring was done annually with missing stakes replaced and their positions recorded.

Figure 1 Major rivers of Can Gio mangroves and rivers where riverbank erosion was monitored

Estuaries of major rivers
(a: Soai Rap, b: Dong Tranh, c: Nga Bay and d: Thi Vai)

Study sites
(1: Dua, 2: Nga Bay, 3: Long Tau and 4: Tac Roi)

Along the eroding riverbanks, 10 x 10 m plots were set up in four different habitat types. They were mixed natural forests, *Rhizophora* plantations, *Nypa* forests and bare land. In each habitat type, three plots were established, and enumerations and measurements were made every three months for two years.

The data were processed using GPS to determine the coordinates of the plots and stakes, which were transferred onto digital maps *via* MapSource Version 5.7 program and MapInfo 7.5.

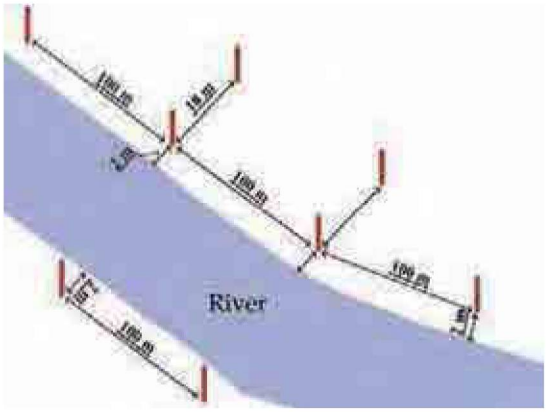

Figure 2 Positions of bamboo stakes piled along the riverbank to monitor erosion

The following procedures described by Minh *et al.* (2002) and Hirose *et al.* (2004) were used to interpret satellite images of mangrove vegetation. Satellite images of Landsat MSS 1972 (http://glcf.umiacs.umd.edu) and Spot Image 2006 (http://imar.usf.edu) were interpreted using the ENVI 4.0 program (Figure 3). Using the MapInfo program, the coordinates of rivers and plots in the studied sites were digitized. The average rate of erosion between two periods was calculated using the following formulae:

Average rate of erosion (E) = Wr/(time interval from 1972–2006)

$Wr = (SR2 - SR1)/(Lr \times 2)$

Wr: average width eroded away on both sides of the river
SR1: area of the river in 1972
SR2: area of the river in 2006
Lr: length of river

3. Results and Discussion

A total of 780 bamboo stakes were piled along the riverbanks in 17 locations (including two communes of An Hua and An Phouc) of 12 forest compartments

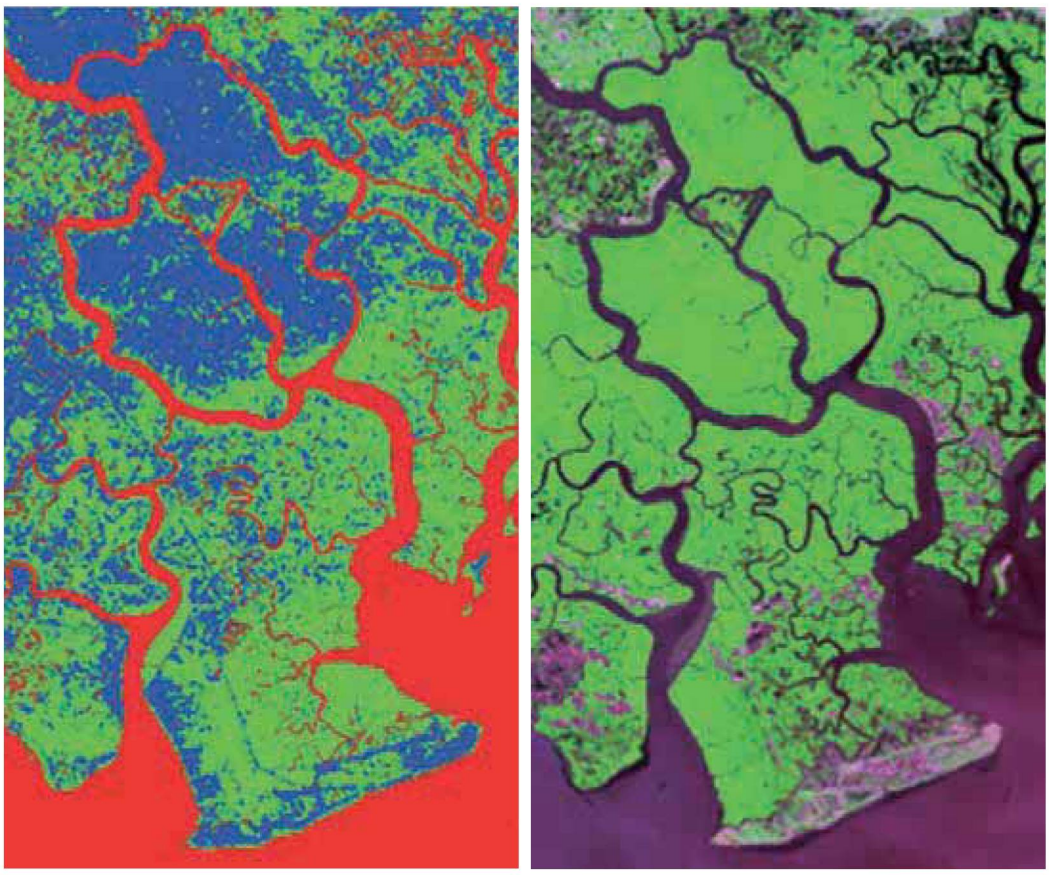

Figure 3 Landsat MSS 1972 (left) and Spot Image 2006 (right) analysed using the ENVI 4.0 program

(Table 1). Long Tau and Nga Bay rivers had the most number of stakes as they are two major waterways used by cargo tankers and ships to reach the port of HCMC (Figure 4). Dua and Tac Roi rivers are smaller rivers used mainly by passenger speedboats commuting between Vung Tau and HCMC.

Table 1 Number and location of bamboo stakes along the studied riverbanks

Forest Compartment	Rivers				Total
	Dua	Long Tau	Nga Bay	Tac Roi	
3	62		4		66
7			44		44
11		11			11
12		41			41
13		8	85		93
18			38		38
19			55		55
24		63			63
10a		36			36
4a		75			75
4b	24				24
5a		18			18
5b		29			29
6a		41			41
6b	39	49			88
An Hoa				35	35
An Phuoc				23	23
Total	125	371	226	58	780

Figure 4 Cargo ships (top) and passenger speedboat (bottom) using the Can Gio rivers

Results showed that Long Tau (1.73 ± 0.47 m/yr) and Nga Bay (1.87 ± 0.40 m/yr) experienced higher rates of erosion than Dua (1.43 ± 0.36 m/yr) and Tac Roi (1.44 ± 0.36 m/yr). However, the differences in erosion rates were not significantly different at 95% confidence level between rivers (Table 2). This implied that larger rivers used by tankers and ships had comparable erosion rates as smaller rivers used by boats. Within rivers, the differences in values were also insignificant. The only exception was in Nga Bay where the erosion rate of FC7 (2.32 ± 0.27 m/yr) was significantly greater than FC3 (1.51 ± 0.26 m/yr).

Table 2 Erosion rates of riverbanks

Location	Rate of erosion (m/yr)			
	Dua	Long Tau	Nga Bay	Tac Roi
FC3	1.42 ± 0.35		1.51 ± 0.26	
FC7			2.32 ± 0.37	
FC11		2.16 ± 0.51		
FC12		1.88 ± 0.42		
FC13		2.01 ± 0.40	1.72 ± 0.28	
FC18			1.73 ± 0.32	
FC19			2.06 ± 0.37	
FC24		1.84 ± 0.42		
FC10a		1.95 ± 0.38		
FC4a		1.44 ± 0.37		
FC4b	1.35 ± 0.26			
FC5a		1.88 ± 0.31		
FC5b		1.58 ± 0.57		
FC6a		1.58 ± 0.48		
FC6b	1.52 ± 0.42	1.73 ± 0.44		
An Hoa				1.36 ± 0.33
An Phuoc				1.53 ± 0.39
Erosion	1.43 ± 0.36[a]	1.73 ± 0.47[a]	1.87 ± 0.40[a]	1.44 ± 0.36[a]

FC: forest compartment, Same letters in superscript indicate non-significant difference at 95% confidence level

Data showed that the erosion rates of plots with forests were less severe than plots located on bare land (Table 3). Examples of erosion of riverbanks with and without vegetation are shown in Figure 5.

The data on erosion rates obtained from the bamboo stakes from December 1970 to November 2009 were compared between habitat types (plantations, natural forests and bare land), and between the rainy season of May to November and the dry season of December to April (Table 4).

Between habitat types, the rate of erosion was 1.6 m/yr for plantations and natural forests compared to 1.8 m/yr for bare land. This finding was consistent with the results obtained from the vegetation plots.

Between seasons, the erosion rate during the rainy season (1.00 ± 0.02 m/yr) was significantly higher

Figure 5 Erosion of riverbanks without vegetation (top) and with vegetation (bottom)

Table 3 Erosion rates of plots in different habitats

Plot	Habitat type	Dominant vegetation	N/ha	$D_{1.3}$ (cm)	H_{total} (m)	Erosion (m/yr)
B1	Bare land	Grasses				1.3
B2						2.6
B3						1.7
NP1	*Nypa* forest	*Nypa*				1.7
NP2						1.3
NP3						1.3
MF1	Man-made forest	*Rhizophora*	3,300	6.0	5.5	1.2
MF2			2,100	7.0	7.5	1.3
MF3			2,500	14.0	13.0	1.8
NF1	Natural forest	*Avicennia*	1,900	0.3	1.0	2.2
NF2		*Ceriops*	6,000	3.5	5.5	1.6
NF3		*Avicennia*	2,500	6.2	13.0	1.8

B: Bare land, NP: *Nypa* palm, MF: Man-made forest and NF: Natural forest

than during the dry erosion (0.71 ± 0.02 m/yr) at the 95% confidence level. The greater rate of erosion during the rainy season may be attributed to rainfall which loosens the soil particles making them more vulnerable to erosion by waves. A comparison was also made between both banks of the rivers (Table 5). Overall, there was no significant difference between the right bank (1.69 ± 0.38 m/yr) and the left bank (1.60 ± 0.36 m/yr).

Table 4 Level of erosion in the forest types

Habitat type	Dec 07 - Apr 08	May 08 - Nov 08	Dec 08 - Apr 09	May 09 - Nov 09	Erosion (m/yr)
I. Plantations					
- *R. apiculata*	0.3	1.3	0.8	1.0	1.7
- *Eucalyptus*	0.3	0.7	0.4	1.0	1.2
- *R. mucronata*	0.1	1.5	0.9	0.8	1.7
- *Acacia*	0.0	1.7	0.7	1.2	1.8
II. Natural forests					
- *Rhizophora*	0.4	1.4	0.8	1.3	2.0
- *Sonneratia*	0.2	1.0	0.7	0.7	1.3
- Shrub	0.1	1.5	0.7	1.3	1.8
- *Phoenix*	0.0	0.9	0.3	1.4	1.3
- *Ceriops*	0.3	1.2	0.9	1.1	1.7
- *Avicennia*	0.2	0.7	0.8	0.7	1.2
- *Excoecaria*	0.4	1.0	0.7	1.3	1.7
- *Nypa*	0.1	1.2	0.6	1.3	1.6
- Mixed forest	0.2	1.3	0.7	1.2	1.7
III. Bare land					
- *Rhizophora*	0.3	0.5	0.7	1.4	1.5
- *Avicennia*	0.2	0.9	1.3	1.2	1.8
- *Xylocarpus*	0.0	1.2	0.6	0.7	1.3
- *Nypa*	0.2	1.5	0.8	1.1	1.7
- *Eucalyptus*	0.3	1.9	0.2	2.4	2.4
- *Phoenix*	0.2	0.5	0.0	1.4	1.1
- Mixed	0.4	1.2	0.7	1.3	1.8

Table 5 Erosion on the right and left banks of the rivers

River	Right bank		Left bank	
	Location	Erosion(m/yr)	Location	Erosion(m/yr)
Dua	3	1.42 ± 0.35	4b	1.35 ± 0.27
			6b	1.52 ± 0.44
Long Tau	4a	1.44 ± 0.37	10a	1.95 ± 0.38
	6a	1.58 ± 0.48	5a	1.88 ± 0.31
	24	1.85 ± 0.42	5b	1.58 ± 0.57
			11	2.16 ± 0.51
			12	1.89 ± 0.42
Nga Bay	7	2.32 ± 0.37	13	1.74 ± 0.30
	19	2.06 ± 0.37	18	1.73 ± 0.32
Tac Roi	An Phuoc	1.53 ± 0.39	An Hoa	1.36 ± 0.33
Average		1.69 ± 0.38^{a}		1.60 ± 0.36^{a}

Same letters in superscript indicate non-significant difference at 95% confidence level

4. Conclusion

The average erosion of the four rivers studied was 1.7 m/yr. This would imply that Can Gio mangrove forests are losing ~133,500 m^2/yr of land to erosion. The presence of trees along the rivers has a positive effect in limiting riverbank erosion as forested areas tend to erode at lower rates than bare soils. There is greater erosion during the rainy season than during the dry season. The effects of waves generated by cargo tankers and ships, and passenger boats warrant further investigations.

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