

**SELECTION OF APPROPRIATE MANGROVE SPECIES AND
PLANTING TECHNIQUES IN GO CONG DONG DISTRICT (TIEN GIANG
PROVINCE) AND PHU TAN DISTRICT (CA MAU PROVINCE)**

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1. Introduction

Mangrove forests are a very important part of the natural environment, and located in the coastal wetland ecosystem. Mangroves reduce the height and energy of swell waves passing through them, height wave is rapidly diminished. Mazda (1997) showed that 1.5km wide mangrove belt of 6 years old *Kandelia obovata* had reduced wave height from 1m offshore to 5cm when it reached aquaculture pond bank^{[4][10]}. Consequently, mangroves are considered as a "green wall" to protect sea dykes and coasts from erosion due to the impact of waves, currents, and to diminish saline intrusion, etc.

However, the negative impacts of climate change and sea level rise as well as the strong development of many economic sectors have badly affected the coastal mangroves. Consequently, mangrove forests are decreasing in area, mangrove forests quality is reduced, the protection function of mangrove forest is limited. Some coastal areas without protected mangrove forests faced with the impact of natural disasters such as storms, floods, tides, waves, winds.

It is necessary to restore mangrove belt in degraded mangrove areas. There are two important factors that affect the success of the rehabilitation of degraded mangroves in the Mekong Delta. They are topographical conditions suitable for mangroves and high wave heights. Therefore, in order to restore mangrove forests, mangrove species should be selected in accordance with topographical conditions and supportive technologies for mangrove planting.

This study presents the research on selection of appropriate mangrove species and technology solutions for mangrove plantation in two typical areas in the Mekong Delta, Go Cong Dong district, Tien Giang province and Phu Tan district, Ca Mau province.

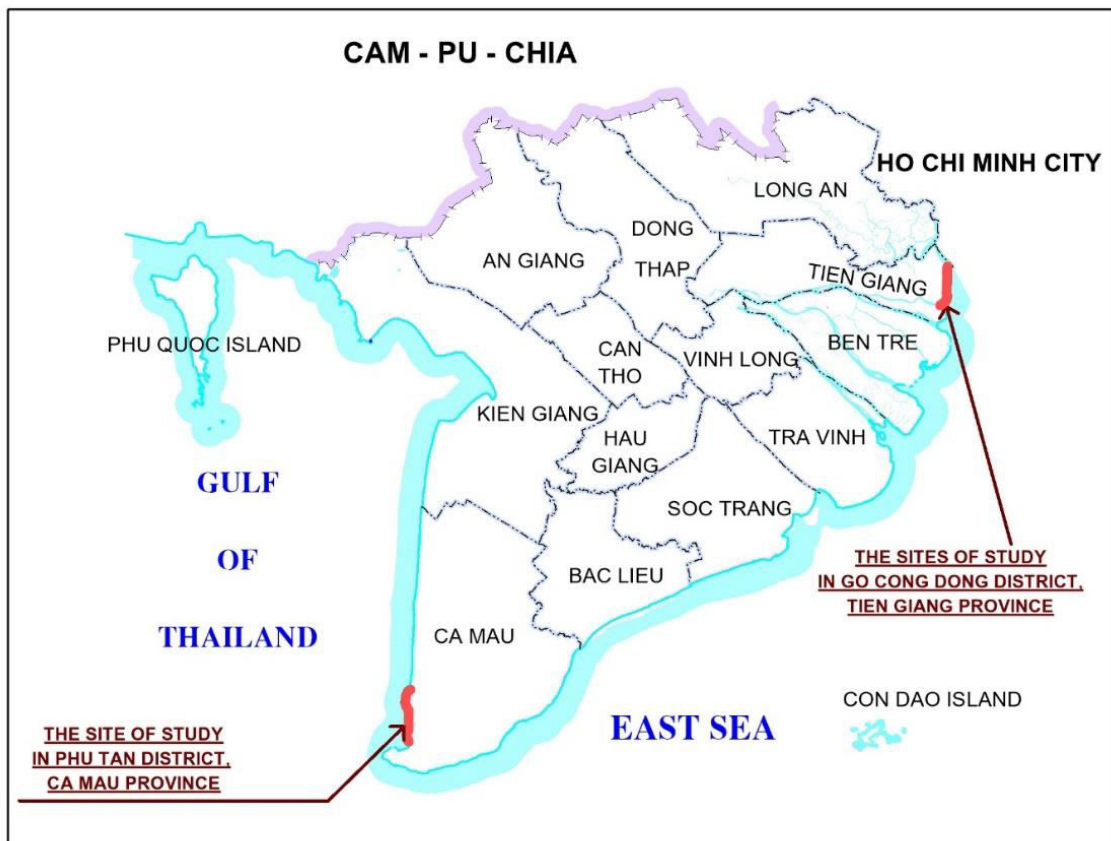


Figure 1. Map of sites of study

2. Content and methodology

2.1. Time and research site

The study period is from August, 2017 until October, 2017.

Coastal mudflats in Go Cong Dong District, Tien Giang Province;

Coastal mudflats in Phu Tan District, Ca Mau Province;

Mudflats inside concrete piles in Dam Doi, Tran Van Thoi and U Minh districts of Ca Mau province.

2.2. Research methods

Secondary data collection

Collecting materials and research of previous authors related to the study area for the analysis, evaluation and selection of appropriate mangrove species and the best techniques for mangroves planting.

Survey method of composition and distribution of mangrove species in the study area

- Identification of mangrove species based on Ngo Dinh Que^[3];
 - Set up a survey line, select representative site for the area, 3 survey points were selected per each area and 5 trees/species were randomly selected per each survey site. Then, the growth and development index of the mangrove species, (tree age, tree height, diameter of base of trunk) at each site were evaluated.
 - + Height of tree (m): Measure from the ground to the top of the tree.
 - + Diameter of trunk base(cm): Was measured two times perpendicularly by vernier caliper at the root of the tree in trees that measured tree height.
 - Survey on the natural conditions of each area, then classifying the alluvial flats based on some criteria such as: elevation of mudflat, tidal inundation, salinity.
 - Comparing the field conditions and ecological requirements of each tree species.
- Selection of suitable mangrove species based on analysed data.

Methods of soil sampling and analysis

- Use method of S. English et al., (1997) for collecting soil samples^[9]: due to the newly planted mangrove roots system underground from 0 cm to 40cm in depth, so soil sample depth is 0-40cm. In Sao Luoi canal mouth, 3 soil samples were randomly collected perpendicular to the shoreline. 3 samples, 20 meters apart in sampling concrete piles areas. Soil samples were taken at 10cm and 40cm in depth, then analysed at Institute of Agricultural Planning and Projection with index: Soil texture (clay, silt, sandy), pH, OM, digestible N, total N, digestible P₂O₅, total P₂O₅, digestible K₂O, total K₂O (Vietnam standard 4046: 1985^[5]).

Methods of topographic survey

Use TOPCOM machine with angle accuracy : $m\beta = \pm 1''$, edge accuracy $m_s = 2\text{mm} + 2\text{ppm}$, using national coordinate system according to fourth-order bench mark to measure topography, elevation; topographic of model building area, measuring the terrain in cross-section, each cross section is 50 meters apart^[6].

Methods of topographic mapping

Use MapInfo software to identify and delineate the map of mangrove forest in the study area.

Coordinate system and grid projection: According to regulation of the coordinate system and grid projection VN 2000-projection for Vietnam.

Methods of Data Processing

Use Excel to process data collection, investigation and survey.

3. RESEARCH RESULTS

3.1. Selection of suitable mangrove species in Go Cong Dong district, Tien Giang province and Phu Tan district, Ca Mau province

3.1.1. Status of mangroves in the study area

Status of coastal mangroves in Go Cong Dong district, Tien Giang province:

Mangrove forest communities distributed along the coastal zone of Go Cong Dong district as follows:

- On Vam Lang town (starting at Vam Lang drainage at Soai Rap), areas outside the dike have high topography (due to sediment accumulation), the areas adjacent to the dike side are slightly higher, the center are low-lying areas. The higher layer has some species such as *Sonneratia caseolaris*, *Rhizophora apiculata*. The lower layer has some species such as *Avicennia marina*, *Ceriops tagal*, *Nypa fruticans*, *Ceriops decandra*. *Rhizophora apiculata* species has average density. *C. tagal* species grows in less submerged topography areas (high topography), with many underdeveloped trees.
- From Vam Lang to Rach Bun drainage: there are some communities of *Avicennia marina*, *Ceriops tagal* and *Nypa fruticans* closed to the dyke. The height varies from 7 to 10m for *Avicennia marina* species and 3-5m for *Ceriops tagal* species.
- Around Rach Bun- sediment accumulated area, *Avicennia alba*, *Avicennia officinalis* species grow quite well, especially in lower layer and the coastal side, the young trees grow well.
- From Rach Bun to Tan Thanh commune, *Rhizophora apiculata* is main species.

Distribution of typical mangrove species from sea to inland is *Avicennia marina*, *Rhizophora apiculata*, mixed species with *Ceriops tagal*, *Avicennia officinalis* and *Avicennia alba*.

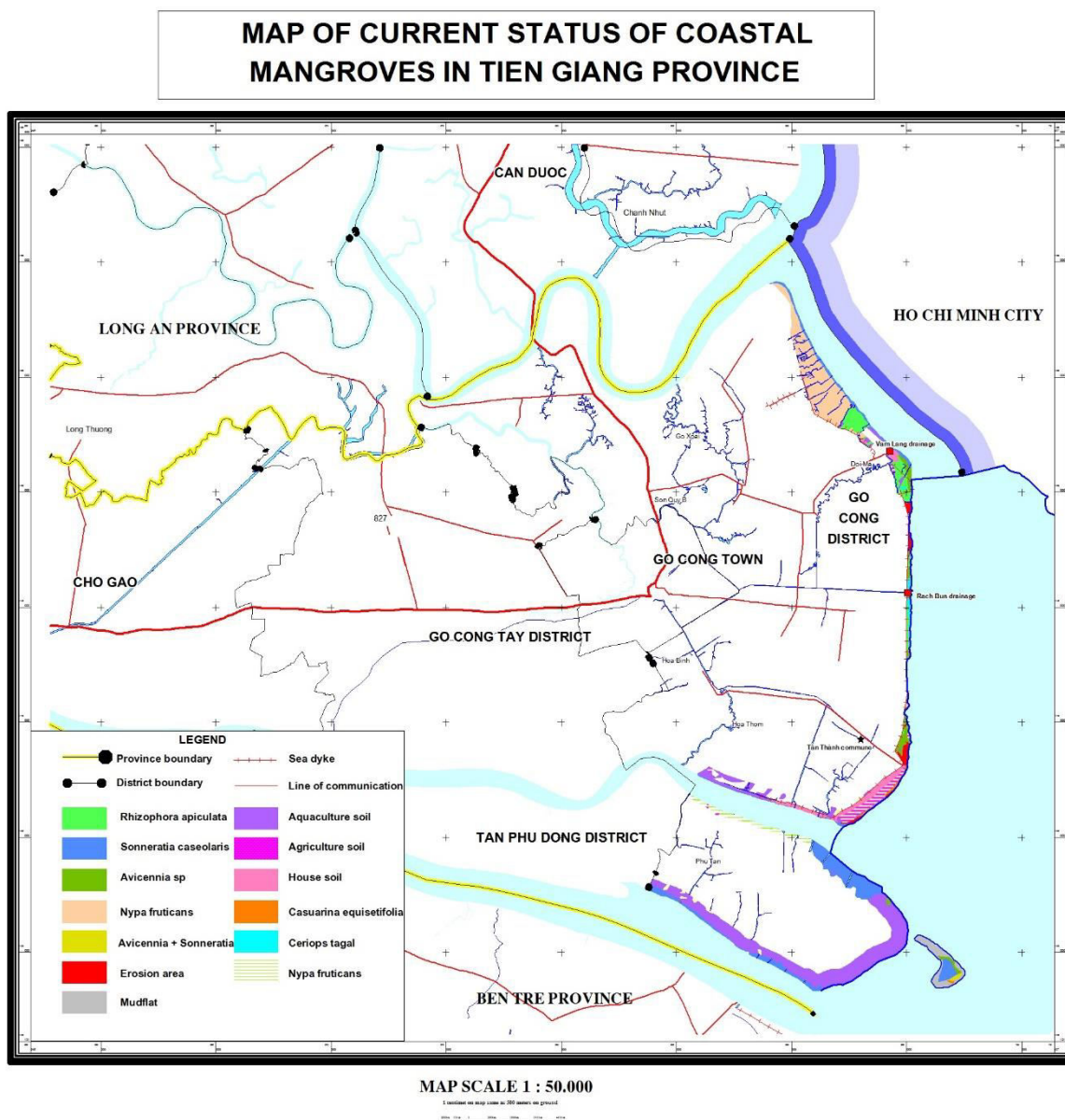


Figure 2. Map of current status of coastal mangroves in Tien Giang province^[9]

Status of coastal mangroves in Phu Tan district, Ca Mau province:

- *A. albais* dominant mangrove species in Ca Mau province and alluvial flat near river canal, can grow with sanility from 10-30‰.
- *A. officinalis* often lives in stable soil area.
- *A. marina* is a pioneer species, especially in areas with high salinity. Itis also dominant one in Ca Mau, often mixed with *A. alba*, *A. Officinalis*.
- *R. apiculata* is the most popular species in Ca Mau, not only in plantation forest but also in natural forest. It is adaptable with areas where the salinity of the surface layer of the soil about 20 - 30 ‰. In Phu Tan coastal area, *R. apiculata* can be developed purely or mixed with *A. alba*, *R. apiculata* or *Nypa fruticans*.

In summary, *A. marina* and *R. apiculata* are the dominat species in mangroves forestsof coastal area of Phu Tan, Ca Mau.

MAP OF THE CURRENT STATUS OF COASTAL MANGROVES AT PHU TAN DISTRICT, CA MAU PROVINCE

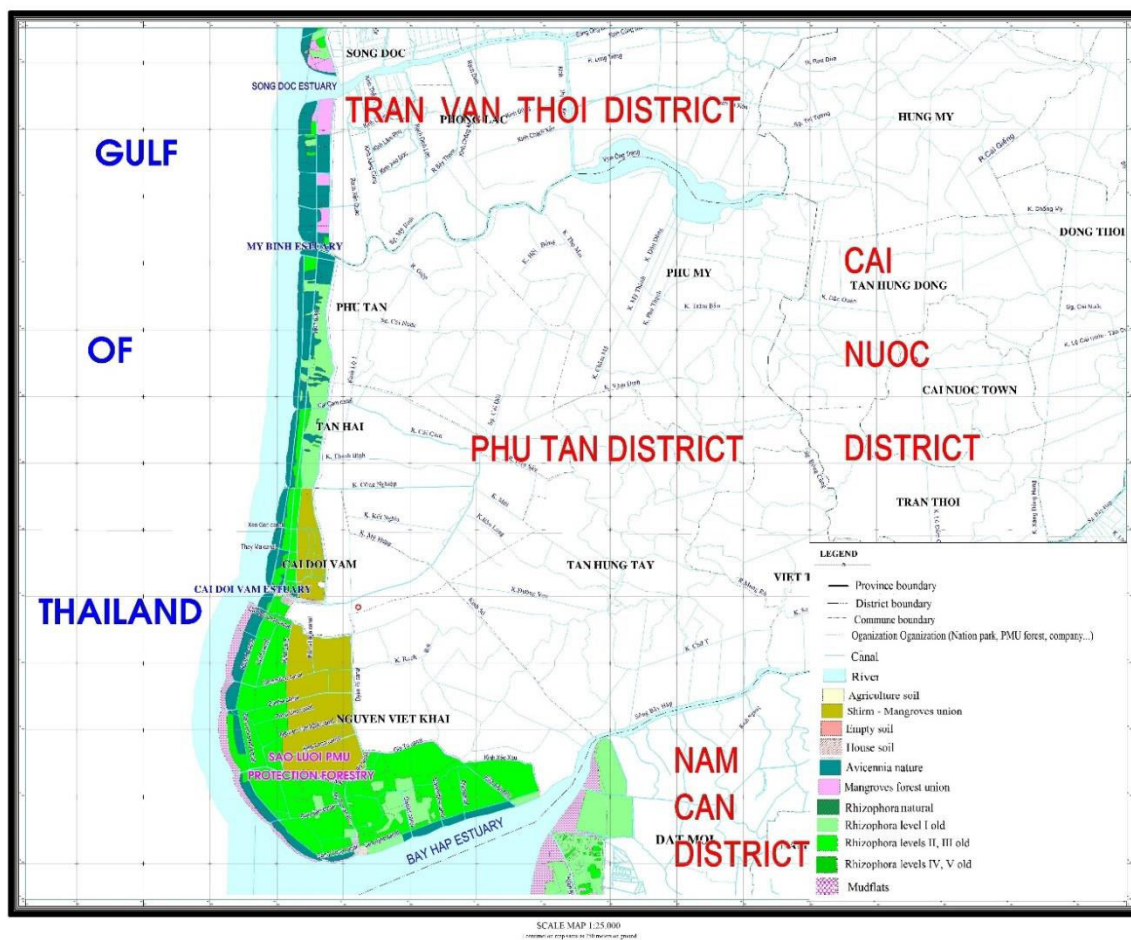


Figure 3. Map of the current status of coastal mangroves in Ca Mau province^[8]

3.1.2. The biological and ecological characteristics of some main mangrove species in the Mekong Delta

Table 1. Biological and ecological characteristics of mangroves species

No	Mangroves species	Salinity of seawater (‰)	Foundation and distribution	Popularity
1	<i>A. marina</i>	20 - 25	In newly accumulated land, less stable soil, soft silt	4
2	<i>A. officinalis</i>	25 - 30	In stable soil area, closer to inland than <i>A. alba</i>	1
3	<i>A. alba</i>	20 -30	In stable silt	4
4	<i>R. apiculata</i>	25 - 30	In soft and stalbe soil	4
5	<i>R. stylosa</i>	25 - 28	In soft and stalbe soil, along the river	1
6	<i>S. alba</i>	15 - 20	Deeply soft mud, new mudflat in estuaries	1
7	<i>S. caseolaris</i>	5 - 15	In brackish water, estuary mudflat, soft mud	3

(Popular species (4), Common species (3), Scattered species (2), Rare species (1))

LMD CZ project: 6.2.1 Restoration of mangrove belts near the coast of the studied sites

3.1.3. Mangrove rehabilitation in the coastal Mekong Delta

- *Advantages and disadvantages of technical solutions for mangrove planting applied in the Mekong Delta:*

There are many technical solutions that support for planting mangrove in erosion area in Mekong Delta such as concrete piles, geotube, T fence, bamboo or melaleuca. However, each solution has its own advantages, disadvantages and application condition. It is important to select the right solution for each specific site. Some *advantages and disadvantages of technical solutions for mangrove planting applied in the Mekong Delta* as following:

Table 2. Analyzing advantages and disadvantages of technology solutions for mangrove planting applied in the Mekong Delta

No	Description	Location	Field conditions	Prices (Euro/m)	Advantages/disadvantages	Note
1	Concrete piles for wave height reduction, accumulation	Ca Mau (Ganh Hao river mouth, Ca Mau Cape, West Sea of Mekong Delta)	Strong wave, medium wave, less sediment	1200-1600	<ul style="list-style-type: none"> - Efficient wave energy reduction and accumulation - Not friendly with environment - No mangroves rehabilitation due to seedlings were prevented by concrete piles - High cost. - May reduce cross shore sediment flux 	<ul style="list-style-type: none"> - Need advanced techniques to decrease the costs - Need to plant new mangrove trees by seedlings after accumulation
2	Geotube for wave height reduction, accumulation	Bac Lieu (Nha Mat)	Strong and medium wave, less sediment	200-400	<ul style="list-style-type: none"> - The foundation have sunk, elevation have reduced due to lack of stability analysis - Quickly damaged - New currents appear along construction 	<ul style="list-style-type: none"> - Apply in stable sandy beach
3	T fence for wave height reduction, Accumulation	Soc Trang (Vinh Tan), Bac Lieu (Vinh Trach Dong), Ca Mau (Khanh Binh Tay)	Strong wave (Soc Trang, Bac Lieu)	40-48	<ul style="list-style-type: none"> - Friendly with environment; - Low cost; - Quickly damaged. - A long term strategy should consider reconstructions 	<ul style="list-style-type: none"> - Applied in area with wave height less than 0,8m - Need mangrove planting immediately after accumulation
4	Bamboo or melaleuca fence for	Soc Trang (Vinh Hai, Vinh Tan),	Wave height 0,6 to 1,2m	48-60	<ul style="list-style-type: none"> - Friendly with environment; - Low cost 	<ul style="list-style-type: none"> - Applied in area with wave height

LMDCZ project: 6.2.1 Restoration of mangrove belts near the coast of the studied sites

	wave height reduction, accumulation	Bac Lieu (Nha Mat, Vinh Trach Dong, Vinh Thinh), Ca Mau (Ca Mau cape, Cai Doi Vam, Khanh Binh Tay), Kien Giang (Nam Thai, Binh Son)	(Soc Trang, Bac Lieu, Ca Mau) Wave height less than 0,8m (Ca Mau cape, Nam Thai, Binh Son)		-Mangroves rehabilitation immediately after the work completion - Quickly damaged - A long term strategy should consider reconstructions	less than 0,8m - Need to combination with wave height reduction work in area with wave height higher than 0,8m
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- *Analyzing the causes of mangrove tree unregeneration in some mudflats behind the concrete piles in coastal area of Ca Mau:*

One of the effective measures for wave, erosion reduction and accretion in Ca Mau province is concrete piles. According to the survey data, alluvial accumulation occurred behind the concrete piles with sedimentation rate of 1m/year after 1 - 2 years of construction completion. However, the problem is that although the alluvial accumulation behind the concrete piles is very good, there are not naturally regenerated mangrove trees after many years of construction. According to requirement of applied solutions for the wave height and current reduction, accumulation and mangrove restoration in Mekong Delta, it must restore the mangrove belt inside to ensure sustainable development. This section will analyze the causes of mangrove tree regeneration inside the concrete piles.

There were some concrete piles built in Dam Doi, Tran Van Thoi and U Minh districts in Ca Mau province. One site behind the concrete piles of Sao Lung canal, Khanh Binh Tay commune, Tran Van Thoi district will be studied, in comparison with the other works in order to analyze, evaluate and clarify the cause of mangrove tree unregeneration.

Location: The selected site is the typical location of the mudflat behind the concrete piles, in front of Sao Luoi canal mouth, Kinh Hon Bac village, Khanh Binh Tay commune, Tran Van Thoi district, Ca Mau province.

Geographic coordinates: from 9°12'24.78"N and 104°48'54.34"E to 9°12'21.49"N and 104°48'53.20"E.



Figure 4. Location of mudflat inside concrete piles at Sao Luoi canal mouth

a) Topographic factor:

The topography sloped downwards from west to east. The elevation of the mudflat inside the concrete piles varied from +0.29 m to +0.13 m (reference level is mean water level). In which, mean high tide level is +0,98 m, mean low tide level is -0,4 m, mean tide level +0,17 m.

Exposed time of study area was calculated based on the Tide Table observed at Song Doc hydrological station (Figure 6).



Figure 5. The topography of mudflat inside concrete piles at Sao Luoi canal

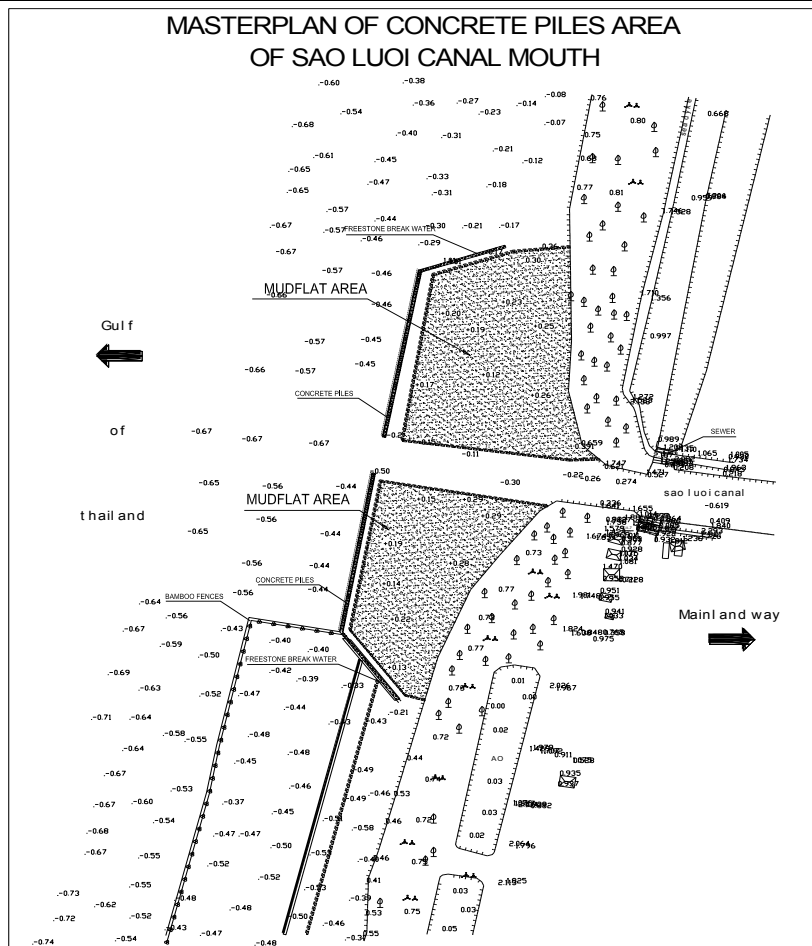


Figure 6. Masterplan of concrete piles area of Sao Luoi canal mouth

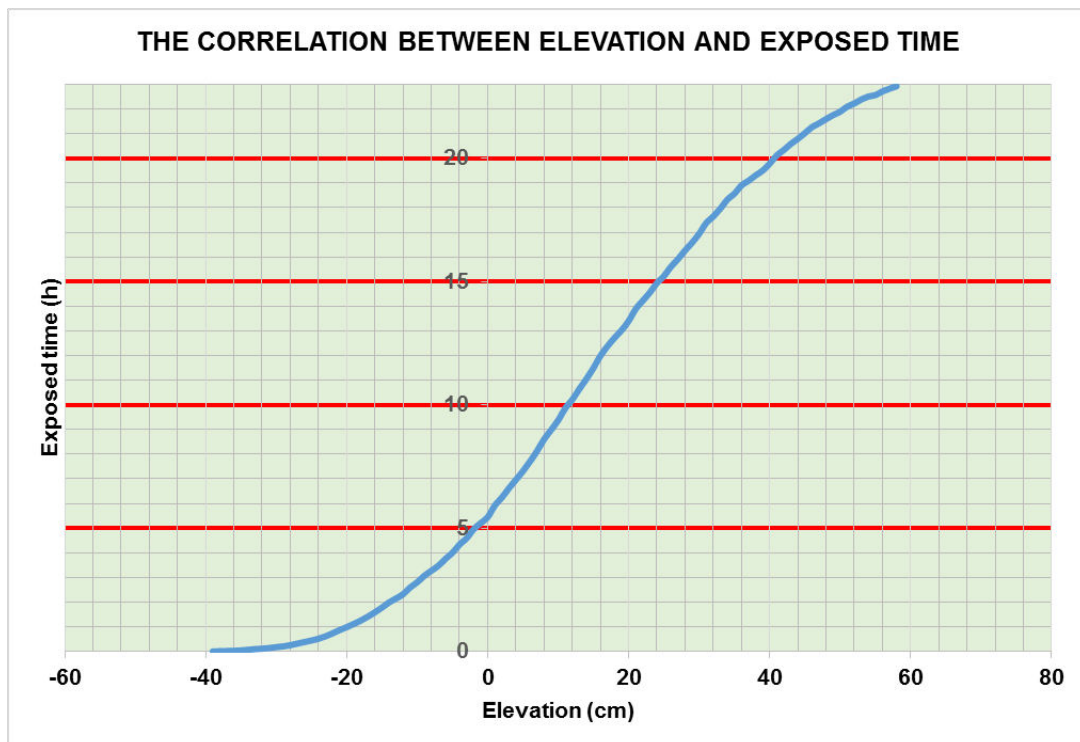


Figure 7. The correlation between elevation and exposed time

LMD CZ project: 6.2.1 Restoration of mangrove belts near the coast of the studied sites

According to topography data, the exposed time of mudflat inside concrete piles varies from 10 to 16 hours/day. Therefore, the mudflat of the study area is tidal inundation of shallow water, favorable for the development of mangroves^[1].

b) Characteristics of foundation:

The foundation of mudflat inside concrete piles is regularly deposited with sediments, soil at 0 to 20 cm depth is a soft sediment layer, the stable sediment layer is in the depth of 20 to 50 cm (figure 8).

Study areas are strongly affected by waves, the beach surface varies seasonally due to the impact of seasonal sediment transport, the 10-20cm liquid mud varies seasonally.



Figure 8. The foundation of mudflat inside concrete piles at Sao Luoi canal

Soil texture: heavy soil, in total 3 samples, the average rate of clay, silt and sand are 28.27%, 38.83%, and 32.9%.

Soil chemical properties: 3 soil samples analysis results show that pH indicators are frequently neutral to weak alkaline (pHKCl: 6,87 to 7,28), high soil organic matter content (OM%: 0,7-3,5%, total N: 0,065 to 0,112%); high total P(0,1% to 0,11%) and low digestible phosphorus (61,12 to 78,88 mg/kg); total K and digestible potassium from low to moderate (total of K₂O 0,51-1,6%, digestible K₂O: 60,25 - 139,78 mg/kg).

Table 3. Some physical and chemical properties of soil of mudflat inside concrete piles at Sao Luoi canal mouth

No	Sample notation	Analytical criteria								Soil texture (%)		
		pH (KCl)	Total (%)				Digestible(mg/100g)			0,2-0,02 (sand)	0,02-0,002 (silt)	< 0,002 (clay)
			OM	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O			
1	SL_KBT_20	6,87	2,11	0,075	0,11	1,34	0,24	6,11	10,30	16,48	46,50	37,02
2	SL_KBT_40	7,28	0,70	0,065	0,10	0,51	0,28	7,89	6,03	62,64	24,23	13,12
3	SL_KBT_60	7,12	3,52	0,112	0,11	1,60	0,50	6,36	13,98	19,57	45,77	34,66
Average		7,09	2,11	0,08	0,11	1,15	0,34	6,79	10,10	32,90	38,83	28,27

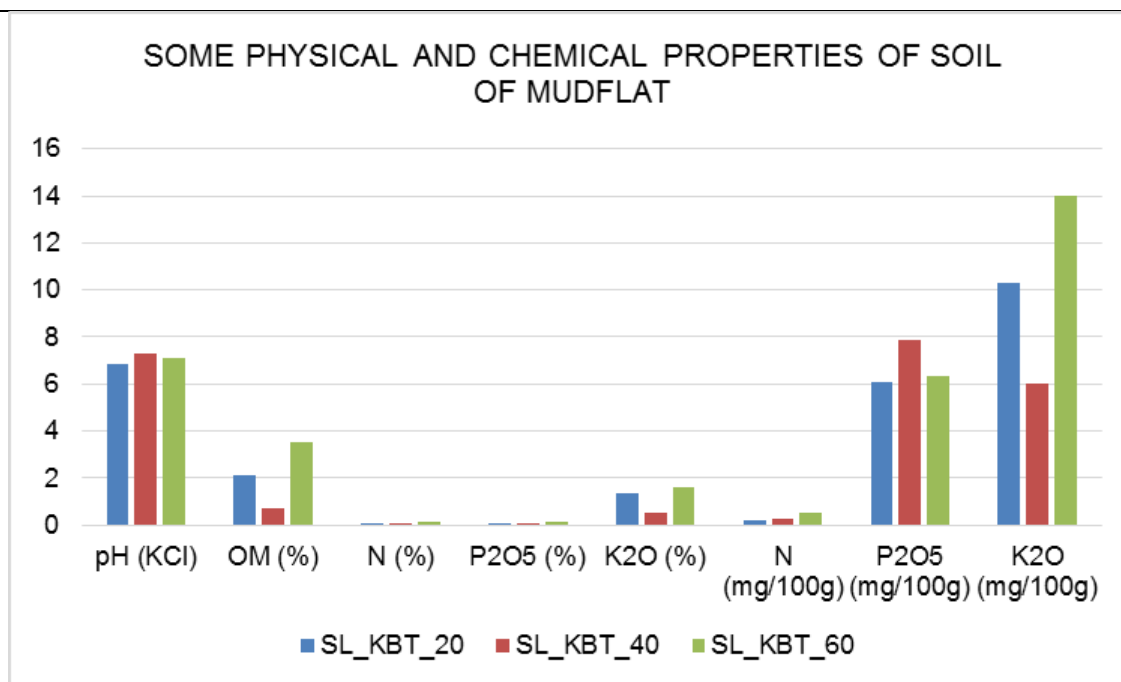


Figure 9. Some physical and chemical properties of soil of mudflat inside concrete piles at Sao Luoi canal, Khanh Binh Tay commune, Tran Van Thoi district, Ca Mau province.

The analysis data of 3 soil samples of mudflat inside concrete piles at Sa Luoi canal, shows that the soil texture has a relatively high rate of silt and clay (total percentage of mud and clay reached 67.1%), favorable for the development of mangroves. pH (KCL) is neutral level, high soil organic matter(2.11%), moderate total nitrogen content(2.11%), poor digestible nitrogen content (0.34mg/100g) and total phosphorus (0.11%), moderate digestible phosphorus content (6.787 mg/100g), moderatetotal potassium (1.15%) and digestible potassium (10.102 mg / 100g). In general, soil of mudflat inside concrete piles is favorable for the development of mangroves.

c) Analysis of sediment deposition and restoration of mangrove forests inside concrete piles

Concrete piles at Sao Luoi canal mouth was completed in April 2015. The mudflat surface inside the concrete piles has changed from 80 to 110 cm depending on each location after 14 months (June 2017). The average sediment deposition in the concrete piles is 67 cm/year.

According to the natural law, when sedimentdeposition meet certain elevation that has enough minimum exposed time, mangroves will naturally regenerate and gradually stabilize the soil[7]. However, if deposition rate is too high, it will fill in mangrove seedlings and mangrove trees cannot be regenerated. Inconcrete piles at Tan Thuan commune, Dam Doi district, although the sedimentdeposition rate was similar to the one at concrete piles area in Sao Luoi canal mouth, mangroves still regenerate naturally on the mudflats inside the concrete piles.



Figure 10. *Avicennia marina* regeneration in the mudflats inside concrete piles in Tan Thuan Commune, Dam Doi District, Ca Mau Province (2014)

Figure 11. *Avicennia marina* regeneration in the mudflats inside concrete piles in Tan Thuan Commune, Dam Doi District, Ca Mau Province (2017)

According to GIZ evaluation, in comparison with the Melaleuca fence for wave height reduction, sedimentation, the average sedimentation deposition rate inside the fence is 14 cm/year. Mangroves regenerated naturally grew well due to receiving mangrove seed source from mudflats.

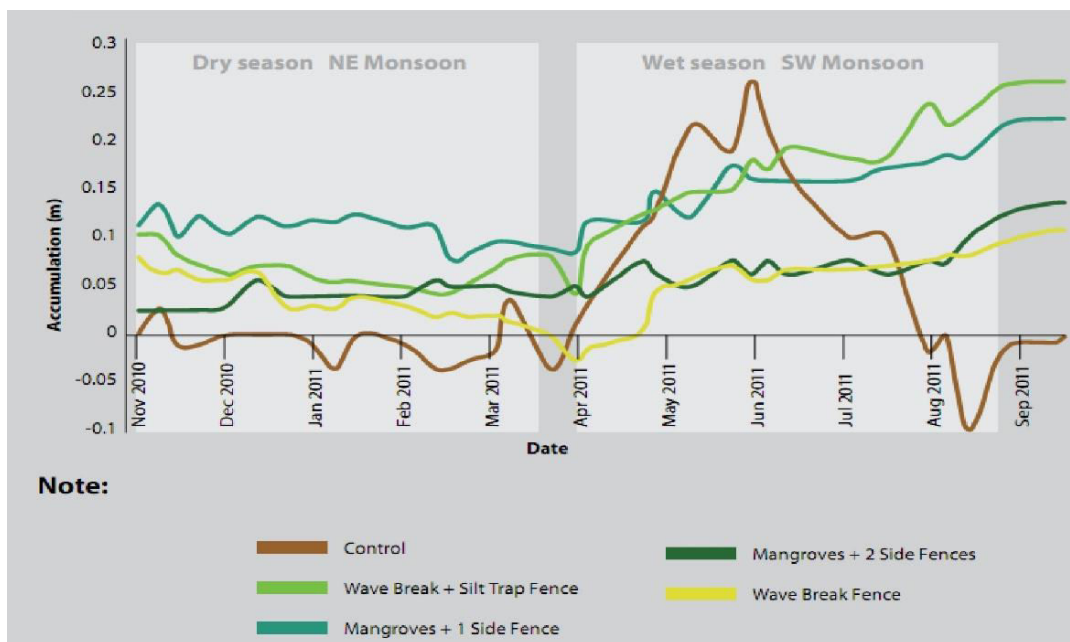


Figure 12. The effectiveness of sediment deposition behind Melaleuca fence in Vam Ray hamlet, Binh Son commune, Hon Dat district, Kien Giang province^[2].



Figure 13. Newly planted and naturally regenerated mangroves behind Melaleuca fence in Vam Ray hamlet, Binh Son commune, Hon Dat district, Kien Giang province.

The natural regeneration condition of mangroves is having seeding source on mudflats during the fruiting season of mangrove trees. After the construction of concrete piles, the embankment prevented the mangrove seeds moving along the tidal stream from other areas to the shore. At the shore, there is only a thin mangrove belt (from 30 to 50 m) developed on the high tidal inundation foundation area (tidal inundation from 5-7days/month). When mangrove fruits ripen, they can not be broadcast to the mudflats for natural regeneration. Therefore, in most of the mudflats inside concrete piles, mangrove trees can not be regenerated naturally. Mangroves planted by seedlings develop very well. Hence, in order to restore the mangroves inside the concrete piles, mangroves should be planted by young trees propagated in nursery.



Figure 14. Newly planted *A. marina* inside concrete piles in Khanh Hoi commune, U Minh district, Ca Mau province (2015)



Figure 15. *A. marina* growing well inside concrete piles in Khanh Hoi commune, U Minh district, Ca Mau province after planting 2 years (2017)

3.1.4. Selection of mangroves species to plant in Go Cong Dong district, Tien Giang province and Phu Tan district, Ca Mau province

Selection of mangroves species based on the principle that priority is given to the dominant species that suitable local condition and has wide ecological amplitude. In addition, it is necessary to have suitable density of trees to create enhance wave height reduction effectiveness.

Table 4. Natural condition in coastal area of Go Cong Dong, Tien Giang and Phu Tan, Ca Mau

Location	Natural condition in study area			
	Average salinity (‰)	Tidal regime	Tidal amplitude (m)	Altitude (m)
Go Cong Dong, Tien Giang	From 15 to 26	Non-uniformity semi-diurnal tide	From 3,5 to 3,6	From - 0,5 to +0,7
Phu Tan, Ca Mau	From 25 to 30	Uniformity diurnal tide	From 1,0 to 1,3	From 0,2 to +1,5

According to data analysis results, *A. Marina* and *R. apiculata* are two common species in this study area. In comparison with the ecological requirements of mangrove species and natural condition of Go Cong Dong district (Tien Giang province), suitable species are *A. marina* and *R. apiculata*. In which *A.marina* is pioneer belt, *R. apiculata* is planted behind *A. marina* belt. In Phu Tan district (Ca Mau province), *A. marina* is selected (table 5).

Table 5. Expected mangrove species in the Mekong Delta

Location	Natural condition in study area				Species
	Average salinity (‰)	Tidal regime	Tidal amplitude (m)	Altitude (m)	
Go Cong Dong district (Tien Giang province)	From 15 to 30	Non-uniform semi-diurnal tide	From 2 to 4	From +0,2 to +0,7	<i>A. marina</i> and <i>R. apiculata</i>
Phu Tan district (Ca Mau province)	From 30 to 35	Uniform diurnal tide	< 1,0	From +0,05 to +1,5	<i>A. marina</i>

3.2. Selection of mangrove planting techniques

The measures against erosion include hard and soft solutions. These solutions generally have current and wave control as well as longshore sediment transport functions. Hard solutions included structures such as groynes, offshore breakwaters, submerged breakwaters and revetments or seawalls. Soft solutions included sand dunes, beach nourishment and planting mangroves. However, the disadvantage of hard solutions are erosion at toe or area under of the construction, and high cost (eg, embankment at Ganh Hao river mouth, Bac Lieu province, concrete piles at Khanh Hoi river mouth, U Minh district, Ca Mau province). While, soft solutions usually require a long period of time (five to ten years) to be effective. In some cases, combination of hard and soft solutions or solution of soft+soft techniques should be selected.

In terms of technique, coastal protection measures must be based on the understanding of indirect causes, direct causes, and mechanisms of erosion. These measures should have long-term effectiveness, suitable with Vietnam's socio-economic conditions, no negative impacts on the environment, no erosion in unwanted areas. It is necessary to limit causes of erosion

In order to developing accretion area, solutions to prevent soil erosion must be developed, limit the causes of erosion in areas where accretion is required. The orientation of developing solutions to create accretion in the Mekong Delta should be directed towards soft solutions or soft solutions combined with hard solutions and planting of mangroves. For techniques of planting mangrove trees, it is necessary to study the selection of suitable mangroves kind, including plant morphology and plant physiology for planting on new land created accretion. The layout of the construction causing accretion, need to meet the requirement not to eroded the surrounding area.

Table 6. Table of selecting the technique for mangrove planting in Go Cong Dong district (Tien Giang province) and Phu Tan district (Ca Mau province)

Natural conditions		Level of erosion	Wave height	Topographic	Foundation	Selecting the technique for mangrove planting
Tien Giang	Section 1: from Vam Lang to Tan Thanh (from K0 to K341+500)	From 1,0 m to 1,5 m	From 1,2 m to 1,4 m	From + 1,5 m to - 1,9 m	Fine sand, less mud	- Offshore breakwaters - Fence reduced wave, current and created accretion (Figure 17)
	Section 2: 2,5km adjacent to Tieu river	From 0,5 m to 1,0 m	From 0,4 m to 0,8 m	From +1,6 m to - 1,5 m	Fine sand, argillaceous	Fence reduced wave, current and created accretion

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Natural conditions		Level of erosion	Wave height	Topographic	Foundation	Selecting the technique for mangrove planting
	estuary (from K31+500 to K34)				sand	
Phu Tan	From Bay Hap river estuary to My Binh river estuary	From 0,8 m to 1,2 m	From 0,6 m to 1,0 m	From - 0,6 m to + 0,2 m	Soft clay	Fence reduced wave, current and created accretion (Figure 18)

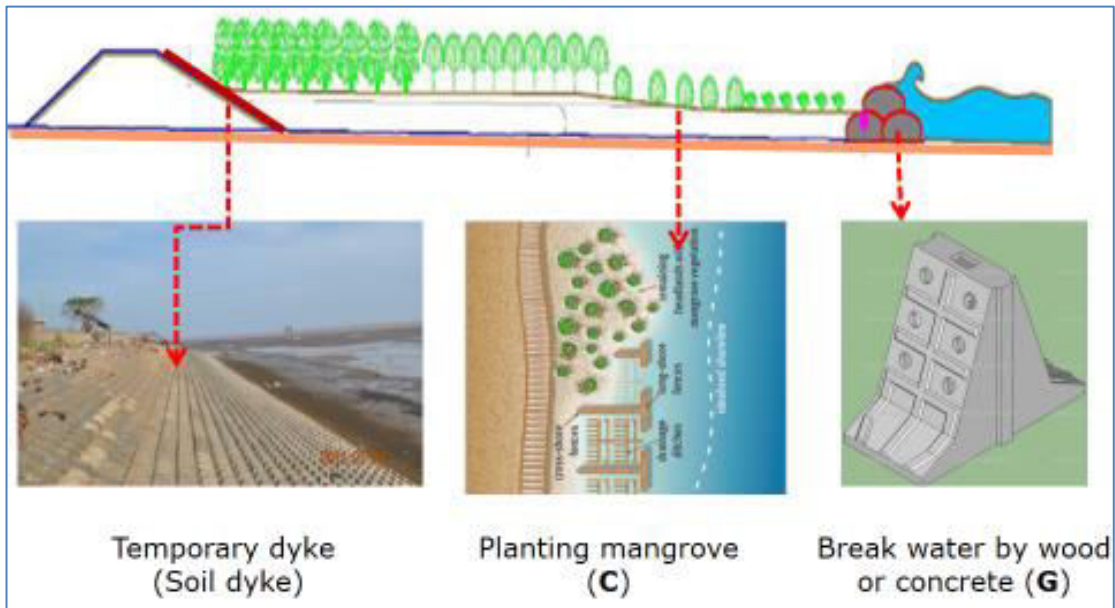


Figure 16. Mangrove restoration technology is expected to be applied to Go Cong Dong, Tien Giang

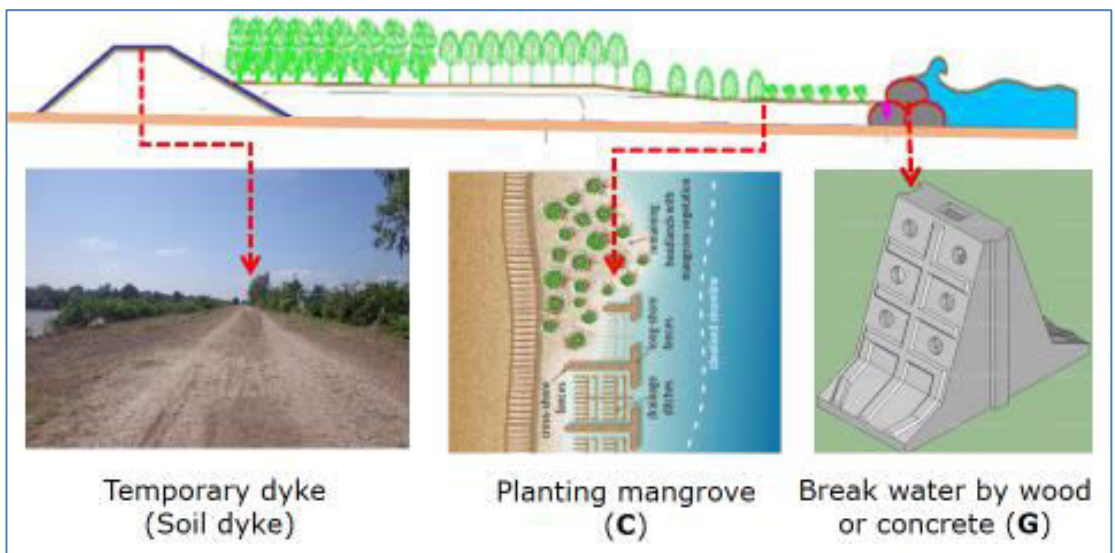


Figure 17. Mangrove restoration technology is expected to be applied to Phu Tan district, Ca Mau province

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

A. marina and *R. apiculata* are suitable mangrove species in the coastal area of Go Cong Dong district, Tien Giang province. In which *A. marina* was pioneer species, planted in outside, *R. apiculata* planted after the *A. marina* belt;

A. marina is suitable mangrove species in the coastal area of Phu Tan district, Ca Mau province

The suitable technology applied to the coastal area of Go Cong Dong district, Tien Giang Province is a combination of offshore breakwater and fence for wave, current reduction and accumulation. Suitable technology applied to the coastal area of Phu Tan district, Ca Mau province is fence for wave, current reduction and accumulation.

4.2. Recommendations

For wave reduction works and coastal mangrove rehabilitation, it is better to use root control bag raised seedlings for transplantation to ensure high survival rate and take a short time to become mature forest.

For erosion area, it is necessary to identify topographic elevation, minimum exposed time to have successful mangrove restoration.

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