Management of Natural Resources
in the Coastal Zone of Soc Trang Province

Mangroves of Soc Trang 1965 - 2007

Pham Trong Thinh

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Author
Pham Trong Thinh

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Designed by
Golden Sky
Email: info@goldenskyvn.com

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February 2011

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Acronyms

ACTMANG	Action for Mangrove Reforestation, Japan
CWDP	Coastal Wetland and Development Project
DARD	Department of Agriculture and Rural Development
DBH	Diameter at Breast Height
FPSD	Forest Protection Sub-department
GIS	Geographic Information System
NGO	Non-governmental Organisation
NTFP	Non timber forest product
TEV	Total Economic Value

1 Ecological Characteristics of the Coastal Area of Soc Trang Province

1.1 Geographic location

Soc Trang is situated between 9°14’N to 9°56’N and 105°34’E to 106°18’E. It is bordered to the north-west by Hau Giang Province, to the south-west by Bac Lieu, to the north-east by Tra Vinh, and to the south-east by the Vietnamese East Sea (South China Sea) (Figure 1). The coastline extends for 72 km.

1.2 Climate

The coastal area of Soc Trang has a mild, equatorial climate with a majority of fine, sunny days at high, stable temperatures and moderate rainfall. The annual average temperature is 26-27°C, varying by 12–13°C seasonally with monthly average variations of 3-4°C, and daily fluctuations of 7-8°C. Annual rainfall is approximately 1,828 mm (Figure 2), and total annual solar radiation is high and stable at around 130 kcal/cm^2/year. Wind and rainfall levels vary with the seasons. The climate is characterised by distinct seasons of summer wet and winter dry periods. These seasonal conditions correlate strongly with sedimentation and erosion regimes of coastal areas.

Figure 1: Location of Soc Trang province.

The summer wet season is defined mostly by rainfall where 85% of annual falls from May to October, with highest (292.4 mm) falls in October (Hong *et al.* 1997). Lowest radiation levels occur between June and September with approximately 9 kcal/cm^2/month. Light south-westerly winds prevail during this time with wind speeds usually less than 3 m/s. During the rainy season, the Mekong River carries sediments from upstream to deposit in the estuarine areas, creating a vast mud plain running thousands of meters towards the sea.

The winter dry season is defined by lower rainfalls from November to April, with lowest monthly falls (2.2 mm) in February (Hong *et al.* 1997). Skies are predominately clear during this season, as shown by relatively high total solar radiation levels between January and April of 12–16 kcal/cm^2/month. During the dry season, the north-east monsoon prevails with wind speeds usually in excess of 3 m/s. Winds sometimes reach 10m/s in March and November or December, causing serious erosion in coastal areas, removing almost all newly deposited materials left from the previous rainy season - including newly planted seedlings.

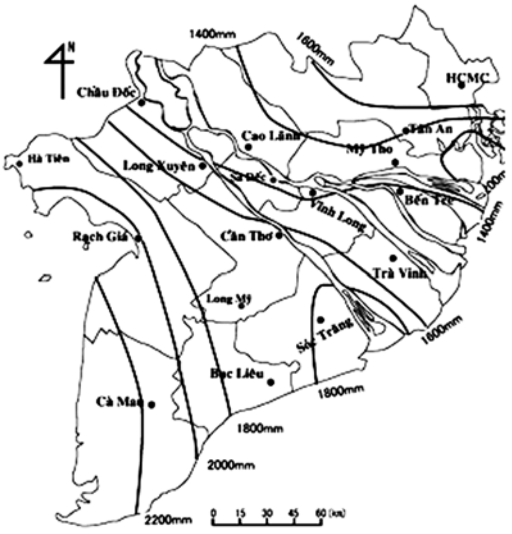


Figure 2: Rainfall map of the Mekong Delta (Yamashita 2005).

1.3 Hydrology

The coastal area of Soc Trang is affected by the flow regime and discharge of the Mekong River, the tidal regime of the Vietnamese East Sea and long-shore currents.

The Mekong River has a large catchment area with high levels of discharge that fluctuate with the seasons. The river originates in south-eastern China and flows through Myanmar, Laos, Thailand, Cambodia, and the Mekong Delta of Vietnam. The river is 4,800 km long, with a total catchment area of 1,795,000 km^2 and an annual average discharge of 15,000 m^3/s. The river carries about 500 billion m^3 of water annually into the sea. From Phnom Penh (Cambodia), the river flows into the Mekong Delta of Vietnam. Here it is called Cửu Long, which means 'nine dragons'. The southernmost arm of the Mekong, the Hau River, forms the north-eastern boundary of Soc Trang Province.

The tidal regime of the Vietnamese East Sea is uneven and semi-diurnal. The differences between daily lowest sea levels are large, up to 2 m. The difference between mean lowest sea level and mean highest sea level varies from 3.6 to 4.2 meters, with these values occurring from August to January, overlapping with the end of the summer wet and beginning of the winter dry seasons. Tidal peaks reach maximum levels in October and November and minimum levels in April and May (Euroconsult 1996).

Strong winds during the dry season force the tidal influence much further inland than it occurs during the rest of the year. The interaction between winds, tides and river flow influences the natural environment of these predominately estuarine areas. Being at such a low elevation, almost the entire estuarine area is intruded by salt water through the numerous streams and canals. Annually, the largest area affected by tidal intrusion is observed in April and May.

The average temperature of water in the estuaries of the Mekong River is about 30-35°C. The difference in annual water temperatures varies from 4.9-8.5°C, with highest values occurring in March and April and lowest values observed in December or January (Euroconsult 1996).

Most of the areas under the mangroves are salty acid sulphate soils. These soils contain lots of pyrites and might cause severe negative impacts to nature if they are exposed to sunshine, dried and oxidised.

In the dry season, average water salinity values in the coastal area were usually above 16 g/l in April (Sâm 2003). The average maximum and minimum salinity values observed in April (2000) were 23.5 g/l and 13.6 g/l, respectively. During the rainy season, salinity levels drop to 8.08 g/l.

Variations in salinity are caused by interactions between tidal water and freshwater from upstream. During the rainy season, large amounts of fresh water in runoff flows dilute salinities along the river. In contrast, during the dry season salinity levels rise as freshwater flows decrease.

The pH values of water are usually neutral. The difference in pH values of water between inside and outside of shrimp ponds range from 0.1 to 0.3.

1.4 Geomorphology and landscape

The Soc Trang coastal area is situated in one geo-morphological unit called a coastal plain (World Bank and Government of Vietnam 1993). The coastal plain area is comprised of small and low sand ridges lying parallel to the coastline, with muddy swamps in between. Almost all areas of the coastal plain are inundated under high tide.

Sand ridges are aligned in a north-west to south-east direction, parallel to the coastal line. The ridges are 3-4 meters high and comprised of 70% sand, 15% mud, 10% clay, 2-3% organic matter, and 1-2% ferric oxide with yellowish orange spots. Newer ridges contain more clay and mica than older ones. These sandy soils have high exchangeable capacity but poor nutrient levels due to the influence of salt water.

Saline, marine clay soils are rich in nutrients and less acidic. These soils form in depressions and swamps, which gradually fill with sediments, forming a suitable environment for mangrove plants. These sediments are composed of about 50% clay, 30% mud, and 20% organic matter. The clay is of a gray or brownish colour due to high levels of organic matter and a pyrite layer.

Further inland, the saline swamps become more elevated, salinity levels are lower, and soils are more acidic. These floodplains are comprised of sand or mud depending on the materials supplied from the river. The geomorphologic processes in the coastal area influence the formation and shape of the current coastline.

The deposition and erosion processes

Along the 72 km coastline of Soc Trang Province, the deposition and erosion processes are very dynamic. Interaction between natural factors like the currents, tides, wind, and waves causes severe erosion along the coast. This process is becoming more severe with the disappearance of mangroves.

There are two opposite processes, sedimentation and erosion along the coastline of Vinh Chau District (see Figures 3 and 4). Severe erosion occurs in Lai Hoa to Vinh Phuoc as well as along the coast of Vinh Hai near the My Thanh river mouth (for all geographic locations, see Figure 6). Specific measures of erosion rates along the coast were made from remote sensing information, maps and field observations in Vinh Tan (8-15 m/year), and Lai Hoa (20 m/year).

Figure 3: Coastal sediment deposit near Vinh Chau town.

Figure 4: Coastal erosion near Vinh Tan commune.

Figure 5 shows the position of the coast line 10 years ago, which has now moved 300 meters inland. The sluice gate is standing about 300 metres from the existing coastline.

Accretion has similarly been occurring very quickly. This is evident in the annual deposition along the coast and enlarged size of the coastal area in some places, like An Thanh Nam commune (Cu Lao Dung District), and Trung Binh commune (Tran De District).

Figure 5: The sluice gate, which was at the dyke 10 years ago, is now 300 m from the coastline.

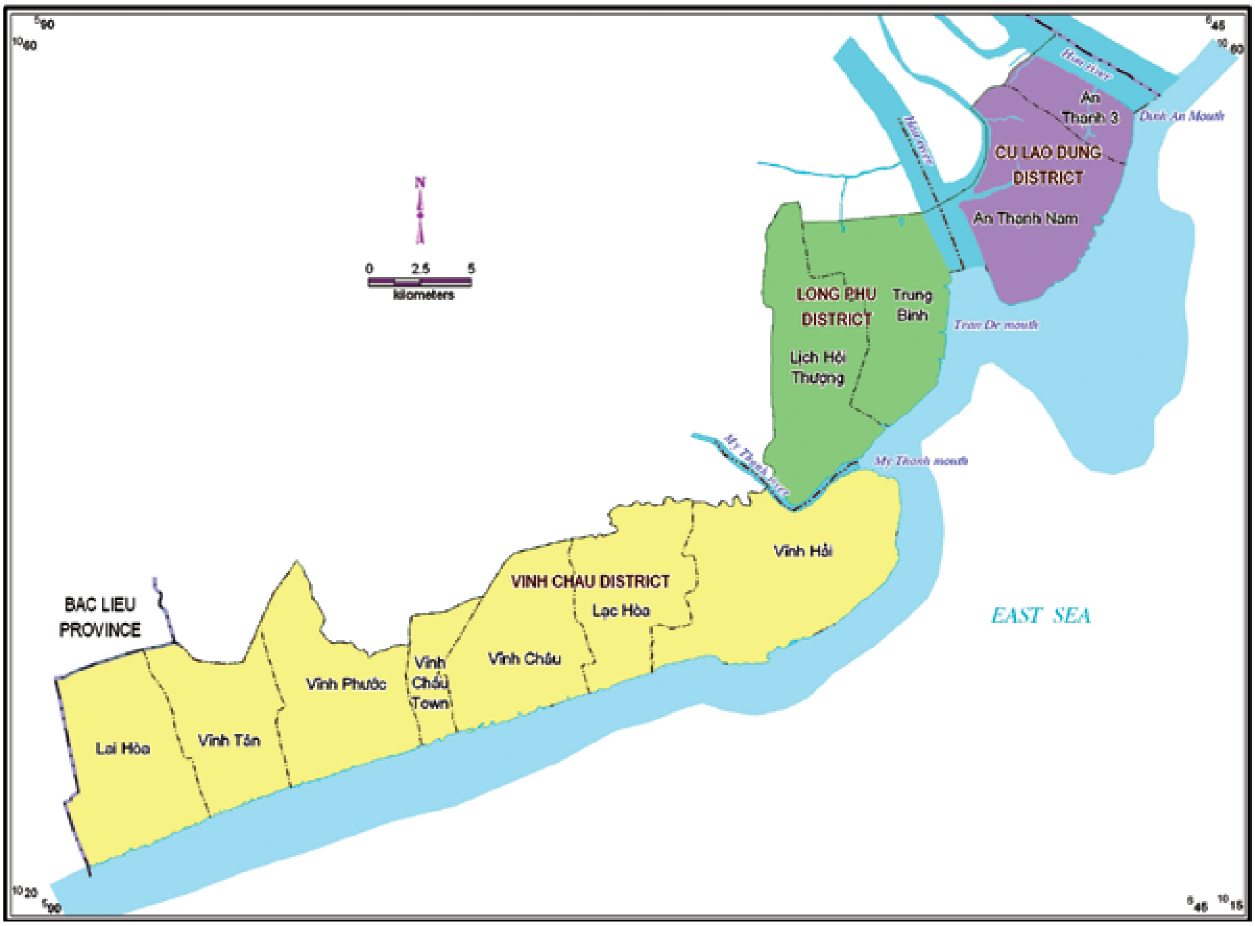


Figure 6: The coastal area of Soc Trang Province.

Figure 7 shows the variation in mangrove cover in Cu Lao Dung from 1965 to 2007. The two most striking features are the significant reduction in terms of mangrove forest area and the accretion.

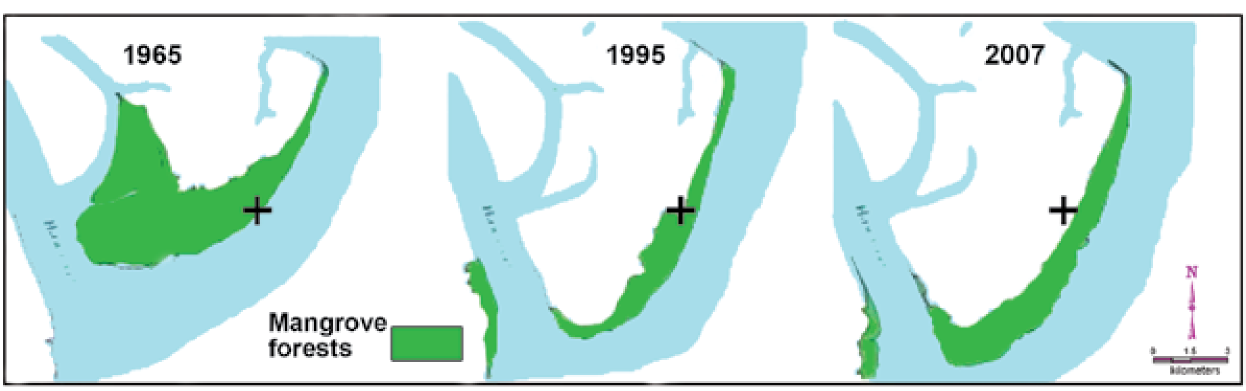


Figure 7: Variation of mangrove and coastline in Cu Lao Dung. The cross marks the same geographic position for all 3 years.

Details about the variation in land area in Cu Lao Dung from 1965 to 2007 is presented in Table 1. The total area of An Thanh Nam and An Thanh Ba village (An Thanh 3) was about 5,498 ha in 1965, 6,726 ha in 1995 and 7,559 ha in 2007. From 1965 to 2007, the total area of the two villages increased by 2,061.7 ha. Annually, the area of these two villages has increased by about 48 ha. The real forest cover of the villages was 1,791.9 ha in 1965, 719.3 ha in 1995 and 1,107.2 ha in 2007.

Table 1. Changes in land area in Cu Lao Dung from 1965 to 2007.

Year	Land area (ha)	Forest (ha)	None forest (ha)	Increase in land area (ha)
1965	5,497.7	1,791.9	3,705.8	
1995	6,725.8	719.3	6,006.5	1,228.1 (1965 to 1995)
2008	7,559.4	1,107.2	6,452.2	833.6 (1995 to 2007)

In summary, accretion was observed along the coastline of Soc Trang in some places as follows:

- About 7.8 km (45 m/yr) along the coastline of An Thanh Nam (Cu Lao Dung), Trung Binh (Tran De)
- About 3.2 km (15 m/yr) in Lac Hoa (Vinh Chau)
- About 8.3 km (10 m/yr) in Vinh Hai (Vinh Chau)

Erosion and deposition processes are notably seasonal. Results of research carried out in 1996 by the Coastal Wetland Protection Project in the southern provinces of the Mekong Delta (Euroconsult 1996) in the coastal area of Vinh Chau District are summarised below.

The period from November to April is the North East monsoon season, or dry season, with maximum wind speeds of 5-8 m/s. During this period, the wind intensity is highest, causing high intensive waves to hit the coastline at angles of 45-50 degrees.

The high kinetic energy of semi-diurnal tidal waves causes severe erosion along the coast. During this time, the quantity of sedimentation in the Mekong River flow is at its lowest. Sediments carried by the Hau River are deposited at the end of river mouth near Cu Lao Dung and south of the My Thanh branch. The sea current flows in the southwest direction with little sedimentation. Therefore, very little sedimentation is deposited in the coastal area of Vinh Chau.

During this period, the coastal area of Vinh Chau district goes through an erosion process. The coastline in the Vinh Tan and Vinh Hai communes, as well as around the Xom Day water gate erodes at an average speed of 15 - 30 m/year. These conditions exist along a stretch of about 3.5 km.

By the end of the dry season, materials of the erosion process along the coast and sediment brought to the river mouth increase due to raining upstream on the Mekong River. These materials accumulate along the coastline forming unstable mudflats. During ebb tide, vast 2-3 km wide mudflats are exposed with a mud layer of up to 2 m thick, especially during the peak of the rainy season from September to October. The composition of these materials is mainly clay.

The coastline along the communes from Vinh Chau town to water gate number 9 is undergoing both deposit and erosion processes. The same situation is found south of Trung Binh commune (Tran De District) and in the Vinh Phuoc, Vinh Tan and Lai Hoa communes in Vinh Chau District.

When the monsoon season stops, the sediment carried down the Mekong River ceases to flow and the deposition process stops. The coast returns to an erosion cycle, which causes it to recede at an annual rate of 10-15 m/year.

From June to November, the wind speed is usually lower than that of the north-eastern wind during the dry season. The erosion rate during the rainy season is also lower than that of the dry season. During this period, the waters of the Mekong River carry large amounts of sediment from upstream to be deposited in the estuaries. This situation can be observed in An Thanh Nam and An Thanh Ba of Cu Lao Dung District; the Trung Binh, Lich Hoi Thuong, Lieu Tu communes of Tran De District, and near Vinh Chau town.

Research around water gate number 5 (in An Thanh Nam commune) in 2005 shows that in April a soft layer of mud accumulates on the ground. In June, sedimentation proceeds rapidly, leaving a layer of 10.7 cm of mud and a rather flat ground surface. This coincides with the wet season, which brings sediments from the Hau River. In August, only small amounts of sedimentation are deposited and the mud layer is 11.3 cm thick (Cao 2005).

In December the surface mud layer disappears and only the compact mud remains. From December to February, the ground surface erodes, the sedimentation and mud layer are washed away, and sandy materials from the ocean intrude the area, covering the ground. Towards the end of February, the ground is firmly covered by solid sand. The ground erodes by 21.3 cm compared to December levels.

The sedimentation and erosion processes affect forest planting and restoration of the coastal area. The selection of an appropriate planting season and planting method are crucial to the success of any planting programme.

Coastal sand beaches

Coastal sand beaches are distributed around Vinh Hai commune. The sand deposit flat is mainly formed from marine sediment or along the eroded shores. The tidal inundation regime is similar to that for the mudflat. The sand flat is currently used for clam farming or harvesting aquatic products. In the long run, *Casuarina* trees could be planted when permanent sand ridges are formed.

The system of sea dykes along the coast of Soc Trang Province has been established and upgraded for several decades to prevent saline intrusion and support agricultural production. The dyke system from Bai Gia to the boundary between Soc Trang and Bac Lieu has been completed. The elevation at the top of the dyke is 2.5-3.2 meters. The dyke system forms a boundary between the full protection zone along the shore and the agricultural zone inside the dyke. However, the dykes experience severe annual erosion where there are no mangrove trees protecting them from erosion.

1

2

Mangrove Ecosystem in Soc Trang Province

2.1 Mangrove forest

“Mangroves are the characteristic littoral plant formations of tropical and subtropical sheltered coastlines. They have been variously described as ‘coastal woodland’, ‘tidal forest’ and ‘mangrove forest’. Generally, mangroves are trees and bushes growing below the high-water level of spring tides. Their root systems are thus regularly inundated with saline water, even though it may be diluted due to freshwater surface run-offs and only flooded once or twice a year. Mangroves depend on terrestrial and tidal waters for their nourishment, and silt deposits from upland erosion as substrate for support. The tides nourish the forest and mineral rich river-borne sediments enrich the swamp. Thus the mangroves derive their form and nurture from both marine and terrestrial influences.” (FAO 1994 p. 5 and p.1).

A general feature of this forest type is that it is usually distributed in riverine, coastal, and intertidal zones that are inundated during daily or monthly high tides. The soils of mangrove forests are saline and saturated. To cope with such conditions, mangrove root systems have highly specialised structures and functionality allowing them to prosper. Several species of mangrove plants dominate the sub tidal and high tidal areas of the Mekong River coastal zone (Figures 8 and 9).

There are several key mangrove species. *Rhizophora* has an arch-formed, stilt root system while *Sonneratia* and *Avicennia* have protruding root suckers as breathing roots, or pneumatophores. Fruits of many mangroves such as *Rhizophora* germinate on the parent trees before falling and anchoring into the ground. Plants in coastal areas not adapted to tidal inundation and saturated soils are not categorised as mangroves.

Figures 8 and 9 show pictures of two species of mangrove that dominate the sub tidal and high tidal Mekong River coastal zone.

Figure 8: *Sonneratia* in areas inundated by daily high tides.

Figure 9: *Ceriops* on high grounds inundated by monthly high tides.

Depending on the level of adaptability to tidal inundation, water salinity, and soil development, a series of different mangrove zones are formed. Estuaries located at the interface between the freshwater from the river flowing into the sea and the daily tidal water typically have the mangrove varieties *Sonneratia caseolaris* or *S. alba*. In Mekong River estuaries, these trees form a thick green belt on sub tidal to intertidal sites at suitable locations along the river mouths.

Nypa fruticans is also a representative of estuarine plant communities but usually appears further inland behind *Sonneratia caseolaris*.

At long distances from the estuaries, the water salinity is often higher than in the estuary. In these locations, some salt-tolerant species such as *Avicennia marina* or *Avicennia officinalis* occur. These trees also form a natural green belt along the coastline at the intertidal zone.

In saline soils at higher elevations - inundated only during monthly high tides or yearly high tides - *Lumnitzera racemosa* or *Hibiscus tiliaceus* usually occur.

The establishment and development of mangrove forests is closely related to the environmental conditions influenced by tidal inundation, tidal flow and sedimentation, as key factors controlling their growth and composition.

2.2 Species composition of mangrove forests

Due to the special environmental features, only a few plant species can tolerate and grow normally in inundated, muddy, saline conditions that are completely different from the conditions in high, dry lands. FAO listed 84 species of mangroves, of which 66 are woody, 13 are shrubby, 2 are palms, and 3 are ferns (FAO 1994). Other accounts list different numbers (like Duke 1992), reflecting the subjective nature of the definition of mangroves.

For Vietnam, Sâm (2005) listed 37 species of true mangroves. Can Gio (near Ho Chi Minh City) is the area with the highest number of mangroves (33 species) followed by Ca Mau (32 species). Surveys in the estuarine and coastal zones in Soc Trang recorded 26 species in 2008. These are true mangroves of estuarine and coastal zones, which are presented in Table 2.

Table 2. True mangrove species of coastal zone of Soc Trang Province.

No	Vietnamese name	Scientific name	Life form
	Họ bần	**Sonneratiaceae**	
1.	Bần đắng (bần trắng)	*Sonneratia alba* J. Smith	Medium wood
2.	Bần chua	*Sonneratia caseolaris* (L.) Engl.	Medium wood
	Họ mấm	**Avicenniaceae**	
3.	Mấm trắng (mấm lưỡi đồng)	*Avicennia alba* Blume	Medium wood
4.	Mấm đen	*Avicennia officinalis* L.	Medium wood
5.	Mấm biển	*Avicennia marina* (Forsk.) Vierh.	Medium wood

No	Vietnamese name	Scientific name	Life form
	Họ Đước	**Rhizophoraceae**	
6.	Đước (Đước đôi)	*Rhizophora apiculata* BL.	Large wood
7.	Đưng	*Rhizophora mucronata* Lume	Large wood
8.	Vẹt dù	*Bruguiera gymnorhiza* (L.) Lam.	Small wood
9.	Vẹt tách	*Bruguiera parviflora* (Roxb.) Wight & Arn	Medium wood
10.	Vẹt trụ (Vẹt hôi)	*Bruguiera cylindrical* (L.) Bl.	Small wood
11.	Vẹt khang	*Bruguiera sexangula* (Lour.) Poiret	Medium wood
12.	Dà quánh	*Ceriops decandra* (Griff.) Ding Hou	Medium wood
13.	Dà vôi	*Ceriops tagal* (Perrottet) C.B. Robinson	Medium wood
14.	Trang	*Kandelia candel* (L.) Druce	Medium wood
	Họ Bàng	**Combretaceae**	
15.	Cóc vàng	*Lumnitzera racemosa* Wild	Small wood
	Họ Ba mảnh vỏ	**Europhorbiaceae**	
16.	Giá	*Excoecaria agallocha* L.	Small wood
	Họ Xoan	**Meliaceae**	
17.	Xu ổi	*Xylocarpus granatum* Koenig	Small wood
	Họ Cau dừa	**Palmae**	
18.	Dừa nước	*Nypafruticans* Wurmb	
19.	Chà Là nước	*Phoenix paludosa* Roxb	
	Họ Ô rô	**Acanthaceae**	
20.	Ô rô biển	*Acanthus ilicifolius* L.	Herbaceous
21.	Ô rô trắng	*Acanthus ebracteatus* Vahl.	Herbaceous
	Họ Trôm	**Sterculiaceae**	
22.	Cui biển	*Heritiera littoralis* Aiton ex Dryander	
	Họ Ráng	**Pteridaceae**	
23.	Ráng đại	*Acrostichum aureum* L.	Fern
24.	Ráng đại	*Acrostichum speciosum* Wild.	Fern
	Họ Bông	**Malvaceae**	
25.	Tra	**Threspecia populnea* (L.) Soland. Ex Cor.	Small wood
26.	Bụp	**Hibiscus tiliaceus* L.	Small wood

*NOTE: Most authors disagree with the last two (25 & 26) being called mangroves (Duke 1992).

2.3 Adaptation of mangrove trees to environment

Our understanding of the adaptive capacity of mangroves to their environments and their physiological and ecological requirements, provides practical way to more sustainably manage mangroves. The selection of species for planting under particular conditions needs to be based on the ecological requirements of each species. If *Rhizophora* were planted on permanently submerged tidal sites, and *Avicennia* or *Sonneratia* planted on high grounds without tidal inundation, they would not survive.

Mitigation that impedes or alters tidal ecosystem processes will hinder or halt the growth of mangroves. In some cases, the installation of dykes causes changes in flow hydrodynamics, hinders tidal exchange, limits the accretion of sedimentation, increases the retention of toxicants in soils, and impedes root respiration causing plants to stop growing or die.

The specific physiological characteristics of each mangrove species determines its zonal location and general distribution along coastal and estuarine areas (Macnae 1966). Distribution patterns are the end result of interactions among various factors (Duke *et al.* 1998), such as tidal frequency, water salinity in the soil, and inundation depth. In general, the chief factors affecting mangrove distributions are: (i) temperature; (ii) salinity and rainfall; (iii) duration and depth of inundation; (iv) wave action and exposure; (v) connectivity and exchange of water currents; and (vi) development of soils. These factors interact with each other (Duke 2006).

FAO (1994) provided data on the changes in species composition and changes in water quality parameters monitored in Thailand by Aksornkoae (1975) from the coastline to inland in Thailand (Table 3).

Based his observations of the ecological characteristics of mangrove forests in Malaysia, Watson (1928) divided the vegetation mats of the mangrove forests in Malayan Peninsular into 5 inundation classes:

- (i) Mangroves inundated by all high tides from 0 to 8 feet, Sonneratia alba belongs to this group
- (ii) Mangroves inundated by all medium-high tides from 8 to 11 feet, predominant species are *Rhizophora and Bruguiera*
- (iii) Inundation by normal high tides from 11 to 13 feet, a common species is *Xylocarpus granatum*
- (iv) Inundation from 13 to 15 feet, a common species is *Lumnitzea littora*
- (v) Inundation only during exceptionally high tides from 15 feet up, predominant species is *Hibiscus tiliaceus*.

Table 3. Variation in species composition correlated to water quality parameters in Thailand.

No	Vietnamese name (Genus)	Water quality parameters							
		T°C	pH	Salinity ‰	DO ml/l	CO mg/l	PO_4	NO_3	S_iO_2
1.	Dừa nước (*Nypa*)	29.5	7.2	22.21	4.40	16.00	1.179	2,025	87.57
	Đước (*Rhizophora*)	28.2	6.8	21.18	2.68	17.73	0.966	2,533	9.61
2.	Mấm (*Avicennia*)	29.1	7.0	22.04	3.37	17.91	1.290	2,220	94.33
	Vẹt (*Bruguiera)*	27.9	6.7	20.96	2.36	16.48	0.823	2,418	99.72
3.	Xu (*Xylocarpus*)	28.2	6.8	21.18	2.68	17.73	0.966	2,533	9.61
		27.8	6.7	20.67	2.15	16.82	0.838	2,365	92.46

No	Vietnamese name (Genus)	Water quality parameters							
		T°C	pH	Salinity ‰	DO ml/l	CO mg/l	PO_4	NO_3	S_iO_2
4.	Dà (*Ceriops*)	27.8	6.7	20.67	2.15	16.82	0.838	2,365	92.46
	Cóc (*Lumnitzera)*	27.5	6.6	18.62	1.55	19.82	0.834	2,407	100.82
5.	Ráng (*Acrostichum*)	27.5	6.6	18.62	1.55	19.82	0.834	2,407	100.82
		27.6	6.6	19.49	1.70	20.62	0.859	2,590	107.84

Source: (Aksornkoae 1975)

De Haan (1931) considered salinity to be the primary factor controlling the distribution of mangroves, and tidal inundation as a subsidiary factor. Based on water salinity, he divided the coastal area into 2 zones: a brackish water to salt-water zone with salinity of 10-20‰ (zone A) and a fresh water to brackish water zone (zone B) (FAO 1994).

Zone A is further divided into subzones:
- (i) Sub-zone A1, has a ground surface inundated by tides 1 or 2 times per day and over 20 inundation days per month
- (ii) Sub-zone A2 has a ground surface inundated by tides 10-19 days per month
- (iii) Sub-zone A3 has fewer than 9 inundation days per month
- (iv) Sub-zone A4 is only inundated for 1 day each month

Zone B is divided into 2 subzones:
- (i) Sub-zone B1 is seldom inundated by tides
- (ii) Sub-zone B2 is inundated on a seasonal basis

2.4 Dominant mangrove communities on the coast of Soc Trang

The Southern Institute for Forest Inventory and Planning describes the main mangroves occurring in large communities through either regeneration or artificial planting in the coastal estuaries in Soc Trang (Phân Viện ĐTQHR Nam bộ 2003) as follows:

Sonneratia* communities including *Sonneratia alba* and *Sonneratia caseolaris occur naturally. The total area of these communities in 2003 was 722 hectares. They were distributed in the An Thanh Nam, An Thanh Ba, Lich Hoi Thuong, and Trung Binh communes, along estuarine and coastal areas near the Mekong River mouths.

The *Sonneratia* community was established through natural regeneration on the mudflats, which were newly accreted due to frequent inundation by the semi-diurnal tides of the East Sea. Together with the occurrence of the accreted flats in the coastal estuaries, the scattered forests are gradually becoming denser to form permanent communities. Mature communities in Trung Binh commune (Tran De District) have densities of 5,000 trees per hectare.

Well-grown *Sonneratia* can disperse to the surrounding area by natural regeneration. Mature forest belts are effective in protecting coastal areas from strong erosion, speeding up the deposition of sediment on the shore, buffering against disasters, and contributing to the protection of agricultural crops and residential areas behind the belts.

Natural *Avicennia* community of *Avicennia alba*. The total area of these forests in 2003 was 162 hectares, distributed mainly on the Vinh Hai coast. *Avicennia* trees regenerate naturally on the accreted flats, a distance away from the river mouths, on soft mudflats inundated by the semi-diurnal tide (Phân Viện ĐTQHR Nam bộ 2003).

On elevated hard ground, *Avicennia* forests grow much slower. Over time, the ground surface is raised due to sediment deposition, the *Avicennia* and *Sonneratia* communities degrade, grow more slowly, and gradually die, making room for other species such as *Rhizophora* and *Lumnitzera.*

Planted *Sonnenratia* community. The total areas of planted *Sonneratia* in 2003 was 1,355 hectares, distributed mainly along the coasts of the An Thanh Nam, An Thanh Ba, Lich Hoi Thuong, Trung Binh, Lieu Tu, and Vinh Hai communes. *Sonnenratia* grows on the accreted, soft mudflats inundated by semi-diurnal tides.

Planted *Avicennia* community. The total area of planted *Avicennia* was 440 hectares in 2003, distributed through the Vinh Hai, Lac Hoa, and Vinh Chau communes.

Planted *Rhizophora* communities. The total areas of *Rhizophora apiculata* was 254.14 hectares in 2003, distributed along the coast of the Lai Hoa, Vinh Phuoc, Vinh Tan, Lac Hoa, Vinh Chau and Vinh Hai communes. These forests were planted pure or mixed with naturally regenerated *Avicennia* on the accreted mud flats and on the soft mudflats inundated by the semi-daily tides of the East Sea.

On elevated ground without tidal impact, forests grow slowly. In this case, ditches could be made through the plantation to bring tides into the forest and to improve tree growing conditions.

2.5 Values and services of mangrove forests

Howe *et al*. (1991) lists the values and functions of mangrove forests and the impacts that would reduce or destroy the values and functions of mangrove forests.

Mangrove forests protect the coastal zone from waves, erosion, break winds, and accelerated accretion of sediment

The deep root system of mangroves helps reinforce the new accretion. The broad canopy with the sturdy branches of mangrove trees attenuates wave energy to protect the shore. Research by Mazda (1997) concluded that a stretch of 6 year old mangroves 1.5 km in width could reduce the amplitude of offshore waves from 1.5 m to 0.05 m by the time they reach the coastline.

The mangrove belt's capacity to reduce wave energy depends on some factors such as the species of mangrove, the status of the vegetation mat, the depth of inundation, and the conditions of the wave occurrence (Mazda 2006).

It is clear that mangrove trees are highly capable of reducing wind energy from the sea to the land and reducing the height of waves during high tides, as in Figure 10. The intensity of wind blowing through a mangrove forest is markedly reduced. If the mangrove stretch is dense and wide, the wind would change course so that the residential and infrastructural development behind the forest would be protected and the extent of damage would be much reduced in comparison with a scenario without the forest.

Figure 10: Mangrove forests protect communities in the coastal zone.
Left: Coast with forest protection belt. Right: Coast without forest protection belt.

Research by Mazda (1997) in Thuy Hai commune, (Thai Thuy district, Thai Binh province) during high tides from November 17 to November 21, 1994 shows that a 6 year old *Kandelia candel* belt 1.5 km in width could reduce offshore wave heights from 1 m to 0.05 m when it reaches the shore, and fully protects the coastline from erosion.

The dense root system of mangroves also retains the sediment carried from the inland to the sea. Accumulation of sediment along with decayed organic matters and detritus raises the ground level and speeds up the accretion process. Due to the mangrove forest, the accreted flats expand for hundreds of meters into the sea, such as at the mouths of the Mekong River and the Ca Mau Tip.

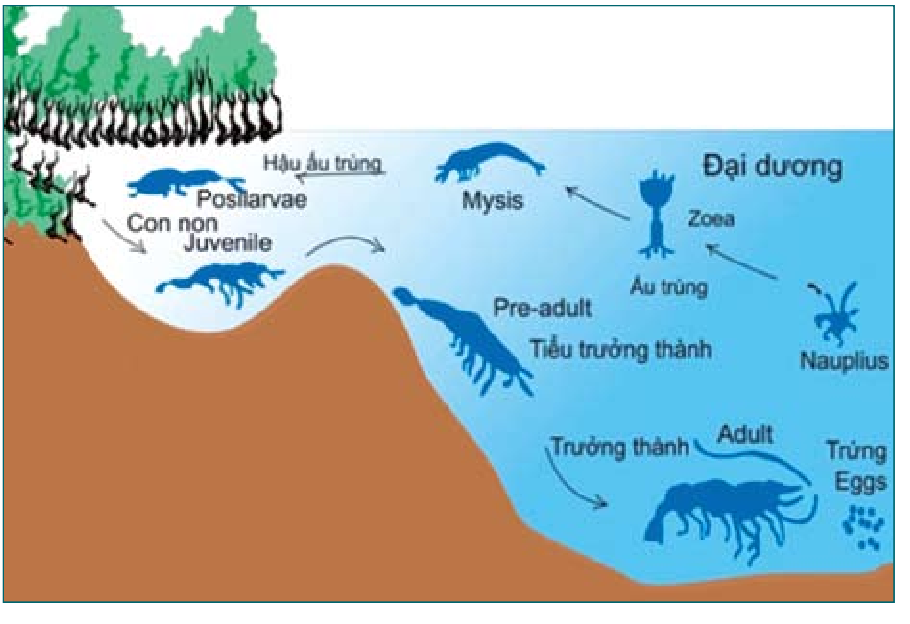


Figure 11: Mangroves - a place for nurturing and protecting parent shrimps and crabs (Redrawn with permission from Bui Thi Nga and Huynh Quoc Tinh, 2008).

Mangrove forests provide nutrients for many organisms living in the estuaries and near the shore, which are important nutrient pools for many kinds of aquatic organisms.

The tidal inundated flats and the channels at the estuarine areas are ideal feeding areas for birds during low tides. According to EJF (2003), there are 386 species and subspecies of birds, 260 species of fish, and hundreds of invertebrate species in the mangrove forests on the coast and in the estuaries of the Mekong Delta.

An inventory in the Thanh Phu estuaries of the Mekong River (Thọ 1998) recorded 27 species of reptiles, 8 species of amphibians, 16 species of mammals, and 60 bird species. Some threatened species were also found here, including *Gekko gekko, Varanus salvator, Lutra perspicilata, Felis viverina, Pelecanus philipensis,* and *Mycteria cinerea.*

185 phytoplankton species were recorded in the mangroves of Thanh Phu (Ben Tre), of which Bacillariophyta accounts for 79%, as well as 93 species of zooplankton, including 57 species of Arthropoda (62.29%), and 90 species of zoobenthos, including 41 species of Arthropoda (45.56%). The estuarine zone had 661 species of fish in 319 families, of which bottom dwelling fish accounted for 72%, Priacanthidae accounted for 54.43%, Canrangidae 25.5% and Priancabidae 3.79% (Hằng 2003).

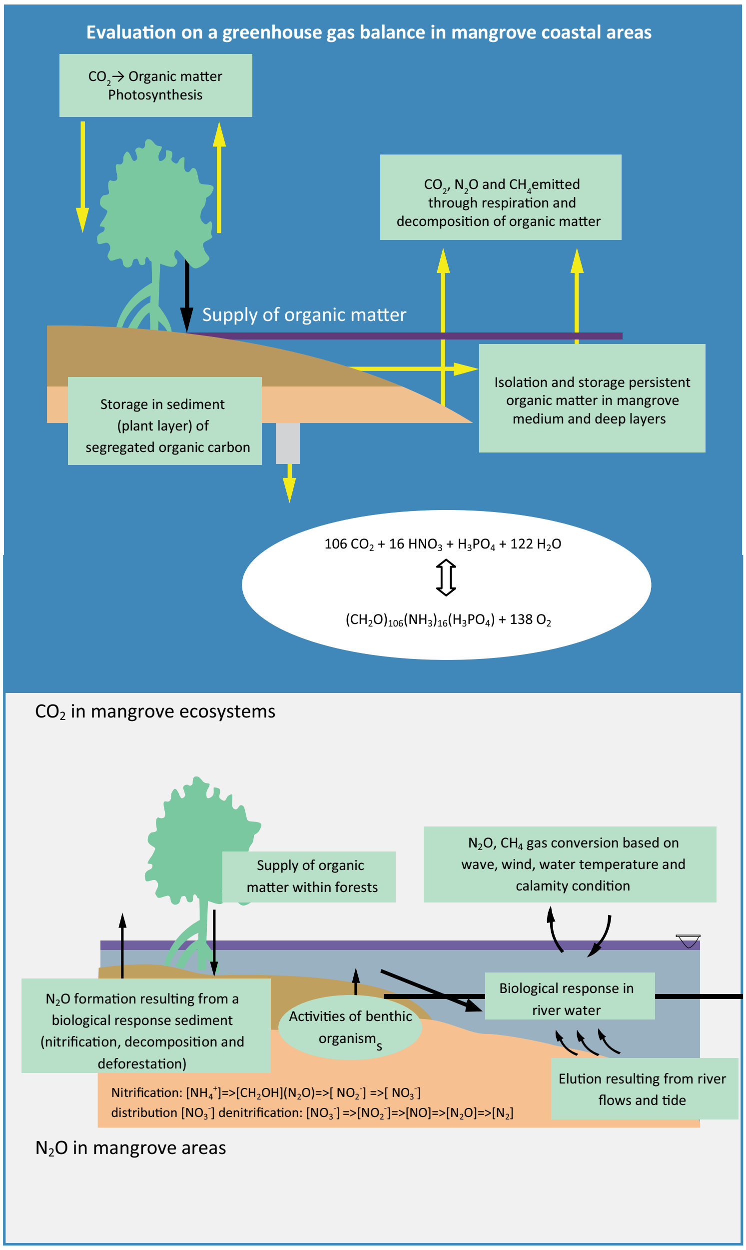


Figure 12: Carbon valuation of Mangrove (Redrawn and reworded with permission from Tri, 2007).

The surface dwelling fish species account for 28%, with the middle and surface water layers having scads (cá bạc má), anchovy (cá nục), Lizardfish (cá mối vạch), flying fish (cá chuồn đen), and codfish (cá thu vạch). About 68% of ocean fish live near the shore and depend on the productivity of mangrove vegetation, while the remaining 32% live in deep water ecosystems. Two thirds of the annual fish catch in the world depends on the integrity of coastal wetland ecosystems (Hằng 2003).

About 20 species of shrimp have been recorded in Thanh Phu mangroves in Ben Tre province (Hằng 2003). These included 12 marine shrimp of five families and eight fresh water species.

2

High commercial value species include *Penaeus indicus; Metapeneus ensis, M. lysanassa* and *M. spinulatus*. Young clams occur in almost all of the estuarine mud flats, providing important income and jobs for local inhabitants.

Scientists have proven the close relationship between mangrove rehabilitation and yields of marine products, (Pedersen 1996). Each hectare of mangrove can maintain a yield of 450 kg of aquatic products annually (Hinrichsen 1999). Ecological values and benefits of mangroves can be seen in Figures 11 and 12.

Provision of goods to the local population

Mangroves serve multiple uses. Phan Nguyên Hồng and Hoàng Thị Sản recorded 30 tree species providing wood, charcoal, and fuel wood; 14 species providing tannin; 24 species providing organic materials for fertiliser, land improvement or soil retention; 21 species providing medical herbs; 9 species serving as shelter to breed lace; 21 tree species harbouring honey bees; and 1 species providing resin or sugar for beverage making (Hồng and Sản 1993).

Rhizophora apiculata, Sonneratia, Avicennia and Bruguiera are timber trees. Mature *Rhizophora apiculata* reaches dimensions of 40 cm breast height diameter and 25 meters in height. Annual growth of *Rhizophora apiculata* in Ca Mau reaches a rate of 1.2 cm in diameter, 0.85 m in height. Yearly, *Rhizophra apiculata* plantations can provide a harvest of 20 m^3 over a 25-year cycle. *Rhizophora* timber can be used for making furniture and various items involved in house construction.

Charcoal made from *Rhizophora* and *Bruguiera* provides an important source of energy. Traditionally, charcoal of *Rhizophora apiculata* is favoured and widely used by people living in the coastal zone, and fishermen also like to use charcoal. Charcoal made from *Rhizophora* is preferred in some industries as it provides high energy as coal (6,375-6,675 cal/kg). In the coastal zone of the South, charcoal made from *Rhizophora* is still commonly used to this day. The yield of charcoal in Vietnam is about 20% of the weight of the wood or 1 stere of wood weighing 800 kg would produce 165 kg of charcoal.

Tannin is a substance present at high levels in the bark of mangrove trees. Tannin content levels in the barks of the different mangrove species are as follows: *Ceriops (29.85%), Bruguiera (13.6%), Lumnitzera (13.4%), and Rhizophora (12.2%). Nipa fruticans* is a useful plant for the locals. The leaf is used for house thatching. Fruits are edible and the resin of the flower can be used for producing sugar, wine and vinegar. The plant helps to protect channel banks form erosion (Lợi 1972).

A tourism destination and research site

The natural landscape and pleasant climate make mangrove forests a tourist attraction. Many mangrove forests are famous as ecotourism destinations, including Can Gio and Ca Mau Tip. Mangrove forests also attract researchers who come to conduct research. Mangroves in Soc Trang province have great potential for tourism if they are well-protected.

Conservation of cultural and natural values

The coastal estuarine mangrove forests in Soc Trang play important roles in protecting the landscapes of the wetlands and maintaining the ecological processes of the coastal and estuarine areas. The mangroves maintain natural succession processes.

The role of mangroves in coping with rising sea levels / the impacts of climate change

During recent years, the adverse impacts of climate change on natural resources and society have become more evident, in terms of increasing scale and intensity. The coastal lowlands are increasingly subject to the impact of strong waves and wind. The mangrove forest ecosystems serve to reduce the impacts of climate change and rising sea levels.

The mangrove forests have dense root systems above the ground, which serve to absorb wave energy. With thick foliage and branches, mangrove forests form a fence to attenuate wave energy. Sediment and organic detritus accumulates to strengthen and raise the ground. The fruits and seeds of mangroves then germinate and rapidly colonise the mudflats.

The sea dykes in Thai Thuy (Thai Thuy District, Thai Binh Province) are 86.6 km long and were built a long time ago. In 2005, storms number 6 and number 7 coincided with the high tide period, causing high waves in this area. The dykes, however, were not damaged owing to the mangrove forests planted after the Xuan Hai dyke was damaged in 1996. Recognising this contribution, the agricultural sector determined that mangrove rehabilitation is an important investment for maintaining sea dykes.

Mangrove forests also help limit saline intrusion and protect groundwater. In coastal cities and towns, high tides cause inundation in many residential areas. One of the reasons for this is that most of the channels were once lined with *Nypa* and many other mangroves such as *Sonneratia, Xylocarpus, Avicennia, Kandelia, Xylocarpus* before being cleared to build industrial zones and residential areas, resulting in poor drainage.

Mangrove forests protect animals during high tides and waves. Many species of bottom dwellers, such as small crabs and snails living in holes or on the mud surface, could find shelter in the trees to avoid high tides and waves. Afterward, they could return to their habitats. The biodiversity of mangrove forests is thus maintained. The organic detritus and materials brought by the rivers quickly decompose, providing a rich source of feed for the animals.

Economic value of mangroves

According to “The Economic Valuation of Alternative Uses of Mangrove Forests in Sri Lanka”, each hectare of mangrove forest in Sri Lanka has an annual economic value as follows (Batagoda 2003):

- Non-wood forest resources, US$ 108
- Local recreation value, US$ 933
- Global recreation value, US$ 1,196
- Global option value, US$ 1,039
- Local option value, US$1,491
- Global bequest value, US$ 562
- Local bequest value, US$ 1,714
- Global existence value, US$ 1,399
- Local existence value, US$ 883
- Benefits of providing breeding grounds for fish, US$ 218
- Erosion control benefits, US$ 3.6
- Biodiversity maintenance benefits, US$ 18
- Carbon sequestration benefits, US$ 75
- Storm protection benefits, US$ 76 and pollution treatment benefits, US$ 4,494
- Accordingly, the study estimated the Total Economic Value (TEV) of a conserved mangrove forest at US$ 12,229 per hectare, per year.

2

According to *Proceedings of the National Academy of Sciences* for release July 21, 2008, scientists at Scripps Institution of Oceanography at UC San Diego, writing in the new online edition, showed that Mexican mangroves - trees that form forest ecosystems at the land-sea interface - demonstrably boost fishery yields in the Gulf of California (PNAS 2008).

They found that thirteen fishing regions in the Gulf of California produced an average of 11,500 tons of mangrove-derived fish and blue crab per year between 2001 and 2005, generating nearly US$ 19 million for local fishermen.

The annual value of mangrove ecosystem services worldwide has been estimated at more than US$ 1.6 billion. Such services benefit human populations through climate regulation, water supply availability, erosion control, waste treatment, food production and recreation.

The researchers weighed economic, geographic and ecological factors and determined that a hectare (10,000 square meters, or roughly 2.5 acres) of mangrove fringe - the edge of the mangrove forest in contact with the sea - in the Gulf of California is valued on average at about US$ 37,500 per year. The forest is essential to the long-term well-being of many other people whose livelihoods depend on the fisheries.

In Soc Trang, the coastal and aquatic resources in the *Sonneratia caseolaris* forest at the estuarine areas are rich. The harvesting methods are also diverse depending on gender and age. While men catch fish, women and children catch young crab and other aquatic organisms such as clam, shellfish, etc. These resources contribute to the livelihoods of many households living in the coastal zone. *Sonneratia caseolaris* forest belts create an ecological environment for aquaculture in the buffer zone. They act as a giant water filter for the farmer to get fresh water into aquaculture ponds and filter water released from the ponds.

Estuarine wetlands carry high economic values. According to Nguyen Huu Ninh and Mai Trong Nhuan (Ninh 2003), economic values of estuarine mangrove forests in the Mekong Delta can be estimated at 3,099.36 US$/ha/year, including value from wood and fuel wood, and 3,083 US$/ha/year from indirect values.

The theoretically estimated yield matches reasonably well with the data on catches, which show that 1 hectare of mangrove forest provides approximately 700 kg of fishery products.

Summary of the Services and Values of Mangrove Forest

Services of Mangroves

- Barrier to salt water and wave energy
- Protection against storms, wind, erosion, and sea advance
- Reduces damage, protects sea dyke and construction along the coast
- Retention of nutrients
- Production of biomass
- Maintenance of natural ecological processes on the coastal zone
- Tourism and research

2

Provision of Products

- Wood, fuel wood, non timber forest products, medical herbs
- Wildlife resources
- Fishery resources

Attributes

- Biodiversity
- Native cultural heritage

For these reasons, mangrove forests need to be managed and developed as part of the solution for a climate change coping strategy.

3

Variation in Mangrove Forest along the Coastal Zone and Environmental Consequences

3.1 Variation in mangrove forest resources

Located at the river mouths of the Mekong River, the coastal zone of Soc Trang offers advantageous natural conditions for mangrove vegetation, with *Sonneratia caseolaris*, and *Avicennia marina* being the dominant mangrove trees that naturally occur in large populations.

Changes in mangrove cover along the coastline of Soc Trang Province from 1965 to 2007 has been analysed based on a topographic map (scale 1:50,000, sheet number 6117IV, 1965) and satellite image interpretation (SPOT satellite 1995, Landsat ETM December 2001 and QuickBird 2007). The results are shown in figure 13. For shoreline and mangrove cover changes from 1889 -1965 see Joffre (2010).

The topographic map of 1965 shows mangrove forests distributed along the estuary in An Thanh Nam commune (Cu Lao Dung District), Trung Binh and Lich Hoi Thuong communes (Tran De District), Lac Hoa (Vinh Chau District). During this period, the mangroves stretched along the My Thanh River and Tra Nien channel as far as 15 km from the coastline inland. The total area of the dense forests in the An Thanh Nam, Lich Hoi Thuong, and Lac Hoa communes was about 4,003 hectares, comprised mainly of *Sonneratia* and *Nypa fruticans*.

From 1977 to 1982, local people replanted forests on the barren lands void of forest; some areas regenerated naturally due to suitable conditions in terms of tide, soil, and seedling supply. This resulted in the rapid expansion of forest area. However, from the end of the 1980s, vast areas were converted for agricultural and shrimp farming purposes, leading to a rapid reduction of mangrove forest.

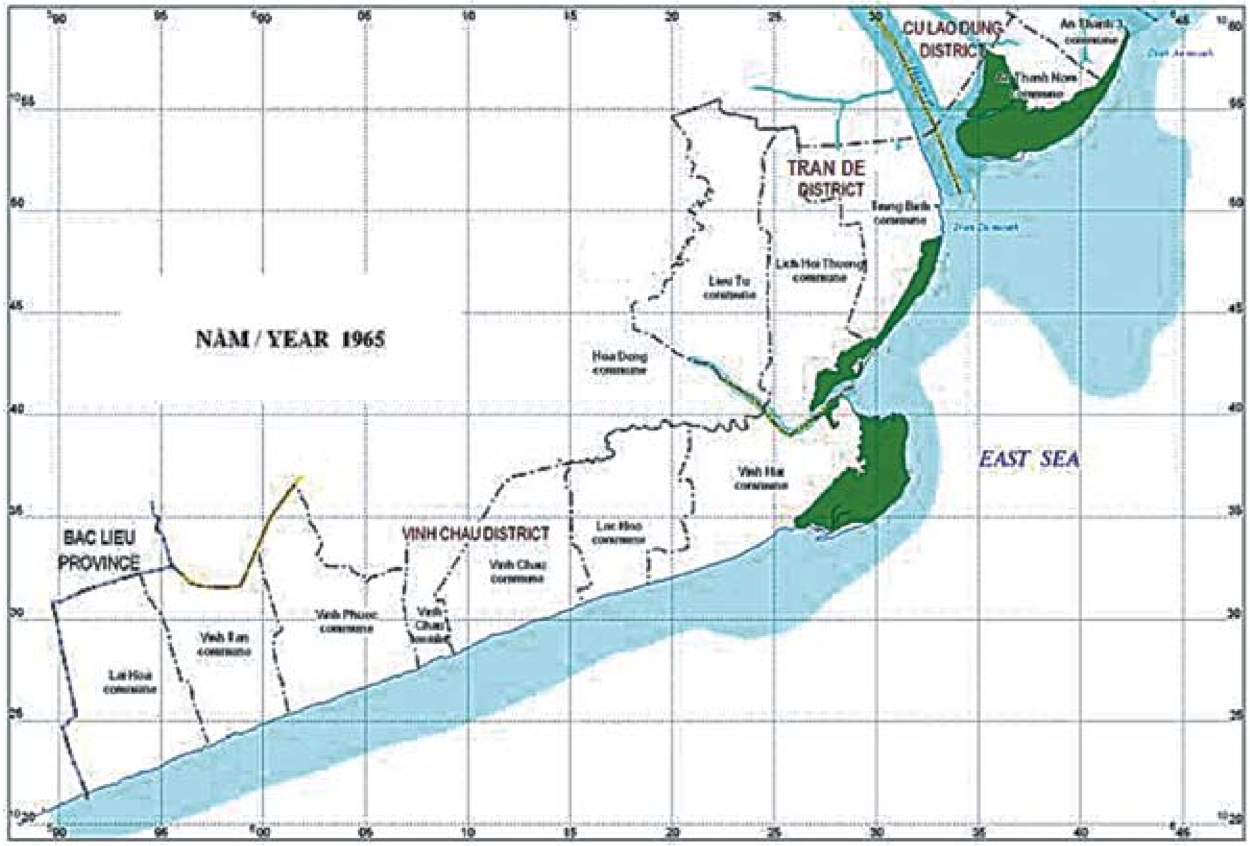
During the 1990s, poor planning for cutting forest and converting these resources into aquaculture and agriculture lands were the main causes of forest depletion on a large scale, resulting in erosion of the coastline and intrusion of salt water inland.

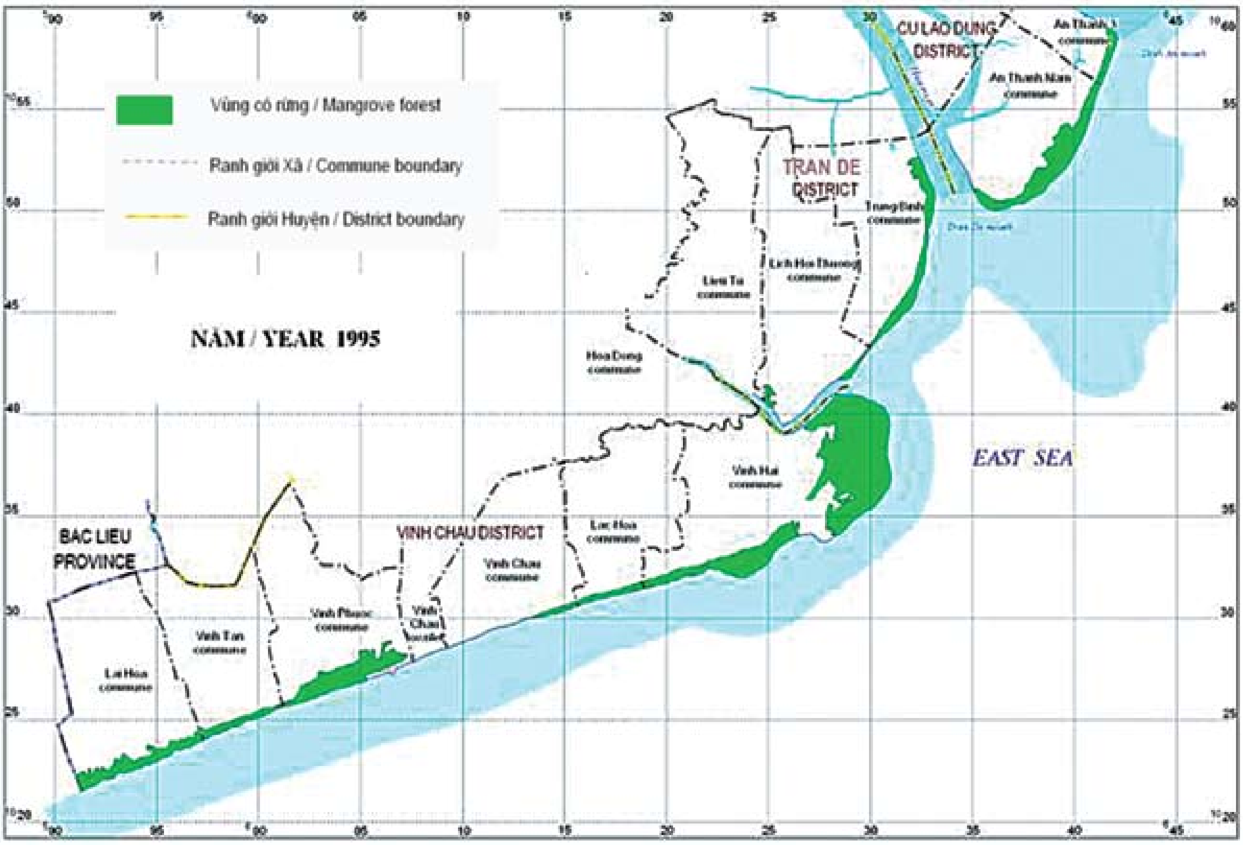
According to data published by the Institute of Forest Inventory and Planning, Ministry of Forestry in 1983, the total mangrove area in Soc Trang was 3,000 hectares.

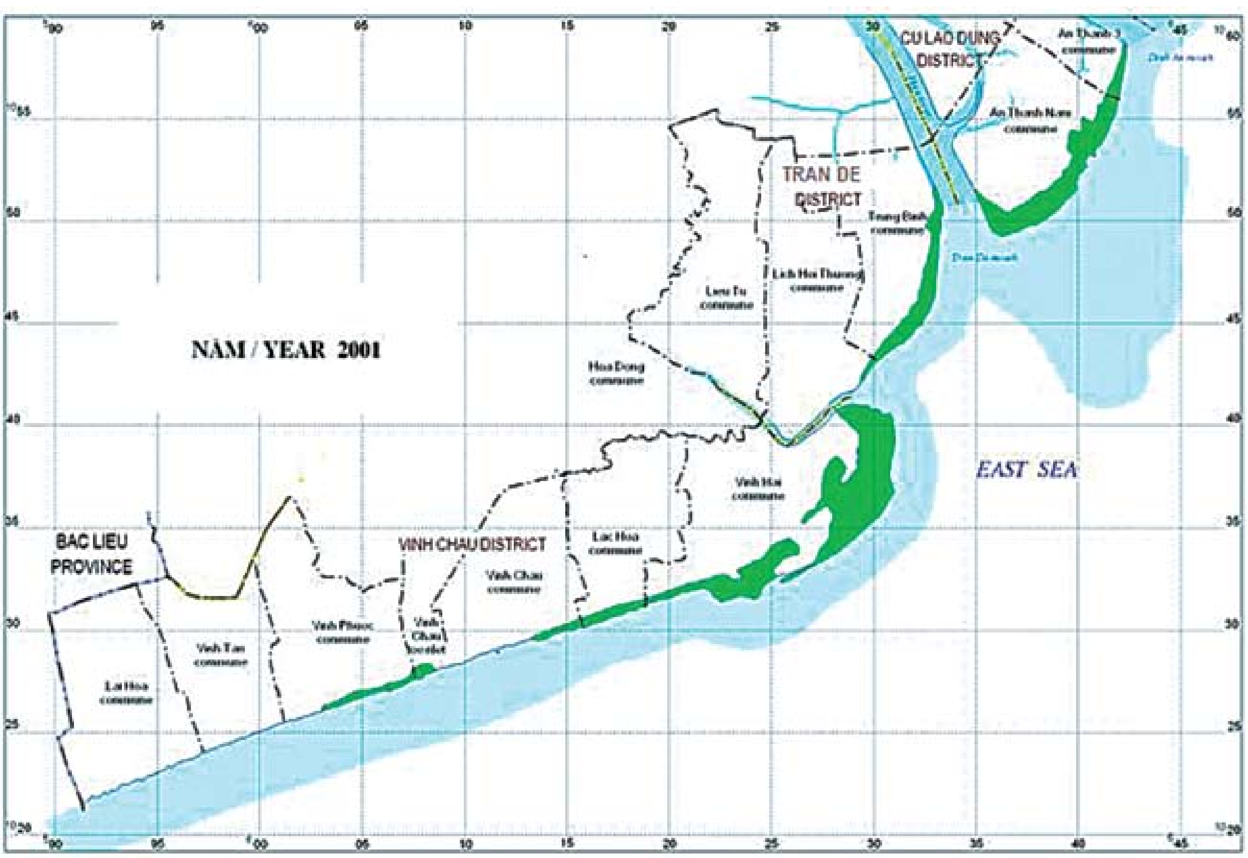
In 1995, as part of the rehabilitation of mangrove forest, project implemented by the Forestry Inventory and Planning Institute, about 4,585 hectares of mangrove forest were recorded using SPOT satellite images. From 1995 to 1998, the MILIEV project planted 98 hectares in the Vinh Chau and Tran De Districts of Soc Trang Province.

In 2001, the total mangrove forest area in the coastal zone of Soc Trang was 4,336 hectares according to Landsat ETM satellite images from December 11, 2001. The Southern Sub-Institute for Forestry Inventory and Planning (2003) recorded 2,990.79 hectares of mangroves, of which 884.07 hectares were natural forest, comprised of 721.91 hectares of *Sonneratia* and 162.16 hectares of *Avicennia*. Forests covered 2,106.72 hectares, included 1,354.87 hectares of *Sonneratia*; 199.6 hectares of *Rhizophora*, and 440.14 hectares of mixed *Rhizophora* and *Avicennia*.

Over the 15-year period from 1980 to 1996, in the Mekong estuaries, which includes the three provinces of Ben Tre, Tra Vinh, and Soc Trang, 37,349 hectares of forestland were converted into agricultural land and for other uses. These were natural, plantation, and scrubland areas. The annual losses were recorded as 4,833 hectares and 850 hectares, during 1980-1986 and 1986-1996, respectively (Thịnh 1996). Variations in mangrove areas in Soc Trang from 1965 to 2007 are presented in Figure 14.




Vùng có rừng / Mangrove forest
Ranh giới Xã / Commune boundary
Ranh giới Huyện / District boundary
NĂM / YEAR 1995
CU LAO DUNG DISTRICT
An Thanh Nam commune
TRAN DE DISTRICT
Trung Binh commune
Lich Hoi Thuong commune
Lieu Tu commune
Hoa Dong commune
Vinh Hai commune
EAST SEA
Lac Hoa commune
VINH CHAU DISTRICT
Vinh Chau commune
Vinh Chau townlet
Vinh Phuoc commune
Vinh Tan commune
Lai Hoa commune
BAC LIEU PROVINCE


NĂM / YEAR 2001
CU LAO DUNG DISTRICT
An Thanh Nam commune
TRAN DE DISTRICT
Trung Binh commune
Lich Hoi Thuong commune
Lieu Tu commune
Hoa Dong commune
Vinh Hai commune
EAST SEA
Lac Hoa commune
VINH CHAU DISTRICT
Vinh Chau commune
Vinh Chau townlet
Vinh Phuoc commune
Vinh Tan commune
Lai Hoa commune
BAC LIEU PROVINCE

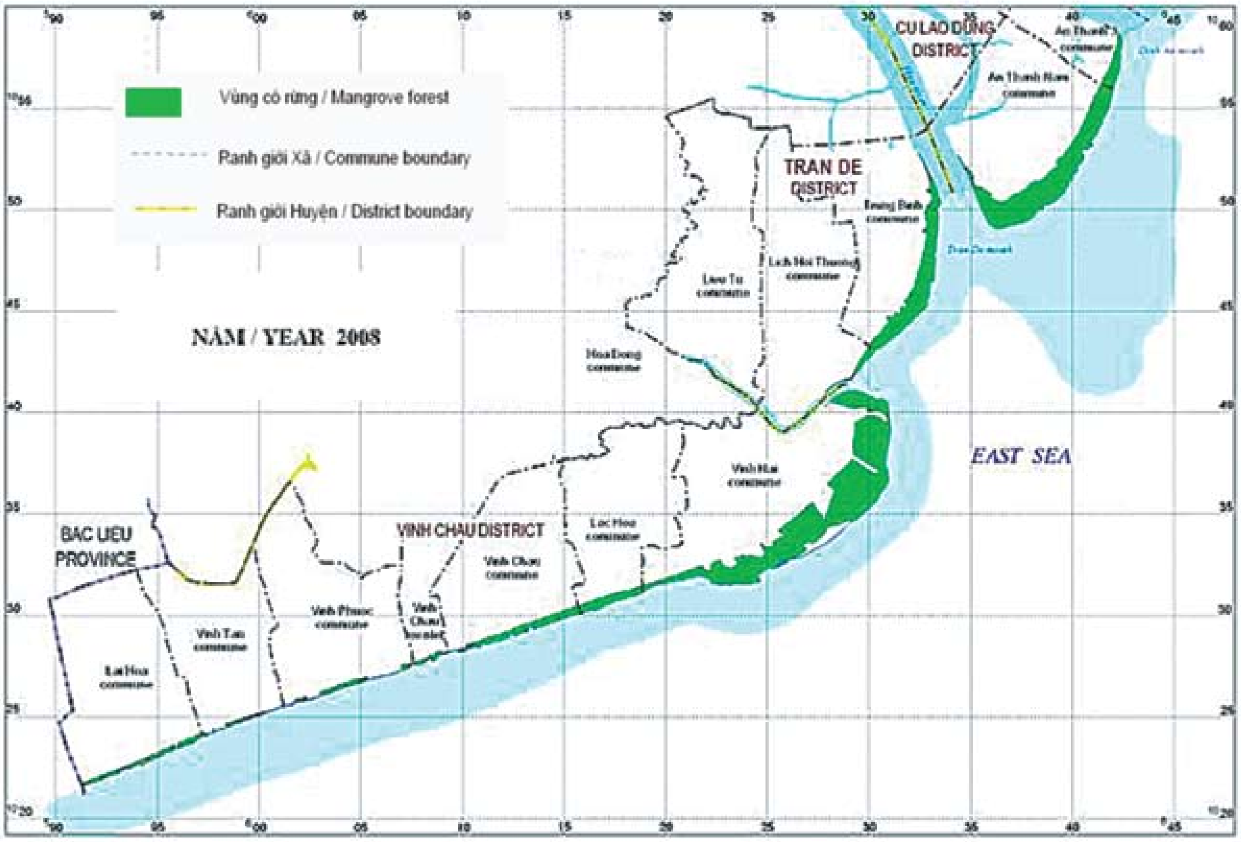


Figure 13: Maps of mangrove forest along the coast of Soc Trang Province from 1965 to 2007.

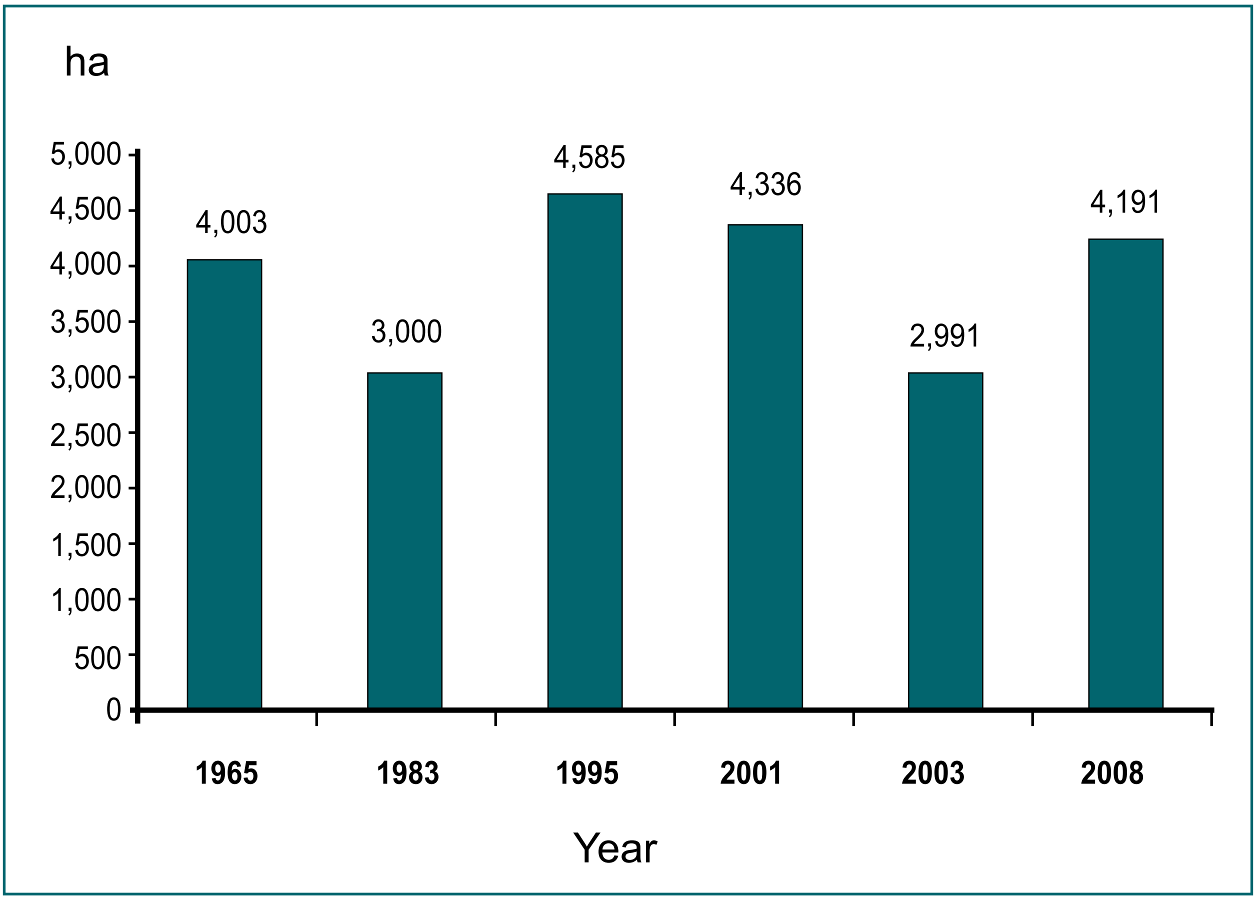


Figure 14: Variation in mangrove forest area in Soc Trang.

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3.2 Causes of loss of mangrove forest resources

Mangrove forests are open ecosystems of the coastal zone, which receive and exchange materials with the outside environment through tidal action, inundation and sedimentation processes. Any impacts, which disturb ecological processes of mangrove forests, would consequently change the environment and damage ecosystems. Factors disturbing environmental attributes of mangroves may be due to the following causes (Howe *et al.* 1991):

(i) Changes in hydrology regime, impeding the tidal flow
(ii) Construction of infrastructures, blocking flows
(iii) Cutting and clearing vegetation, over harvesting the fauna
(iv) Alternation of substrate
(v) Oil, chemical, or organic pollutions

In the past, mangroves in the coastal zone of Soc Trang have experienced sever declines. The causes of mangrove loss include (i) the expansion of shrimp aquaculture into mangrove forests (ii) low awareness among communities regarding the functions, values, and lack of sustainable use skills, and (iii) coastal erosion. These causes have led to negative environmental and social consequences in the coastal zone.

a) Clearance of mangrove forests for shrimp aquaculture

The shrimp farming movement in mangrove forests began in 1987 when the aquaculture sector began exporting dried and frozen shrimp products to other countries.

These farming systems were of several types: extensive, improved extensive, semi-intensive or intensive. ‘Extensive’ and ‘improved extensive’ are popular systems for mangrove areas. Aquaculture farms extended to sizes of up to 10 hectares, with the forest surrounded by embankments and mangrove trees cleared to make ditches. These ditches were 10 meters in width and 1.5-2.0 meter deep. Water in the ponds was controlled by water gates, with one or two gates per pond. In ponds with only a single water gate, the tide entered and exited through the same opening. In ponds with two gates, the tide entered through one gate and exited through another one.

During the high tidal period around the beginning or middle days of the lunar month, water gates were opened and young shrimp and aquatic larvae from the wild enter into the pond with the tides, stocking the pond. The water gate is then closed and kept that way for 30 to 45 days enabling the shrimps to mature; the farm functions as the trap, and food for aquatic organisms and shrimp is available in the pond. In the case of ‘improved extensive’ farms, seedlings and food are added. After a few weeks of keeping the water contained, the gate is opened at low tide to drain the water out. Farmers use nets to capture all the organisms, and some farmers empty their ponds after 15 days to harvest all the aquatic organisms in the pond. They are unable to wait until aquatic organism mature, but they have to earn enough for their living expenses.

During the first 2 or 3 years after cutting the forest, the pond is full of nutrients with organic matter and seedlings available in the pond. When the number of ponds was rather small, the quantity of annual aquatic products harvested was rather good - about 300 to 400 kg per hectare. A few years later, the pond became polluted with organic matter accumulation, water circulation was restricted, and the reduction in wild shrimp larvae correlates with an increased area of ponds.

Many negative impacts connected with environmental pollution and disease were caused by the failure of aquatic farming systems. With long inundation periods, tidal circulation is very limited, so organic matter accumulates at the bottom and the toxicity generated by farming activities severely impacts mangrove trees. They gradually stop growing and eventually die.

During the 1990s, Vinh Chau was one of the districts using the greatest mangrove area for shrimp farming of all the coastal communes. Due to a lack of farming techniques, within a short period shrimp crops failed, resulting in a loss of revenue and invested labour. Significant swathes of mangrove forest were destroyed and became fallow land with only shrubby plants remaining.

At that time, some families in the new economic zone (Vinh Phuoc and Vinh Tien cooperatives) built small shrimp ponds of 0.5 to 3.0 hectares on the fallow land or secondary forestland using the family's own labour. They were also impeded by their lack of technical knowledge, shortage of capital and the change to a water environment. Most of the households in the new economic zone are still indebted to the bank due to this shrimp farming failure.

Dense forest is considered to be the reason for the shrimp farming failure, since it produced too much biomass, which subsequently accumulated at the bottom of the pond, reducing oxygen and then toxicity into the water. Therefore, farmers tried to clear forests to have more open water for their farms, which caused a more rapid degradation of mangrove forests.

Decreasing yields from the wild led many people to clear more forest for shrimp farming. Many households left their traditional livelihoods near the shoreline and offshore fishing, and began cash cropping into shrimp farming or working as hired labourers for other shrimp farmers. It was not only those households living in the mangrove forest who built shrimp ponds, but also households in the neighbouring areas who came to encroach upon the coastal mangrove forest for raising shrimp.

The large benefits of shrimp farming caused rich people to fervently hire labourers and purchase machinery to build more farms in the mangrove forests. Many government agencies and individuals received land allocation in mangrove forests and also tried to convert these lands into shrimp farms or to lease out the lands for shrimp farming. The land allocation for shrimp farming was arbitrary and did not follow any planning method. The district and even commune authorities could allocate forestland to farmers without any consideration or evaluation of land-use planning, which also contributed to the degradation of mangrove forests.

The destruction of mangrove forests became increasingly serious within the years between 1987 and 1997, corresponding with the increase of frozen shrimp export and the enlargement of extensive shrimp farming in mangrove areas. In some communes such as Vinh Phuoc, Lai Hoa, Vinh Tien, forests were also cleared for shrimp farming. The destruction of mangroves for shrimp farming, as in Figures 15 and 16, is very widely observed in coastal areas.

Figure 15: *Avicennia* forest destroyed by illegal cutting.

Figure 16: *Rhizophora* forest dying due to the building of a dyke.

3

b) Clearance of mangrove forest for agriculture

Soil under mangrove is of a high salinity and is not suitable for almost any cultivated crop, but alluvium soils are fertile. In the rainy season and in some places with available fresh water, people clear forests for dry cropping. Mangrove forests in the coastal estuaries used to be cleared for agricultural crops such as onion, tobacco, watermelon, squash, chilly, green bean and so on, but the outcome of these plantings was mixed. Migrants gradually cleared mangrove forests for agriculture farming in the Ho Lang area near the My Thanh river estuary.

In some other areas, mangroves were cleared to make room for planting coconut, which also failed and led to negative ecological consequences due to a lack of knowledge regarding the soil development process. A typical example is the coconut plantation in Giong Chua village, Vinh Hai commune, in Vinh Chau district. According to plans from the (former) Hau Giang Province, 550 hectares of mangrove forest at the estuary of My Thanh River would be cleared to make room for a coconut plantation. After 5 years of coconut cultivation, the soil degraded and all the coconuts died. Similarly, the salt production cooperatives in Vinh Phuoc and Vinh Tien cleared mangrove forest and invested tens of millions of VND (in the 1980s) for growing coconuts, but the soil became dried and cracked in the sunshine. Salt leached onto the land surface, and in the dry season, high levels of evaporation from the soil caused the salt concentration levels to increase making the ground unsuitable for cultivation.

c) Clearance of mangroves for salt production and *Artemia* production

Salt production is a traditional occupation engaged in by coastal communities. For salt production, since 1987 about 1,500 hectares of mangrove forests have been cleared in Vinh Phuoc and Vinh Hai. During this time, Can Tho University began its pilot development of *Artemia* in Vinh Chau District. After clearing mangrove forests in the two salt production cooperatives in 1989, salt production expanded and the *Artemia* production pilot was successful. The area for production of salt, shrimp, and *Artemia* in Vinh Chau stretched along the Giong Bien road in the Vinh Phuoc, Vinh Tan, and Lai Hoa communes and encompassed a total area of 1,985 hectares, of which 100 hectares were for *Artemia* production.

Artemia is usually raised after a salt harvest season, when the water is clear and the salt content is still appropriately high for raising *Artemia*. At present, although the *Artemia*-shrimp production research institute of Can Tho University in Vinh Phuoc has demonstrated initial success, experiences from the pilot project cannot be transferred to the community yet, as it requires a high level of investment and technology.

d) Awareness, policy, and institutional issues

The disappearance of mangroves has been caused by an inadequate level of awareness among people regarding the role and services of the forest as well as the associated environmental consequences. Mangrove forests were once considered to be public property. In fact, no institution or individual was a real landowner of the forest. Forest management institutions were very weak and lacked the infrastructure, funding, equipment, and legal framework to play a role in promoting forest management responsibility.

Community awareness regarding the role and service of the forest was very poor and lacking. Local authorities (commune and village) have not paid attention to forest protection.

In fact, shrimp farming contributed to the local budget in the form of land taxes. Forest rehabilitation, on the other hand, required investment, which led to poor levels of awareness about the benefits of the forest.

e) Ineffective forest management

Socio-economic policy has been unsuccessful in providing incentives for people to protect the forests, because the values and benefits of forests, while invaluable, have been ignored in the socio-economic development strategy. The investment in forest rehabilitation over the past years has not been appropriate to the local conditions. Investments for the forests were only aimed at planting, while other things such as protection and site improvement were ignored.

Mangrove forest protection and rehabilitation comes into conflict with the obstacle presented by the difficult living conditions for the local communities. In 1992 and 1993, the Government launched Decision 327/CT and 264/CT to incentivise forest rehabilitation on fallow land and newly accreted land. In 1998, the Prime Minister launched a national program for rehabilitation of 5 million ha of forests across the country, which took the place of Decision 327/CT and 264/CT (Chính phủ 1992) and (Chính phủ 1993).

Under these policies, forest lands along the coast were allocated to farmers and contracts were made in order to provide more job opportunities and income to people. Rates of 50,000 to 100,000 VND were paid per hectare each year for protecting the land.

From 2000 to 2007, the World Bank Project on Coastal Wetland Protection and Development also applied this policy for protection of mangrove forests in the coastal full protection belt of Soc Trang Province. Up until 2004, contracts were also made with local social associations instead of households for the protection of mangrove forests in remote areas of An Thanh Nam commune (UBNDT Sóc Trăng 2007).

However, this process still faced many difficulties, for instance, how to share benefits between the state and local people. Without any benefits, people tried to make any income possible by destroying the forest instead of protecting it.

Investment in forest protection was still very low, and rehabilitation and planting activities did not bring enough direct income to meet the basic needs of the farmers. Advanced techniques for sustainable farming did not transfer to farmers or result in their improved livelihoods. Funding from poor clearance and poverty elimination programs remains low, and the living conditions for people in the coastal areas are still very poor, so they try to earn money from the forest by any means possible.

Inadequate management institutions and a weakened capacity for carrying out information campaigns, training, education, and patrolling for the environment and forest protection, as well as the immediate profits of shrimp farming lure residents and migrant people who clear mangrove forests for shrimp production, which leads to a failure in terms of the rehabilitation objectives.

Eliminating negative causal factors in order to promote mangrove protection requires several strategies. It is necessary to set up models for sustainable management of the coastal ecosystem and create suitable conditions for people to be involved in coastal management. Local farmers need sustainable likelihood opportunities and must get a shared benefit from the integrated management of coastal resources including a stable income to meet their daily needs. The causes and consequences of mangrove loss in Soc Trang Province are presented in Figure 17.

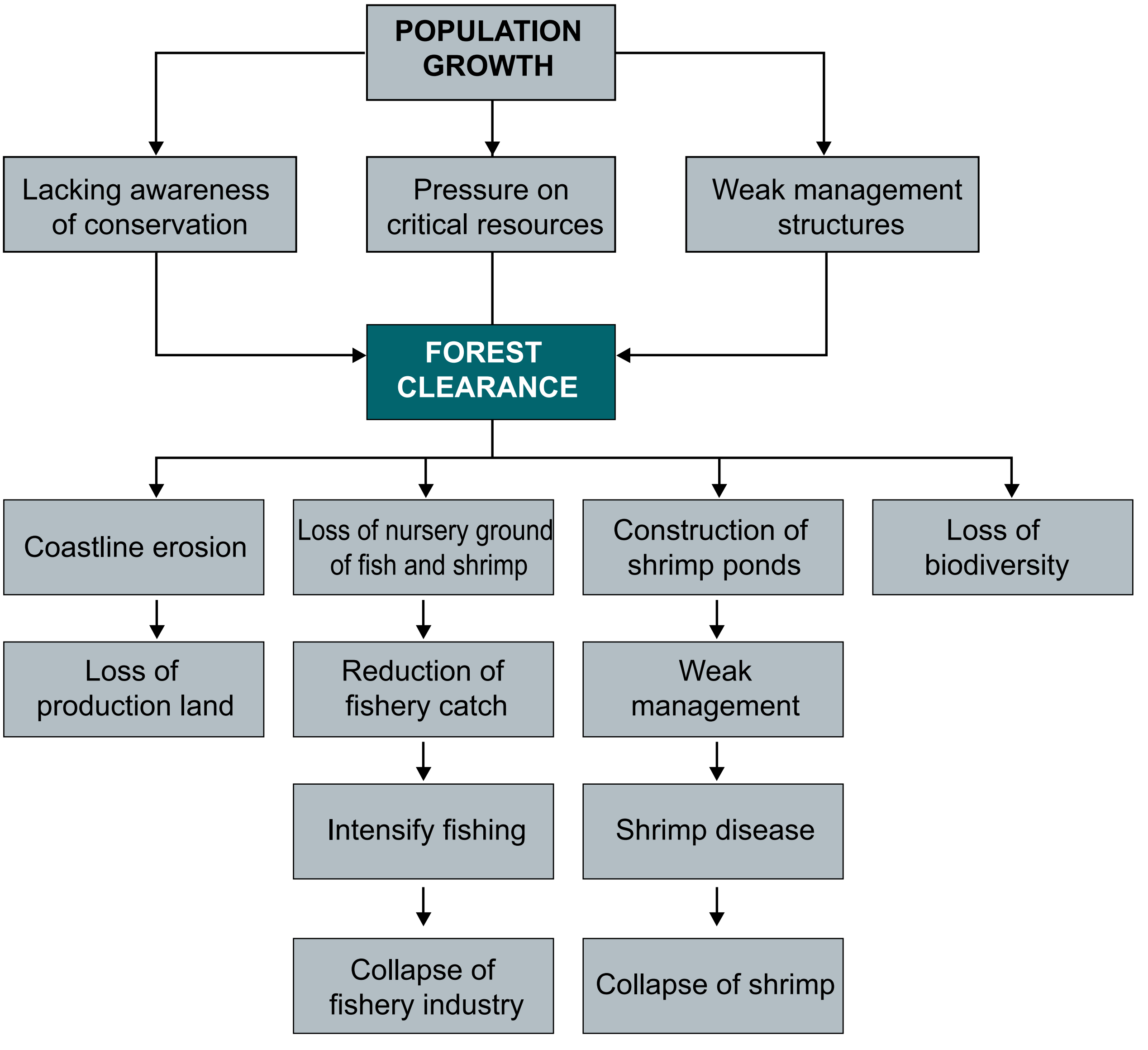

Figure 17: Causes and consequences for the loss of mangrove forests

3.3 Consequences of the loss of mangrove forest resources

The loss of mangrove forest resources causes shortfalls for the coastal fishing industry. Habitats providing large natural stocks of shrimps and fishes of high commercial value have been lost.

Degradation of mangrove forests has resulted in the reduction of habitat biodiversity. Birds and wildlife have almost disappeared in the coastal zone. The threat of strong waves and storms has been increasing year by year and impacts the sea dykes, infrastructure, assets, crops, and houses in the coastal communities. Each year, more investment is needed to maintain these structures.

In the early morning of October 27, 1992, a storm and tornado caused sudden strong waves into the Tran De and Vinh Chau districts, which broke sea dykes and destroyed tens of thousands of hectares of shrimp farms, rice fields, and orchard land, while also damaging thousands of houses. About 60-70% of the victims were members of the Khmer ethnic group. The damage was estimated at 117 billion VND (Khương 2005).

In Vinh Chau District, strong waves rushed as far as 4,000 meters inland, with the first waves causing inundation levels of up to 2 meters, damaging 50-70% of the 42 km of sea dykes, of which 13 km of sea dykes were destroyed, and 11 saline prevention water gates collapsed. About 4,300 hectares of shrimp ponds were submerged, with 300 hectares of *Monodon* ready for harvest being completed destroyed. In addition, 420 hectares of cropland with high commercial value such as onion, garlic, Logan gardens and 160 hectares of rice field were destroyed. Almost all of the 1,100 victims were members of the Khmer ethnic group. Waves sank four boats, killed one student, and another three people went missing. Many schools and roads were damaged, and salinity intrusion caused difficulties for agriculture for several years afterwards.

In this disaster, 13 dyke sections along 5 km in the coastal communes of Tran De District were destroyed. 78 houses in the Mo'O of Trung Binh commune collapsed, 126 large sea-filter nets were swept away, four people were killed, and 1,300 hectares of shrimp ponds that had been recently constructed on an Eleocharis grassland field were severely affected by salt water. In the coastal communes and Cu Lao Dung, 2,500 hectares of rice and 5,800 hectares of sugar cane and onion were severely damaged. Thousands of hectares of cash crops and industrial plants were affected, resulting in low yields. In addition, aquaculture fish in 5,425 fishponds in the previously mentioned communes were swept away. The total estimated loss in Tran De District was 75.6 billion VND.

In My Xuyen District, an area situated further inland, high water caused damage to 2,000 hectares of rice, with damages estimated at 3 billion VND. Due to the tremendous damage from the tsunami in 2004 in the Indian Ocean to surrounding countries, the provincial people's committee and the local authorities have taken steps to plant forests and build saline prevention dykes.

After recognising the consequences of the destruction of mangrove forest, the government and people have made a major effort to restore coastal forests in recent years. Since 1993, thousands of hectares of mangrove forest have been planted using various sources of funding. In 2004, NOVIB (the Netherlands) provided financial support for planting 20 hectares of *Rhizophora* forests in Vinh Phuoc commune.

In 1996, the MILIEV project (the Netherlands) and ACTMANG supported the planting of 5 hectares of Rhizophora mucronata. Governmental program 327 offered funding for the planting of thousands of hectares of mangrove forest. Since 2000, with the support of the World Bank, hundreds of hectares of mangroves have been planted. This shows that restoration of mangrove forest has received the attention of the people as well as national and international organisations. Experiences and lessons learned from planting activities are presented in the next chapter.

4 Coastal Forest Planting, Management, and Protection in Soc Trang Province

Coastal forest rehabilitation in Soc Trang Province has had many achievements over the past 15 years, which are the result of support from a number of quarters. This includes support from the central government through several planting programmes, Programme 327 from 1993 to 1997, credit budget from the World Bank (from 2001 to 2007), and assistance from other international organisations based in the Netherlands and Japan, as well as World Bank.

From 1993 to 2007, Soc Trang Province restored 2,357.66 hectares of mangrove forest. The three main species include *Sonneratia* (1,394.4 hectares), *Rhizophora* (521.12 hectares) and *Avicennia* mixed with other species (440.14 hectares).

The outcome of the forest planting over the last 15 years is that the stretch of *Sonneratia* from Ho Lan channel in Vinh Hai commune, through Vinh Chau and Tran De district to An Thanh 3 commune of Cu Lao Dung district forms a green wall to protect the sea dyke along the coast.

Recent outcomes of the forest planting have helped to enlarge mangrove forest areas in the coastal zone of Vinh Chau, Tran De, and Cu Lao Dung. These areas have stabilised and are gradually regaining the protective mangrove functions in terms of wave and wind breaking, reduction of sea dyke damage, and providing a nursery and habitat for many aquatic species of high commercial values such as shrimp, fish, and crustaceans.

These programmes have a lot shortcomings as discussed in the previous chapters and the following sections. These shortcomings include: inadequate rehabilitation techniques at different sites particularly on eroded areas and high land or fallow lands, a lack of appropriate structures for optimising the protective capacity of the forest belt and reducing coastal erosion, and a lack of policies and institutions for integrated management of coastal zone. In addition, mechanisms for involving local people in forest management are still lacking. The results of forest rehabilitation over the past years will be assessed and presented in this chapter and will serve as good lessons for implementing the rehabilitation of forests in the coastal zone of Soc Trang Province.

4.1 Planting under the governmental programme 327

Decision 327/CP of the Government, dated September 9, 1992 aims to rehabilitate forests on barren and freshly accreted lands, and provide more livelihood opportunities to local farmers in remote areas. This decision has raised the awareness level of people at all levels regarding forest protection and rehabilitation. Under the framework of this decision, Soc Trang Province prepared and approved the provincial master plan for forest development. The master plan is comprised of several projects for restoring mangrove ecosystems in estuaries and coastal areas in order to protect coastal zones from natural disasters due to the ocean's influence, mitigate coastline erosion, and retain and consolidate newly deposited mudflats. These projects are also expected to restore nursery grounds for shrimp and fish and promote sustainable development in the coastal zone.

From 1993 to 1997, this programme rehabilitated 1,900 hectares of mangroves. The two main species used in this programme were *Sonneratia marina* and *Rhizphora apiculata,* which were planted at new accretion areas along the Cu Lao Dung and Tran De coastlines. Results from a survey of the team in May 2008 including some features of forest areas are presented in Table 4.

Planting of *Sonneratia caseolaris*

Data in Table 4 shows that *Sonneratia caseolaris* grows very well with average DBH (diameter at breast height, i.e. measured at 1.3 metre above the ground) varying from 11.6 cm to 12.7 cm and total height from 8.6 to 12.3 m; forest densities vary from 1,100 to 1,600 trees/hectare. The number of remaining trees observed in May 2008 occupied from 24% to 32% of the areas and were regularly distributed. With an age of 15 years old, this density level is acceptable. The trees in the forest are healthy and almost all of them are vigorous, with the number of dead or eliminating individuals being negligible, as indicated in Figure 18.

At Plot 2 and Plot 13 (Table 4), the forest was planted within a 50 m wide belt along the existing forest. The ground surface was compacted mud with a subsidence of 5-10 cm; tidal maximum inundation was about 0.8 m. The site selected for the planting of *Sonneratia caseolaris* proved to be appropriate. Formerly scattered trees protected young seedlings from strong waves, resulting in a high survival rate in the existing forests. Natural young seedlings are appearing under the forest crown.

The forests are growing well and are strictly protected. Naturally regenerating classes are growing up, which diversifies the forest structure and increases the protective function of the forest.

Table 4. Planting achieved by Programme 327 In Cu Lao Dung and Vinh Chau districts.

Site monitored (Commune)	Plot Number	Species	Planting year	Planting density	Average DBH, height and number of existing stands monitored in May 2008		
				Seedlings/ha	DBH (cm)	Height (m)	Number (trees/ha)
An Thanh Nam	2	*S. caceolaris*	1993	5,000	11.6	10.9	1,600
An Thanh Nam	13	*S. caceolaris*	1993	5,000	12.7	12.3	1,200
Vinh Chau town	26	*R. apiculata*	1995	20,000	5.2	7.5	6,400
Vinh Phuoc	27	*R. apiculata*	1995	20,000	5.7	8.1	6,700
Vinh Hai	41	*R. apiculata*	1995	20,000	6.0	10	6,300

Figure 18: ***Sonneratia caseolaris*** **planted at An Thanh Nam commune, in 1993.**

Figure 19: ***Rhizophora apiculata*** **planted in Vinh Hai commune, in 1995.**

Planting of *Rhizophora apiculata*

Rhizophora apiculata (Figure 19) was planted on two main sites at high and medium elevations. At the high elevation sites, the ground was seldom inundated by tides, and Plots 26 and 27 had average total forest heights of 7.5 to 8.1 m. At Plot 41, tidal inundation is more frequent, so while trees are the same age, they are growing faster and the average total height of the mangrove forest is 10 m.

Differences in forest growth have also been observed in Plot 26 and Plot 27, with the mean diameter and total height of the forest at Plot 26 being 5.2 cm and 7.5 m, respectively. At Plot 27, the mean diameter and total height of the forest are 5.7 cm and 8.1 m, respectively. The forests in Plot 27 are subjected to tidal inundation supplied by canals, which had previously been built for planting coconut. Daily tidal circulation keeps the substrate soft, brings more alluvium and fertiliser to the area, and promotes the exchange of oxygen in the aquatic ecosystem. These processes provide good conditions for tree growth.

4.2 Forest planted by the Netherlands

Within the framework of a project funded by the government of the Netherlands (Project MILIEV), about 98 ha of *Sonneratia caseolaris* were planted in Trung Binh commune, Tran De District, in 1996. These trees are growing well and have an average total height and diameter as shown in Table 5. They are 15 cm in diameter; and 12.5 m in height, while the forest density is 1,100 trees per hectare.

Sonneratia caseolaris was planted on compact mud with subsidence of 5 cm and maximum inundation of about 1.3 meters. *Sonneratia caseolaris* seedlings were planted within 30 meters of the existing *Sonneratia* forests. This plantation was a pilot site with a high level of investment delivered to a small area. Mortality rates in the forest were low and the forests are growing well.

Table 5: Forest planted by MILIEV project at Trung Binh Commune, Tran De District.

Site monitored (Commune)	Plot Number	Species	Planting year	Planting density	Average DBH, height and number of existing stands monitored in May 2008		
				Seedlings/ha	DBH (cm)	Height (m)	Number (trees/ha)
Trung Binh	16	*Sonneratia caseolaris*	1996	5,000	15	12.5	1,100

4.3 Forest planted by the Coastal Wetlands Protection and Development Project

The Coastal Wetland Protection and Development (CWPD) project in southern Vietnam was implemented within the coastal area of four provinces: Tra Vinh, Soc Trang, Bac Lieu and Ca Mau. The project aimed to rehabilitate coastal mangroves to improve nutrient functions of mangroves and coastal protection. Soc Trang Province executed this project from 2000 to 2007 with credit supported by the World Bank and sponsorship by the governments of Denmark and Vietnam.

In this project, some 1,085.67 hectares of forest were planted from 2000 to 2007 on the coast of Soc Trang Province. The forest area was planted at the full protection belt in Soc Trang from 2000 to 2007 as presented in Table 6.

Table 6: Plantation area from 2000 to 2007 of CWPD.

Year	Area of forest planted (ha)			Average DBH, H and N of existing stands monitored in May 2008
	Total	Enrichment of poor forest	New forest	
2000	582.23	466.03	116.2	54%
2001	242.5	91.47	151.03	>90%
2003	37.94	0	37.94	96%
2004	90	61	29	70%
2005	63	0	63	78%
2006	60	0	60	>80%
2007	10	0	10	>80%
Total	**1,085.67**	**618.5**	**467.17**	

Source: (UBNDT Sóc Trăng 2007)

These new forests contributed to an increase in the green coverage of the coastal zone. The capacities of the foresters in all fields of forest management and protection have also improved and been strengthened. Local people have been involved in the project's activities, such as planting, tending, protecting, training and education activities. Their awareness level in regard to the benefits of mangrove forests has also improved. Illegal cutting has dropped by 94% between 2000 and 2006. Some features of the forest are presented in the following paragraphs.

Results of surveys from May 2008 of plantations in Cu Lao Dung, Tran De, and Vinh Chau Districts are assessed and presented in Table 7. In 2000, the project planted 582.23 hectares, including 466.03 hectares enriching degraded forest and 116.2 hectares of new forest in Trung Binh commune (Tran De District), An Thanh Ba and An Thanh Nam communes of Cu Lao Dung District. The average survival rate within 3 months of planting varied from 54% to 96%.

4

In 2001, some 242.5 hectares was planted in the Tran De, Vinh Chau, and Cu Lao Dung districts. Of this forest, 91.47 hectares were planted to enrich poor forests and 151.03 hectares of new forest were planted. The species planted were *Rhizophora, Sonneratia,* and *Avicennia,* and the average survival rate of the plantation was over 90%.

In 2003, the project planted 37.94 hectares of *Rhizophora* in the Lai Hoa, Vinh Tan, and Vinh Hai communes. The survival rate within 3 months of planting was 96%. Hence, the project planted a total of 862.67 hectares of forest by the end of 2003.

From 2004 to 2007, project planted about 223 hectares, with species including *Rhizophora, Sonneratia*, and *Casuarina*. The quantity of forest planted to enrich poor existing forests was 61 hectares and new forest plantings covered 162 hectares. The average survival rates of the forests exceeded 75%.

Planting of *Sonneratia caseolaris*

Table 7 gives data about *Sonneratia cassolaris* that CWPD planted in some locations along the coast of Soc Trang from 2000 to 2006. The original forest densities ranged from 5,000 to 3,300 trees per hectare.

According to observations in May 2008, the existing forest densities vary widely depending on substrate features, inundation levels, and human interference.

Densities of existing stands planted in 2000 are 6.8% for Plot 3, and 54.5% for Plot 21. The density of Plot 42 is 40%and 66% for Plot 33 of forest planted in 2001, while it ranged from36.4 to 33.3% to forest planted in 2006.

Table 7 shows some data on *Sonneratia cassolaris* planted in 2000 in Plot 21 with original densities of 3,300 stems per hectare in Trung Binh commune, Tran De district. In this area, maximum tidal inundation is about 0.9 m. The substratum is loam with subsidence of 20 cm. These forests were planted to enrich seedlings in degraded forests and are 16.1 cm in average diameter and 11.0 m total height, with the average density of the forest at 1,800 trees/hectares.

In Plot 12, Table 7 shows that in An Thanh Nam commune forest stands have an average diameter of 15.4 cm and average total height of 11.4 meter, with a forest density of 2,700 trees/ha. Maximum tidal inundation at this site is about 1.0 meter, with a substratum of sandy loam and a subsidence of 2-5 cm. Seedlings were planted in pots within a 50 m belt along the existing forests. This site was once covered by scattered regenerated seedlings before it was planted. These natural trees protected young seedlings from strong waves and wind.

Data on Plot 3 in Table 7 shows that stands of *Sonneratia caseolaris* planted in 2000 at An Thanh Nam commune Cu Lao Dung district have an average diameter of 8.3 cm and average height of 6.2 meters. The average density of the stand is only 340 trees/ha, while maximum tidal inundation at this site is over 1.7 meters. The substratum was muddy with a subsidence of 20 cm. The low survival rate shown in Figure 20 was caused by high inundation during the planting season, which caused young seedlings to be uprooted and carried away by tidal currents. At other sites belonging to Trung Binh commune in An Thanh Nam, young seedlings were planted at a distance of 100-150 meters from the existing forest. The inundation level was more than 1.7 m, and almost 100% of the seedlings disappeared.

Table 7: *Sonneratia caseolaris* and *Avicennia marina* planted under CWPD.

Site monitored (Commune)	Plot	Species	Planting year	Planting density	Average DBH, height and number of existing stands monitored in May 2008		
				Seedlings/ha	DBH (cm)	Height (m)	Number (trees/ha)
An Thanh Nam	3	*S. caseolaris*	2000	5,000	8.3	6.2	340
An Thanh Nam	12	*S. caseolaris*	2000	5,000	15.4	11.4	2,700
Trung Binh	18	*S. caseolaris*	2000	5,000	10.3	6	900
Trung Binh	19	*S. caseolaris*	2000	5,000	12.9	9.6	900
Trung Binh	21	*S. caseolaris*	2000	3,300	16.1	11	1,800
Trung Binh	25	*S. caseolaris*	2001	5,000	11.2	7	2,100
Vinh Hai	42	*S. caseolaris*	2001	5,000	9.4	13.9	2,000
Vinh Chau	33	*A. marina*	2001	5,000		2.1	3,300
Trung Binh	24	*S. caseolaris*	2006	3,300	4.8	3	1,200
Trung Binh	17	*S. caseolaris*	2006	3,300		2.7	1,100

Figure 20: The forest has had a low survival rate since seedlings were swept away by high inundation.

Figure 21: Barnacle clinging to trees, causing death of tree.

In Plots 18, 19, and 25, of forests planted in 2000, the trees have an average diameter of 10.3 - 12.9 cm and average total height of 6-9.6 meters, with a density of 900-2,100 trees per hectare. Observations at these three locations found that the forests are slowly growing. Masses of barnacles clinging to the stems of seedlings were the main factor decreasing the survival rate of forests (Figure 21).

Planting of *Avicennia marina*

CWDP planted *Avicennia marina* along the coast of Vinh Chau commune (Figure 22). The forest was planted in clay soil on elevated hard surfaces inundated occasionally by high tides.

As shown for Plot 33 in Table 7, the average total height of the 6 year old *Avicennia marina* forest is 2.1 m. Young trees are stunted, growing slowly with too many branches. It has been ascertained that this site is unsuitable for *Avicennia,* as the ground is too dry and elevated. *Avicennia marina* requires a thick layer of mud and daily inundation from medium tides. This site could be improved by lowering the ground surface with ditches to transfer the tide and sediment into the area.

Figure 22: *Avicennia marina* planted with seedlings in bowls 6 year old at Vinh Chau.

Planting of *Rhizophora*

Data from a survey on *Rhizophora apiculata* plantation at Vinh Hai, Vinh Tan, Lac Hoa, and Vinh Hai is presented in Table 8.

Table 8. *Rhizophora apiculata* planted under CWPD.

Site monitored (Commune)	Plot No.	Species	Planting year	Planting density	Average DBH, height and number of existing stands monitored in May 2008		
				Seedlings/ha	DBH (cm)	Height (m)	Number (trees/ha)
Vinh Tan	29	*Rhizophora*	2005	10,000		0.5	500
Vinh Tan	30	*Rhizophora*	2005	10,000		0.4	400
Vinh Tan	31	*Rhizophora*	2006	10,000		0.93	8,800
Vinh Tan	32	*Rhizophora*	2007	20,000		0.89	10,700
Vinh Tan	34	*Rhizophora*	2002	10,000	2.0	2.8	2,300
Lac Hoa	36	*Rhizophora*	2006	20,000		0.93	6,900
Lac Hoa	37	*Rhizophora*	2006	20,000		0.85	400
Vinh Hai	38	*Rhizophora*	2006	10,000		0.98	4,300

Rhizophora apiculata was planted at a number of sites with hard clay soil (Vinh Tan and Vinh Chau Communes), clay soil with ditches to get tidal into the planted areas (Lạc Hoa commune) and potting seedlings (at Vinh Chau commune). Planting densities were 20,000 or 10,000 propagules per hectare.

Rhizophora apiculata was planted in 2005 (Figure 23, Plot 29 and Plot 30) in Vinh Tan commune, Vinh Chau district. This site is on elevated ground and is not inundated by the tide. The survival rate of forest seedlings is very low, with average densities of existing trees of about 400 to 500 trees/hectare. The mean height of the forest is only 0.5 meters. The trees are not healthy; some of them are being eliminated.

Rhizophora apiculata was planted in Plot 34 in 2002 on hard clay ground inundated only during high tides. The 6 year old forest had an average height of only 2.8 meters and average diameter of 2.0 cm, with an average density of 2,300 trees per hectare.

Rhizophora apiculata requires sites with a thick layer of steady mud or soft clay and inundation by daily tides. The aforementioned site is not suitable to this species. In this case, some investment is needed to improve the site conditions in order to get the tide and sediment to the site.

An example for this type of site can be found in Lai Hoa commune of Vinh Chau district, where *Rhizophora apiculata* is planted on hard clay. The forest is growing well due to ditches that are 25 cm deep and 25 cm wide, which helps to bring the tides into the area. This method could be applied to some locations along the coastal zone for the rehabilitation of mangroves on high substratum. However, planting with land preparation in this way may be costly – doubling the cost of standard planting activities.

The *Rhizophora* forests grow very well on compact mud grounds protected by the existing forest belts or regenerated *Avicennia* (in Plot 31 and Plot 32, Figure 24). The average height of *Rhizophora* planted from seedlings in pots was 0.9 m, and the average survival rate was 88% with a density of 8,800 trees per hectare (Table 8).

Figure 23: Hard surface substrata is not suitable for *Rhizophora apiculata*.

Figure 24: *Rhizophora* planted from seedlings in pots at Vinh Chau commune are growing very well.

In Lac Hoa commune of Vinh Chau district, *Rhizophora* was planted in 2006 on compact mud with a subsidence of 5-10 cm. The forest has a planting density of 20,000 trees per hectare and an average total height of 0.93 meters. The current density is 6,900 trees per hectare in Plot 36.

In Plot 37, however, the density of the forest is only about 400 trees per hectare. In this area, local fisherman used push nets to harvest aquatic organisms, while the forest was still in its early stages, which led to the young seedlings being killed and high mortality rates in the forest. To address this situation, a mechanism for involving fishermen in the management of young forests and for maintaining their livelihoods is necessary.

Scattered planting

In order to increase green coverage in the full protection zone, the CWPD executed plans for scattered tree planting along the roads and in the gardens of government offices as well as the schools and pagodas in the project area.

These plans were executed in 2004, 2005, and 2006. The project planted 84,824 scattered trees over 3 years, with 12,383 trees planted in Cu Lao Dung district, 17,687 in Tran De, and 54,754 in Vinh Chau. This only met 74.9% of expectations to plant a total of 114,334 scattered trees. The main reason for this shortfall was that seedling suppliers did not provide enough qualified seedlings.

The project provided seedlings and training on planting techniques to involved people before the actual planting took place. Scattered trees planted around government offices and pagodas were protected, so their survival rates were very high. However, along the roads, cattle damaged trees. Seedlings that were provided without additional support in terms of maintenance costs showed that the survival rate and growth of the trees depend solely on people’s awareness levels.

By the end of 2007, the planted trees were growing well with some trees reaching 5-6 meters in height. This was particularly the case for trees planted around pagodas and government offices. The scattered trees helped to increase the average green area per capita in the buffer zone and economic zone and will provide more timber and non–timber forest products to local community in the long run.

Tending young plantations

The tending for young forests was carried out by contracted households. The contract for tending young plantations was drawn up for a period of 3 years, with costs declining from first to the third year.

Tending activities include patrolling the area to prevent negative interference with young forests, which may be caused by people or cattle, maintaining the site conditions to correspond with the requirements of young trees, and adding more seedlings to sparsely populated sites.

From 2004 to 2007, tending activities were carried out over 482.82 hectares, 37.94 hectares in 2004, 98.94 hectares in 2005, 161.94 hectares in 2006, and 184 hectares in 2007.

According to the project’s final report (CWPD 2007), tending activities for young forests planted in 2004, 2005 and 2006 yielded good results, which caused an increase in the density of sparse forests and consolidation of the full protection belt.

Forest Protection

Since 2001, the CWPD has made contracts with local farmers to protect forests in full protection areas, with each farmer protecting 10 ha. In 2004, contracts were also made with local associations for the protection of remote forest areas. Annual payments equalled 50,000 VND per hectare. From 2001 to 2007, the project made contracts with farmers to protect 533.07 ha (2001) to 2,667.47 ha (2007), (Table 9).

Table 9. Areas of protected forests over the years (ha).

Year	Area of forests being protected in districts			Cumulative sums (ha/Year)
	Tran De	Vinh Chau	Cu Lao Dung	
2001	-	533.07	-	533.07
2002	-	533.07	-	533.07
2003	526.03	712.86	-	1,238.89
2004	526.03	730.90	1,279	2,535.93
2005	555.28	795.25	1,279	2,629.53
2006	555.28	795.25	1,279	2,629.53
2007	555.28	833.19	1,279	2,667.47

Source: CWDP 2007

Under this protective agreement, the incidence of illegal forest cutting was reduced from 112 cases in 2002 to 7 cases in 2006. However, the cost - 50,000 VND per year for one hectare - was too low. Compared with the income generated by local normal labour, it corresponds to the income of a normal labourer over one or two working days. This payment rate did not encourage people to engage in forest protection activities. Under this mechanism, people are passively engaged in the protection of forests, but due to the low payments, people were not interest in the job.

Sustainable livelihoods must be provided for local people on the basis of an adequate mechanism; co-management is one possible solution. People should be proactively engaged in forest activities, and they must share the benefits of sustainable harvesting by-products and Non-Timber Forest Products, or they can fish on the open shallow beaches.

Research activities

In 2005 and 2006, within the framework of cooperation between CWPD and the Southern Forestry Science Sub-Institute, scientific research was carried out for planting *Sonneratia* on eroded and deeply inundated areas and the planting of *Rhizophora* seedlings in pots. Results of this research (Cao 2005) and local farmer experience show that three factors defined the survival of the planted *Sonneratia caseolaris.* These factors were coastal erosion, large number of barnacles clinging to the seedlings, and sedimentation burying young seedlings.

During the Mekong River's high water season from June to October, large amounts of sedimentation from upstream are brought to river mouths and form vast plains thousands meters in width in a thick layer along the coast. Young seedlings might be buried under the mud layer in the case of planting in deeply inundated sites or seedlings that were too small to overcome mud accumulation.

After the rainy season passes, a strong north-easterly wind causes strong waves, which result in severe erosion along the coast and the virtual removal of the new sediment layer. Young seedlings may also be uprooted and carried away in sea currents if they are not big enough and their roots are not firmly embedded in the deep land layer.

Barnacles usually attack the plants between February and June. During this period, barnacles gather in large numbers and cling to the stems of the trees by April. By sticking to the tree, barnacles suppress young seedlings and kill them beneath the sea surface. Their numbers reduce by June when the rainy season comes and salinity levels drop below 10%.

Activities to mitigate these negative impacts include setting the correct schedule for the planting season, which helps the seedlings become strong enough to cope with the waves and winds so that the barnacle attack can be mitigated. Forest planting activities must be completed before June each year. On the other hand, good site selection for planting helps to avert planting failures. Planting should not take place on areas that are too deeply inundated or at the severe erosion sites.

The promotion of natural regeneration is a good solution for forest rehabilitation at the river mouths and on coastal areas. Natural regeneration assistance requires a series of activities such as raising the awareness level of local people and applying administrative measures to reduce the impact of fishing activities in regenerating areas. By using construction to reduce erosion and fix the mudflats, these measures reduce the impact of waves, wind, and tidal flows to support the growth of the regenerated seedlings.

To speed up the rehabilitation on the coast, new forest planting is necessary. Experience from the CWDP and local farmers shows that *Sonneratia caseolaris* is the most suitable species for the estuaries of the Mekong River. However, planting at areas characterised by deep inundation levels also results in failure. *Sonneratia caseolaris* should only be planted in shallowly inundated areas at levels within one meter of the surface. The height of seedlings when planted must be twice that of the average inundation depth of the planting area.

The forest planting project supported by ACTMANG

ACTMANG is the acronym for the Action for Mangrove Reforestation, Japan. This is a small-scale planting project using two species for planting in the Soc Trang coastal zone of *Avicennia* and *Rhizophora*. Data collected from ACTMANG plantings is presented in Table 10.

Table 10. *Sonneratia* and *Rhizophora* planted by ACTMANG project.

Site monitored (Commune)	Plot	Species	Planting year	Planting density	Average DBH, height and number of existing stands monitored in May 2008	
				Seedlings/ha	Height (m)	Number (trees/ha)
An Thanh Nam	4	*Sonneratia caseolaris*	2007	5,000	1.8	700
An Thanh Nam	5	*Sonneratia caseolaris*	2007	5,000	1.8	400
Water gate 3	20	*Sonneratia caseolaris*	2007	5,000	1.75	700
Tra Set village, Vinh Hai	39	*Rhizophora apiculata*	2007	5,000	0.85	1,400

Planting of *Sonneratia caseolaris*

The ACTMANG programme planted *Sonneratia caseolaris* on loose mud with a subsidence of 20-25 cm and a maximum inundation depth of 1.7 m; the forests were planted using seedlings without pots (Figure 25).

In the front area facing the waves, the forest's survival rates observed in May 2008 were 8% (Plot 5, Table 10). Further inland among protected forest stretches, the survival density was 14% (Plot 4 and 20).

In this area, fishing activities take place regularly, causing seedlings to be uprooted and swept away by tidal currents.

Figure 25: *Sonneratia caseolaris* forest planted by ACTMANG.

Figure 26: One years old *Rhizophora* forest at Vinh Hai, Vĩnh Châu.

Planting of *Rhizophora*

The forest planted at Tra Set village in Vinh Hai commune is on ground that is loose mud, protected by an *Avicennia* strip to the front. The site is well suited for *Rhizophora apiculata* trees, but fishing activities have caused severe damage to young seedlings (Figure 26).

Many areas were planted with *Sonneratia caseolaris* from 2000-2003 in An Thanh Nam and An Thanh 3 in Cu Lao Dung district and *Rhizophora* in Hoa Lac commune of Vinh Chau district and experienced the same problem, leading to forests in these areas disappearing almost entirely.

A survey by the team in May 2008 showed that the density of *Rhizophora* planted in Vinh Hai commune of Vinh Chau district was 1,400 trees per hectare (Plot 39, Table 10).

The plantation's survival rate was only 28% compared with the original density, while the average total height of the forest was 0.85 m.

This site is highly suitability for *Aviciennia marina*. Natural seedlings are abundant around this area, so facilitation of natural regeneration is a good activity to undertake to rehabilitate the forest instead of planting.

4.4 Regeneration and growth of natural forest

Two forest types that have formed through natural regeneration in estuarine and coastal areas of Soc Trang are *Sonneratia and Avicennia.* The Southern Institute for Forest Inventory and Planning (2003) has recorded 723 hectares of natural regeneration forest of *Sonneratia caseolaris* in An Thanh Nam (475.82 hectares), An Thanh Ba (62.53 hectares), Lich Hoi Thuong (19.56 hectares), Trung Binh (164 hectares).

Surveys in May 2008 (Table 11) showed that the average total height of the forest ranged from 8 meters to 18.1 meters and the average density was 5,000 trees/ha in Trung Binh commune and 800 trees/hectare in An Thanh Nam commune.

Sonneratia caseolaris usually regenerates naturally on loose depositional mudflats inundated by semi-diurnal tides of the East Sea. On estuarine mudflats, this species appeared in scatter stands, which gradually become denser to form stable communities. Forest belts help to protect the coastline from strong erosion and speed up the sedimentation process, contributing to protecting the agricultural production and residential areas behind them.

Table 11. Natural regenerated forest of *Sonneratia caseolaris* in Cu Lao Dung, Tran De and Vinh Chau Districts.

Site monitored (Commune)	Plot number	Species	Planting density	Average DBH, height and number of existing stands monitored in May 2008	
			Seedlings/ha	Height (m)	Number (trees/ha)
An Thanh Nam	11	*Sonneratia caseolaris*	12.6	8.6	1,100
An Thanh Nam	1	*Sonneratia caseolaris*	25.5	14.1	800
An Thanh Nam	6	*Sonneratia caseolaris*	2.5	2	
An Thanh Nam	10	*Sonneratia caseolaris*	21.4	15.7	1,300
An Thanh Nam	7	*Sonneratia caseolaris*		1	500
An Thanh Nam	8	*Sonneratia caseolaris*		1	550
An Thanh Nam	9	*Sonneratia caseolaris*		1.4	3,000
An Thanh Nam	14	*Sonneratia caseolaris*	21.2	16.6	700
An Thanh Nam	15	*Sonneratia caseolaris*	18.2	15.6	1,400
Mo'O, Trung Binh	22	*Sonneratia caseolaris*		1.6	5,800
Mo'O, Trung Binh,	23	*Sonneratia caseolaris*	4.6	4.4	3,800
Ho Lan, Vinh Hai,	43	*Sonneratia caseolaris*	6.5	4.7	1,000

Avicennia marina trees regenerate naturally in large areas of the coastal zone of Vinh Hai commune (Figure 27a). The Southern Institute for Forestry Inventory and Planning (2003) has recorded 162.16 hectares of regenerated forest with an average height of about 4-5 meters, and diameter of 3.0 to 4.5 meters. The forest density ranged from 4,800 trees per hectare to 10,000 trees per hectare.

Highly suitable sites for natural forests of *Avicennia marina* are loose mudflats inundated by the semi-diurnal tides of the East Sea. The newly formed mudflats along the shore serve as the initial ground for pioneer vegetal species. *Avicennia marina* is a pioneer species colonising coastal mudflats. Its deep root system and large canopy help to speed up the sedimentation accumulation process, and initial forests are scattered stands, which become denser each year forming stable communities.

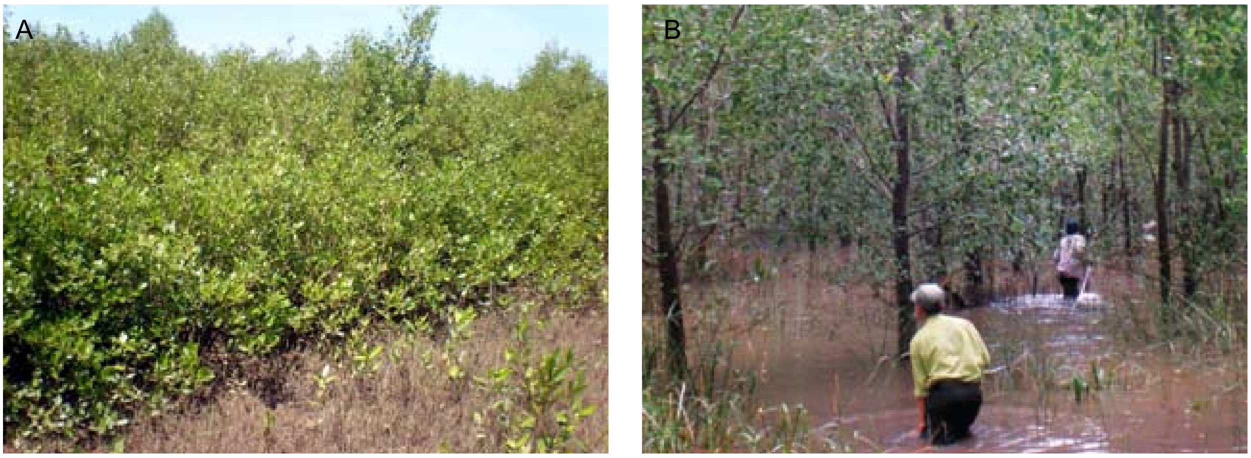

Figure 27: (a) *Avicennia marina* grows densely along the coast of Vinh Hai, Vinh Chau and (b) *Sonneratia caseolaris* densely regenerated at Con Tron.

Forests that are growing well are able to disperse young seedlings to surrounding areas. With sedimentation accumulation, the ground is gradually mounding, which causes reductions in the inundation level and duration of inundation, while at the same time the growth of *Avicennia* gradually slows. *Avicennia marina* is replaced by other species such as *Rhizophora apiculata* Bl., *Threspecia populnea* (L.) Soland. Ex Cor. *Lumnitzera racemosa* Wild.

Naturally regenerated *Sonneratia caseolaris* grows well in the Cu Lao Dung and Tran De districts. The density of forests varies from 500 to 3,800 trees per hectare. At Mo'O Trung Binh Tran De, there are 3,800 trees per hectare in two year old forests, with a total height of 4.4 m (Plot 23), and 5,800 trees per hectare for 1 year old forests, with a total height of 1.6 m (Plot 22).

In An Thanh Nam commune, natural *Sonneratia caseolaris* trees have a large diameter ranging from 12.6 cm to 25.5 cm, and with a forest density running from 800 stems per hectare (Plot 1) to 1,400 trees per hectare (Plot 15) (Figure 27b).

4.5 Nursery activities

Mangrove species are highly capable of natural regeneration in suitable sites. Prior to 1995, the restoration of mangrove forests in the southern provinces was mainly based on natural regeneration or planting without pots (or barren rooted seedlings) on estuary and coastal mudflats, which are highly suitable for mangroves.

Since 1995, many forest areas have been cleared for agriculture or aquaculture. The failure of aquaculture has resulted in a large-scale vacating of the land needed for rehabilitation. Forest rehabilitation on fallow or eroded lands is much more difficult than on new mudflats.

On the other hand, the flowering and ripening of mangrove tree fruits does not coincide with the planting season. The ideal season for planting *Sonneratia caseolaris* is from May to July, which helps to avoid the seedlings being buried by alluvium and strong waves, but the fruits of *Sonneratia caseolaris* ripen in September to December. Nursery settings can provide seedlings of acceptable quality and quantity to coincide with the planting season and site.

Therefore, planting using nurseries seedlings is necessary. Within the scope of the MILIEV project supported by the Dutch government, some nurseries were established at the Tam Giang I State Forestry Enterprise in Ca Mau Province.

In 2003, the CWDP project established two nurseries in Vinh Chau district town and Trung Binh commune. Of the two nurseries, however, only the one at Vinh Chau became operational. This nursery supplied just 50,000 potted seedlings of *Rhizophora* and then stopped making room for planting *Casuarina* (Figure 28). The reason for this decision was that the nursery is situated on an elevated area inconvenient for transporting supplies, seedlings, and for delivering irrigation, which makes the cost of seedlings too high.

Figure 28: (a) Nursery at Vinh Chau, Soc Trang; (b) Nursery at Vinh Chau – currently planting *Casuarina.*

Some experiences gathered in setting up nurseries for mangrove trees follow.

4.5.1 Location for nursery setting

Selecting a location for the mangrove nursery setting is the first step that affects the success of the planting project. Some remarks about the setting of the mangrove tree nursery follow.

Poor location selection characteristics:

- Far from the water source and lacking fresh water
- A depression area or rough land
- Far from the village, difficult to manage
- Nearby cattle grazing areas
- Materials for making bowls or pots are insufficient
- Difficulty in terms of translation

Adaptable locations for nursery setting:

- Nearby fresh water or salt-water sources
- Access to road or creek to mobilise transport
- Near planting sites
- Flat land, land and materials for potting are available

Size of the nursery:

The nursery should be large enough to hold materials for potting, such as soil, fertiliser, preparing bowls, and beds for cultivating saplings and other activities. In general, the nursery size varies from 1 - 10 ha depending on the number of seedlings required, example:

- To produce enough seedlings to plant one hectare of *Rhizophora apiculata* with 10,000 seedlings, a bed area of 350 m^2 plus 150 m^2 spare, (total 500 m^2) is applicable.
- To produce 100,000 seedlings of *Avicennia marina*, an area of 2,000 m^2 is required, of which 65% of the area is for cultivating saplings, while the rest is used for potting, soil preparation, walking, watering, etc.
- To produce 1,000,000 bare-root seedlings of *Sonneratia marina*, an area of 5000 m^2 beds is applicable, with 70% of the area used for cultivating seedlings and other activities using 30%.

4.5.2 Types of nurseries and zoning

Different types of nurseries

There are different types of nurseries for mangrove trees:

Permanent nursery: this aims to produce seedlings for long-term planting programmes on a large scale, so it is costly, and produces high cost seedlings.

Temporary nursery: this type is constructed on a small scale and used over the short-term for one or two years. Temporary nurseries come in two main types:

- Emerged nursery, constructed on high surface; usually watered.
- Submerged nursery using ditches, the ground is lowered to favour tidal flooding; occasional watering

Zoning of nursery (Figure 29)

In general, a nursery garden contains the following areas:

- Area for holding material, storing soils, fertilisers, chemicals, rice husk ash, humus and other materials for potting;
- Area for preparation: soils and other materials are mixed in this area;
- Area for cultivation of seedlings; occupies 60% of total area;
- Irrigation system; an embankment made around the nursery to control tides and used for the transportation of materials;

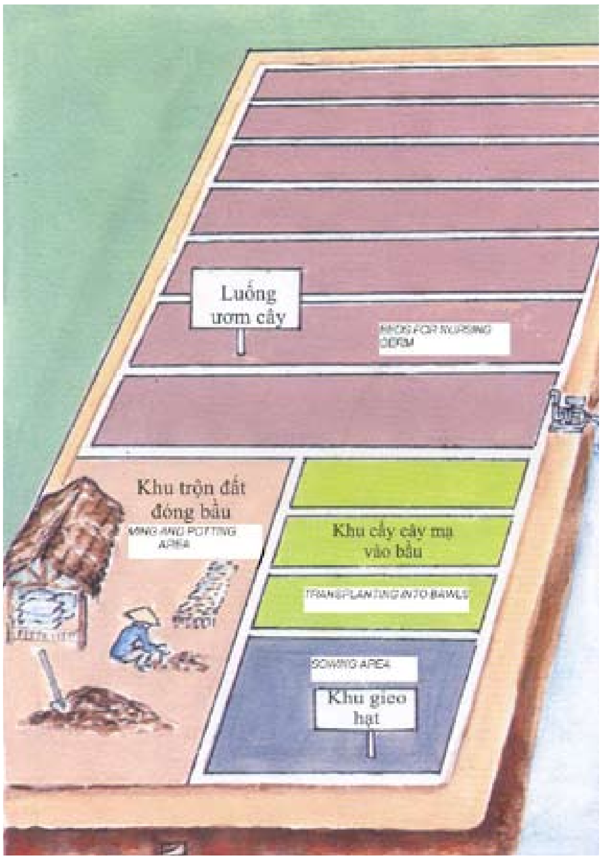

Figure 29: Nursery activities.

- Shading system using adaptable shade, protecting seedlings from strong winds and severe sunshine. Bamboo poles are used to support the roof and the shading crown is at least 1.5 to 2.0 m above the ground to allow for easy access. The shading cover is made from black or green netting, leaves of the *Nypa* palm or other materials.

4

4.6 Status of mangrove forest management in Soc Trang Province

Concerning management aspects, the mangrove forests in Soc Trang Province are defined into two categories - protection and production forests. Protection forests are used to protect sea dykes, infrastructure, built-up areas, etc. from the ocean. This type of forest is on the seaward side of the dyke. Production forests are used to provide commercial products (timber, fuel, etc.).

Protection forests are divided into full protection belts on the seaward and buffer zone in the back. The full protection belt is entirely protected, so people cannot cut trees or conduct other activities in the forest. In the buffer zone, people can use 30 to 40% of the total area of the buffer zone for farming to create by-products.

The legal basis for forest protection and management is provided by the legal documents issued by the Ministry of Agriculture and Rural Development, the Provincial People's Committee, as well as the regulations issued by the provincial Department of Agriculture and Rural Development and the Provincial Forest Protection Sub-department.

The Provincial Department of Agriculture and Rural Development (DARD) is responsible ahead of the Provincial Government for exercising state management over forest protection and development in the province. In Soc Trang Province, the Provincial Forest Protection Sub-department (FPSD) under DARD is responsible for protecting forests along the coast. The FPSD has three district stations in Cu Lao Dung, Tran De and Vinh Chau for patrolling and monitoring the coast and conducting planting activities.

For implementing of Project 661, a project management board was set up under the Provincial Forest Protection Sub-department. This body is in charge of arranging the annual implementation of Project 661, including the making of planting plans, and the drafting of contracts with individuals or organisations for planting and protection.

In this field, the Provincial Forest Protection Sub-department is responsible for the state management function (supervising, patrolling) as well as the implementation function. The functions of FPSD are sometimes not clearly distinguishable. Monitoring activities are not conducted effectively on a yearly basis.

Production forests are allocated to individuals, organisations, companies (such as Phu Thanh Company), the provincial Police Department, and other governmental institutions. In principle, the government allocates forestland to these stakeholders on a planned basis. They can use from 30 to 40% of the land area for aquaculture and the remaining land for planting. Mangrove and aquaculture plots might be separate, or distributed sparsely across the aquaculture plot.

Some of these individuals and organisations, however, only focus on shrimp farming. The prolonged water stocking in the shrimp ponds has led to massive forest destruction. This situation arises for a lack of awareness among people of forest benefits and techniques for designing and operating farming systems. In addition, the potential immediate benefits from shrimp farming are much greater than for sustainable forest management. Some plots are too small - 1 to 3 ha - and the amount of aquaculture (30-40%) does not bring enough income for landholders, so they clear-cut the entire forest area for aquaculture.

Monitoring and supervisory functions were neglected and some companies tried to expand their ponds using prolonged deep inundation to destroy the forest. These actions were not addressed in a strict or clear fashion.

The application of legal regulations has met with practical challenges in real-world situations. The violators are usually members of the poor ethnic classes due to the lack of awareness raising programmes by people in all fields of forest protection and for the coordination between local authorities and forest protection units. These people should be involved in mangrove management through co-management activities. They should participate in land use process and earn their living based on mangrove protection and rehabilitation.

The forest protection groups are still reliant on the Forest Protection Sub-department and there is a lack of collaboration with the local authorities at the village and commune levels. Community participation in the protection and management of coastal resources is still weak.

Forest patrols are not carried out on a regular basis, resulting in situations where forest cutting takes place for a long periods of time and causes great damage, as in Vinh Chau commune of Vinh Chau district. In this case, some 200 hectares of forests of the Phu Thanh company were destroyed due to prolonged water inundation.

4.7 Lessons learned from forest planting successes

Over the past several decades, forest planting in Soc Trang Province has recorded important achievements in terms of increasing forest coverage and forest quality. Three species *(Rhizophora apiculata, Sonneratia caseolaris,* and *Avicennia marina)* were selected for planting programmes in Soc Trang.

Planting methods have also diversified into planting with potted seedlings, propagules or barren-root seedlings. However, forest restoration has also been met with challenges, especially technical issues that lead to lower than ideal levels of effectiveness. Some lessons learned from planting programmes follow.

(i) Selection of appropriate sites corresponding to ecological requirements of mangrove species

Over the past decade, the selection of sites for forest planting did not corresponded at all times to the requirements of species in some places. *Sonneratia* and *Rhizophora*, for example, were planted on newly formed mudflats with deep inundation levels, which were still loose and had not yet stabilised in the Cu Lao Dung, Tran De, and Vinh Chau districts. Similarly, *Avicennia* was planted on elevated ground with low inundation levels, resulting in low survival rates.

The most important issue is that the selection of appropriate sites should correspond to the ecological requirements of the mangrove species. *Sonneratia caseolaris* should be planted on compact mudflats where there are already naturally regenerated *Sonneratia,* within 50 to 100 m of the existing forest belt, with inundation levels of less than 1 meter.

Avicennia marina should be planted on loose mud or compact mud where there are already naturally regenerated *Avicennia. Rhizophora apiculata* and *Rhizophora mucronata* should be planted on compact mud or soft clay among pioneer species of *Avicennia or Sonneratia*. *Ceriops tagal* can be planted on elevated grounds if the ground can be levelled down to allow for inundation. *Lumnitzera* should be planted on mounted ground that is less subject to tidal inundation.

(ii) Determination of right schedule for planting activities

Strong waves and wind occur from November to February, causing severe erosion along the coast and sweeping away young seedlings at some places (such as Vinh Hai commune, An Thanh Nam, etc.). If forests are planted during this season, the seedlings are likely to be uprooted and swept away.

Sedimentation accumulates between June and October in a thick layer of 0.5 to 0.6 cm, which can bury and kill the seedlings.

Barnacles clinging to young seedlings is also bad and causes the destruction of newly planted forests. The number of barnacles is highest in April and causes the most serious damage to newly planted *Sonneratia* seedlings during this time. The trees are submerged under the sea and uprooted by waves.

For these reasons, the planting schedule should be adjusted to support seedlings and avoid sediment accumulation from June to October, barnacle attacks from May to July, and the erosion period from November to February. *Sonneratia caseolaris* should be planted from May to June. *Rhizophora apiculata*, *Rhizophora mucronata* and *Avicennia* should be planted from May to July in the coastal mudflat areas and August to September in inland areas less subject to waves and wind, while *Ceriops tagal* should be planted from August to September.

(iii) Quantity and quality of seedlings

The quality and quantity of seedlings for planting have not been afforded great consideration during the past planting programmes. Standards for planting seedlings were not officially defined, and the density and structure of corresponding forest protection objectives was inconsistent.

The quantity and quality of seedlings should be carefully arranged, paying attention to the criteria for selection of seedlings ready for planting in terms of height, diameter, age and health. Planting species should be diverse in order to increase biodiversity in the coastal zone.

(iv) Eliminating bad causes of human-induced factors

Fishing activities in the newly planted forests may damage young seedlings. In 2004, of the 29 hectares of *Rhizophora* planted in Vinh Chau commune of Vinh Chau district, 7.9 hectares were destroyed. Only about 55% of the seedlings survived as fishermen trampled the seedlings.

Forest planting needs to take into account social factors and that local people need to have alternative livelihoods. On the other hand, awareness levels need to be raised and coordination among sectors and agencies needs to be improved.

Co-management activities in forest protection should be encouraged as this can contribute significantly to the protection of mangrove plantations. During the co-management process, resource users and local authorities use negotiation to jointly identify areas or 'zones' where certain resources are in need of some level of protection, conservation, rehabilitation and/or sustainable use.

Specific rules are attached to each of the identified zones in terms of who can do what, where, when, how and how much in order to ensure that the main aim of the zone is achieved and to enable the successful protection, conservation and sustainable use of resources.

In order to protect land behind the mangrove forest, this area should become a rehabilitation zone, which, to ensure the seedlings are not disturbed, carries the following stipulations. No fishing at all can be done in the area for the first two years after the seeds are planting and then only fishing using non-destructive fishing gear for the following three years by the poorest of the poor resource users.

As part of the agreement, all the resource users are responsible for ensuring that there is compliance with the rules of the zone and over time the mangrove forest area will be successfully rehabilitated. The area can then be re-zoned to perhaps a sustainable use zone where more people are able to access the area to collect resources in a sustainable way, as the objective of rehabilitating the forest area has been achieved.

Forests should be planted in stands and bands in order to leave space for fishing activities in order to maintain the livelihoods of the local population. A co-operative relationship should be established with local communities for managing the planted forests and limiting fishing activities in newly planted areas. For strongly eroded areas, barriers could be constructed to protect the newly planted seedlings from waves and wind.

5

Measures for the Protection and Development of Mangrove Forests

5.1 Viewpoints and objectives

Mangrove forests are an important resource and a vital part of integrated coastal zone management. The protection, appropriate use, and sustainable development of mangrove forest resources contribute to the protection of biodiversity hotspots in the estuaries and coastal zone.

For a long time now, local communities have relied on the resources of mangrove forests. They provide food, fuel wood, employment, income, and protection to the local people. Efforts to manage, protect, use, and develop mangrove forests in a sustainable manner should be based on the principles of protecting and sustaining the livelihoods of local people. The management of mangrove forests requires the participation at all levels of society including the local communities. Traditional and native knowledge and cultural values need to be promoted.

Mangrove forests need to be managed based on the principles of sustainable use. The forest's resources need to be used and promoted, and the natural resources in the coastal zone must be managed in an integrated way. Environmental service providers need to be rewarded for meeting the needs of forest protection.

5.2 Capacity building for integrated coastal zone management

Mangrove forest management needs to be based on an ecosystem management approach. Upstream development activities need to be addressed in order to manage mangrove forests and these management activities must corresponded with the legal policy framework and livelihoods of local people. A legal framework needs to be established for better cooperation and coordination among different sectors and agencies and the local communities.

Institutions need staff with appropriate levels of professional capacity and sufficient funding and financial mechanisms to devise and carry out highly feasible action plans.

Development projects in the coastal zone and watershed must be associated with environmental impact assessments. Multidisciplinary research on mangrove forests needs to be promoted in order to support management activities.

Collaboration needs to be strengthened among various stakeholders from the stage of land use planning to the implementation of projects on forestry land, particularly near special use and protected forests.

Mechanisms for collaboration between the management boards of protected forests and the local authorities and mass organisations in these areas need to be established. Regulations specifying the responsibilities of all stakeholders, levels, and mass organisations in terms of forest protection and development need to be developed.

Information, education, and communication activities with local communities need to be strengthened in order to raise awareness about forest protection among people and to mobilise people to collaborate with the Forest Protection Department, local authorities, mass organisations, and armed forces to effectively prevent forest cutting and encroachment on forestland.

Knowledge transfer and the integration of recommendations into the practical application of study results and experiences into provincial planning processes and policy formulation is essential (focus on contributing to Coastal Protection Plan component of the provincial 5 year plan and District Management Plans).

Use existing mechanisms and establish new ones to integrate responses to the effects of climate change into technical assistance and extension services (i.e. the implementation of plans with integrated adaptation to climate change).

Collaboration and coordination among agencies and organisations must be strengthened and the use of appropriate curricula, textbooks, and teaching aids must be promoted. The participation of research institutes and NGOs in the research activities and protection and development of mangrove forests should be encouraged.

Information and technical training should be provided to support managers at various levels and levels of awareness should be raised among politicians and land use planners. In addition, a mangrove forest information centre should be established.

Methods for the sustainable management of natural aquatic resources should be developed and implemented and mangrove forests should be protected as nurseries for fish, crustaceans, and molluscs.

Areas in which local communities are allowed to harvest aquatic resources need to be zoned and the development of a sustainable and integrated aquaculture system should be encouraged.

Aquaculture in mangrove forests is not sustainable. Hence, the expansion of shrimp ponds into mangrove forests must be banned and the introduction of alien aquaculture varieties needs to be strictly controlled to limit the adverse impacts of aquaculture on biodiversity.

The conversion of forestland for agricultural purposes, salt production, or aquaculture should not be allowed.

5.3. Science and technology research

The value and functions of the forest should be quantified (for nature conservation, landscape protection, environmental protection, provision of NTFPs forest resources) and there should be research conducted along with recommendations for specific measures to sustainably manage and use resources of forest ecosystems.

By strengthening the management of plant varieties, animal breeds and nurseries, and focusing on technology transfer to local households, additional employment can be created and transportation costs can be saved.

Mangrove forests need to be periodically inventoried using remote sensing and GIS techniques. A mangrove forest database needs to be designed and linked with the provincial and national forest resources databases and updated regularly to ensure user friendliness for managers.

By designing and constructing wave-breaking structures to reduce wave energy, along with the positive effects of mangrove forests, sediment deposition can be promoted.

In order to ensure that forest planting is effective, the selection of appropriate species for the particular landforms is very important. It is necessary to replant forest on the dykes created for the shrimp ponds that have been abandoned due to shrimp failure. However, the soils on the dykes is very difficult to use for mangrove rehabilitation or for other plants.

In order to plant forests on these dykes, it is necessary to lower the tops of the dykes to a level that can be inundated by tides. The earth on the dykes should be levelled in order to fill the canals, and then tidal water will bring sediment to deposit into the canals to raise their levels as well as restore the characteristics of saline soil for forest planting.

The earthwork needed for levelling the dykes requires high levels of investment and the resettlement of households raising shrimp in the critical protected forest areas. Therefore, the investment level needs to be tailored to each particular forest planting situation. A uniform investment level should not be applied across all situations.

Erosion can be very severe in certain areas and the project is therefore testing methods to protect the coast from erosion. The GIZ project “Management of Natural Resources in The Coastal Zone of Soc Trang Province” is setting up a model for mangrove rehabilitation in erosion sites, which combines:

- Appropriate dyke design,
- Use of barriers to break waves, limit erosion and increase sedimentation, and
- Rehabilitation of mangroves under relatively sheltered conditions behind the wave-breaking barrier.

The project has supported the development of technical specifications for a dyke design, which is appropriate to the conditions found along the coast in Soc Trang. The Province of Soc Trang will use this design to repair the eroded dyke in Vinh Tan Commune.

The next step is the development of a numerical model, which simulates hydrodynamics and shoreline development with the aim of designing breakwaters/wave breaking barriers. These barriers should lead to accretion at the erosion sites and avoid downdrift erosion (lee-erosion) as much as possible (Schmitt 2009).

The fencing of the regenerated forests is very important as it helps promote the establishment of forests on the mudflat and can be an effective way to prevent fishing methods that are destructive to the forest.

The construction of dykes and wave breaking barriers can reduce erosion along the coast and lead to sedimentation, which in turn supports new forests. The construction of such structures must be carefully considered including bathymetry surveys.

In terms of planting forest on bare land areas, there should be annual planting plans for mudflats with the potential for forest planting. Belts that are 30-50 meters in width running parallel with the shoreline should be planted and the land should be carefully appraised before planting.

For land areas with elevation of 2.5 meters or more, which are only inundated during high tides, or in low areas with stagnant water, small ditches should be made to facilitate water exchange and promote the growth of mangroves.

Objectives for management, conservation, and sustainable development as well as precise activity plans need to be specified. Management frameworks need to be developed in a way appropriate to integrated management approaches, and local people must be allowed to participate in planning and implementation activities. Mangrove species with the potential for regeneration should be protected as a top priority. Nurseries should also be established for mangroves and conserving seedlings for forest restoration.

Strict protection should be provided for land areas with existing natural forest or planted forest, and additional planting should be done in poor forests in order to ensure their protective functions.

5.4 Socio-economical issues

Detailed management regulations within the national legal framework and serving people's interests should be developed, and the effectiveness of policies should be strengthened using integrated measures (education, resource use licensing, and law enforcement). Methods for limiting resource exploitation should be implemented after consulting user and supervision groups.

The dependence of local communities on mangrove forest resources needs to be researched and the impacts of development project and policies on local communities should be assessed.

Ecotourism projects should be implemented, projects for aquaculture should be developed, and honey bees should be raised to create income sources and maintain the sustainable livelihoods of local people.

Regulations need to be developed for environmental protection and management in order to reduce and eliminate the impacts of pollution by applying mechanisms of payment for environmental services. The participation of women needs to be increased in terms of conservation, restoration, and management of mangrove forests.

Forestry staff need to be trained and their capacity needs to be developed so they can perform their forest protection and management tasks. Trainings should be conducted on forest resource management and protection as well as biodiversity conservation. Priority should be given to local staff to attend technical college forestry schools at various levels.

Forestry managerial staff need to be trained in integrated management approaches. In addition to protecting and using forest resources, forest managers need to manage and use other resources of the forests (such as ecotourism, management of aquatic resources, and non-timber forest products). Equipment and facilities need to be provided to forest management boards at different levels and there should be favourable special treatment for forestry staff working in remote areas.

Assessments need to be done of the potential for sustainable mangrove tourism and threats from unplanned activities. Tourism and conservation need to be combined in a sustainable way and legal mechanisms and guidelines for sustainable tourism management should be developed. In addition, materials should be prepared for distribution to tourists (maps, pictures, descriptions of animals).

Collaboration levels should be raised between local stakeholders so that local communities can benefit from tourism. In addition, tourism opportunities need to be advertised in the media.

Scientific knowledge and information must be disseminated about the use and socio-economic and cultural values of mangroves. By coordinating the collaboration between scientists, managers, and local communities, the exchange of information and effective use of previous research can be encouraged.

5.5 Policy

Attention needs to be given to reviewing, making policy adjustments, and eliminating inappropriate policies. Wetlands need to be conserved and used in an appropriate way while being restored. Top priority needs to be given to conserving local traditional livelihoods and resources, and laws and regulations must be observed – particularly those providing conservation guidelines. Regulations should be synthesised into guidelines that are easily understood.

Regulations need to be developed specifying clear areas of responsibility and collaboration needs to be increased among relevant agencies. Activities must be avoided, which cause adverse impacts to mangrove forests or the hydrology systems. Mangrove forests need to be zoned including planning functions and objectives for each zone.

An exclusive investment policy must be developed both at the national and provincial levels for planting protection forests in the coastal zone, because forest planting in the coastal zone is highly risky, especially in newly deposited areas and areas subject to erosion.

Government investment must be focused on managing existing forests and by protecting, planting, improving, and enriching forests. Priority should be given to research and the cultivation of seedlings.

A consistent and comprehensive investment policy is needed. Investment in forest planting must be tied to investments in forest management activities and infrastructure. In addition, investment in forest planting must be accompanied by investments in forest fire control infrastructure. Investment in forest management and protection must be accompanied by investment in local communities in buffer zones and areas near the forests.

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Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Management of Natural Resources
in the Coastal Zone of Soc Trang Province
134 Tran Hung Dao Street,
Soc Trang City, Vietnam

T + 84 79 3622164
F + 84 79 3622125
I www.giz.de
I www.czm-soctrang.org.vn