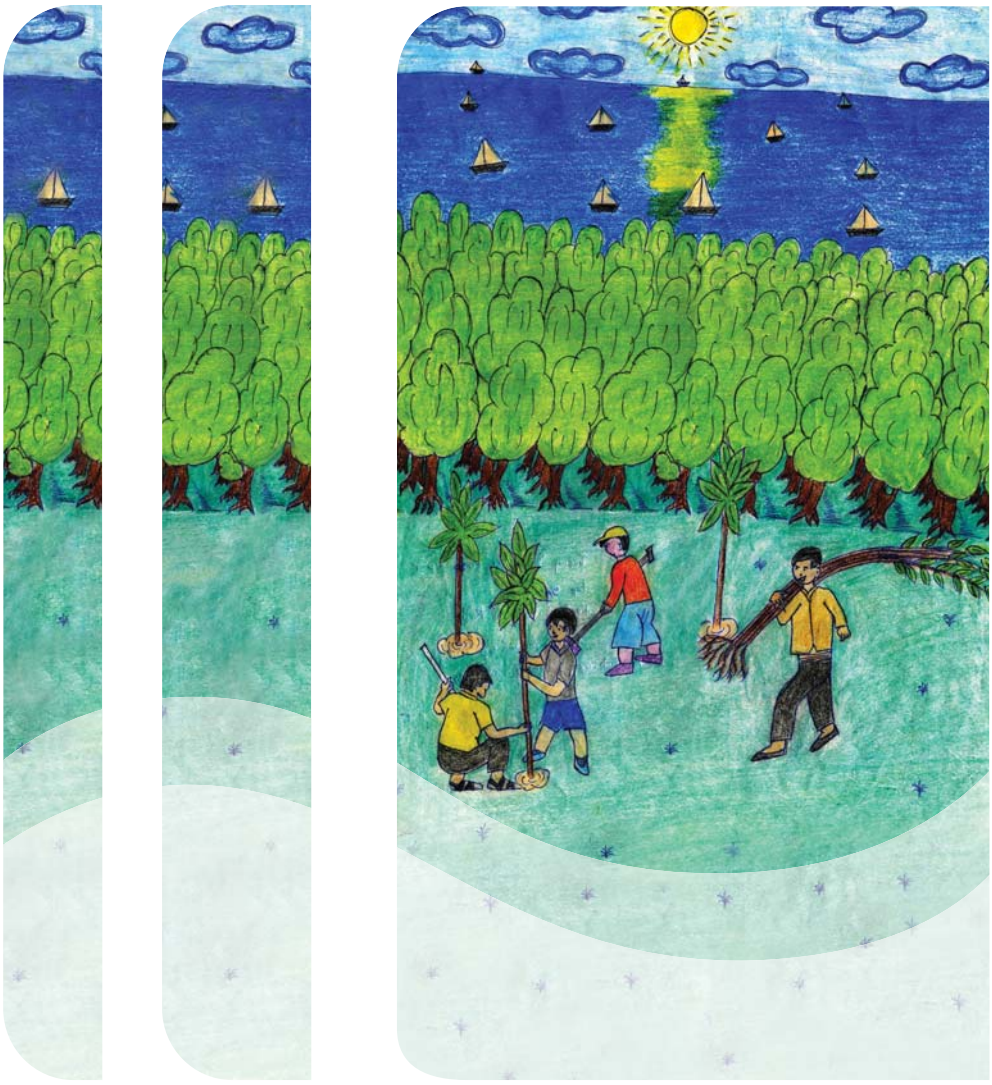


Management of Natural Resources
in the Coastal Zone of Soc Trang Province

Tool Box for Mangrove Rehabilitation and Management

Pham Trong Thinh, Hoang Thoi, Tran Huy Manh,
Le Trong Hai and Klaus Schmitt

gtz
COOPERATION
FEDERAL REPUBLIC OF GERMANY
SOCIALIST REPUBLIC OF VIETNAM
Soc Trang Provincial People's Committee

Published by
Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH
Management of Natural Resources in the Coastal Zone of
Soc Trang Province

Authors
Pham Trong Thinh, Hoang Thoi, Tran Huy Manh,
Le Trong Hai and Klaus Schmitt

Cover photo
Søn Vi Róth, Planting mangrove for flood control, 2008

Designed by
Golden Sky
Email: info@goldenskyvn.com

Tool Box for Mangrove Rehabilitation and Management

Pham Trong Thinh, Hoang Thoi, Tran Huy Manh,
Le Trong Hai and Klaus Schmitt

October 2009

About GTZ

As an international cooperation enterprise for sustainable development with worldwide operations, the federally owned Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH supports the German Government in achieving its development-policy objectives. It provides viable, forward looking solutions for political, economic, ecological and social development in a globalised world. Working under difficult conditions, GTZ promotes complex reforms and change processes. Its corporate objective is to improve people's living conditions on a sustainable basis.

The German Federal Ministry for Economic Cooperation and Development (BMZ) is its major client. The company also operates on behalf of other German ministries, the governments of other countries and international clients, such as the European Commission, the United Nations and the World Bank, as well as on behalf of private enterprises. GTZ works on a public-benefit basis. All surpluses generated are channelled back into its own international cooperation projects for sustainable development.

GTZ has been working with its partners in Viet Nam since 1993 and promotes sustainable development in the three priority areas of Sustainable Economic Development, Management of Natural Resources including Water Supply, Wastewater and Solid Waste Management and Health. Additional projects are situated within the cross-cutting sector Poverty Reduction, implemented on behalf of other German ministries or realised by GTZ International Services. The Centre for International Migration and Development (CIM), a joint operation of GTZ and the International Placement Services (ZAV) of the German Federal Employment Agency (BA) currently has 29 integrated experts working as professionals for partner institutions in Viet Nam.

Foreword

The project “Management of Natural Resources in the Coastal Zone of Soc Trang Province” aims to protect and sustainably use the coastal wetlands for the benefit of the local population. Effective protection, management and rehabilitation of the Mangrove forests are key tasks of the project and will make a significant contribution to the protection of the coastal wetlands from unsustainable utilisation, the negative ecological consequences of shrimp farming and impacts of climate change.

Effective mangrove management and protection is particularly crucial in Soc Trang where only a narrow belt of mangrove forests is found along a coast characterised by a highly dynamic process of accretion and erosion. This process is driven by the flow regime of the Mekong River, the tidal regime of the East Sea and coastal long-shore currents driven by prevailing monsoon winds, and will be intensified by climate change.

This particular situation requires effective mangrove management and protection with emphasis on resilience to climate change. In order to support this, the project has produced a comprehensive tool box for mangrove management covering nursery, planting, tending, protection and monitoring in three separate manuals and a detailed report on the history of Mangrove forests in Soc Trang since 1965.

The tool box has been prepared by a team of scientists from the Southern Sub-Institute of Forest Inventory and Planning (Ho Chi Minh City) lead by Dr. Pham Trong Thinh. Additional input was provided by the Forest Science Sub-Institute of Vietnam (Ho Chi Minh City), Le Trong Hai and Dr. Klaus Schmitt. Dr. Norman Duke from the University of Queensland, Australia, provided a comprehensive review of all parts of the tool box. Based on lessons learnt from previous planting experiences in Soc Trang Province as well as national and international best practice experiences the manual provides clear instructions which species shall be planted where during which time and using which planting technique.

The manuals are intended for use by staff of the Forest Protection Sub-department and farmers in Soc Trang who are engaged in mangrove rehabilitation and management. The concepts and principles covered, however, have a wider application for the Mekong Delta and the coastal zone of Vietnam.

Klaus Schmitt
Chief Technical Advisor

Table of contents

About GTZ ..... **ii**
Foreword ..... **iii**
Table of contents ..... **iv**
List of figures ..... **vii**
List of tables ..... **viii**
Acknowledgements ..... **ix**
Acronyms ..... **x**

1. Introduction **12**
1.1 Soc Trang Province 12
1.2 The Coastal Zone of Soc Trang Province 13
1.3. Ecosystem Services and Benefits Provided by Mangroves 17
1.4. Short History of Mangrove Destruction and Management in Soc Trang Province 18
1.5 Lessons Learned from Plantation and Management Activities 18
1.6 Selecting Species Suitable for the Site 20

2. Producing Seedlings for Planting and Tending Mangrove Forest Plantations **22**
2.1 *Sonneratia caseolaris* (Bần Chua) 22
2.1.1 Collecting, maintaining and processing seeds 23
2.1.2 Producing seedlings with root bags 23
2.1.3 Producing bare root seedlings of *Sonneratia* spp. 24
2.1.4 Planting and tending *Sonneratia caseolaris* seedlings 25
2.2 *Avicennia marina* (Cây Mắm Biển) 26
2.2.1 Collecting fruits for seedling propagation 27
2.2.2 Planting and tending *Avicennia marina* seedlings 27
2.3 *Rhizophora apiculata* (Cây Đước) 28
2.3.1 Collecting and maintaining propagules for planting 29
2.3.2 Planting and tending 30
2.4 *Lumnitzera racemosa* (Cóc Trắng, Cóc Nghệ) 31
2.4.1 Collecting and maintaining seeds 32
2.4.2 Planting and tending *Lumnitzera racemosa* 32

2.5. *Ceriops tagal* (Cây Dà Vôi) 33
2.5.1 Collecting and protecting seedlings 34
2.5.2 Planting and tending *Ceriops tagal* seedlings 34

3. Mangrove Planting and Management with Considerations for Increasing Stand Resilience to Climate Change 36
3.1 Testing new Approaches for Mangrove Reforestation and Afforestation 37
3.2 Physical Measures to Support Mangrove Rehabilitation 39

4. Maintenance, Management and Protection of Mangrove Plantations 40
4.1 Plantation Maintenance 40
4.2 Controlling Disease 40
4.3 Protecting Plantations 41
4.4 Plantation Management 42
4.4.1 Thinning 42
4.4.2 Pruning the forest crown 42
4.4.3 Thinning method used in plantations 42

5. Nursery Setting and Seedling Cultivation 44
5.1 Rationale of Nursery in Mangrove Planting 44
5.2 Selecting the Location for Establishing a Mangrove Nursery 44
5.3 Designing Different Types of Nurseries 45
5.3.1 Different types of nurseries 45
5.3.2 Zoning of the nursery 46
5.3.3 Designing a submerged nursery 46
5.3.4 Designing an emerged nursery 47
5.4 Methods for Planting and Selecting Mature Fruits 47
5.5 Producing Seedlings with Root Bags 48
5.5.1 Preparation of soils 48
5.5.2 Preparing nursery beds 48
5.5.3 Filling bag 48
5.5.4 Sowing 48
5.5.5 Nursery maintenance 48

5.6 Producing Bare Root Seedlings 49
5.6.1 Preparation of soils 49
5.6.2 Sowing 49
5.6.3 Nursing 49

6. Planning, Monitoring and Assessment 50
6.1 Planning 50
6.2 Monitoring and Assessment 51

7. Summary 52
7.1 Flowchart for Planting and Nursery Activities 52
7.2 Seed Characteristics, Planting Methods and Nursery Maintenance 53
7.3 Ecological Characteristics and Planting Methods for Key Mangrove Species in Soc Trang 53
7.4 Scheduling for Annual Planting and Monitoring Activities 54

References 55

List of figures

Figure 1. Location of Soc Trang Province. 12
Figure 2. Isohyets of the Mekong Delta (Source: SIWRPM 1997). 13
Figure 3. Coastal area of Soc Trang Province. 13
Figure 4. Variation of mangrove areas in Vinh Chau District (1965, 1995 and 2008). 15
Figure 5. Variation in mangrove areas in the Lich Hoi Thuong and Vinh Hai communes (1965, 1995 and 2008) 16
Figure 6. Variation in mangrove and coastline in Cu Lao Dung (1965, 1995 and 2008). 16
Figure 7. Forest protects communities in the coast 17
Figure 8. Young trees killed by barnacles. 18
Figure 9. Using trawling nets for fishing may destroy regeneration. 18
Figure 10. Only 10% of trees planted in 2006/07 in deeper inundation survived by May 2008. 19
Figure 11. High and hard surface sites are not suitable for mangrove trees 19
Figure 12. Plantation of *Rhizhophora apiculata* on middle inundation site 20
Figure 13. *Sonneratia caceolaris* 22
Figure 14. Selecting trees to collect seeds in Trung Binh Commune. 23
Figure 15. Producing bare root seedlings of *Sonneratia caseolaris*. 24
Figure 16. *Sonneratia caseolaris* planting sites (a) acceptable with natural regeneration (b) unsuitable, deeply inundated sites 26
Figure 17. *Avicennia marina* (a) foliage (b) flower and (c) fruits. 26
Figure 18. Ripening fruits of *Avicennia marina* (Forsk.) Vierh. 27
Figure 19. Suitable sites for planting *Avicennia marina*. 27
Figure 20. (a) Fruit and (b) branch and fruit of *R. apiculata*, (c) branch and fruit of *R. mucronata* 28
Figure 21. Selecting propagules of *Rhizophora apiculata*. 29
Figure 22. Site selection for planting *Rhizophora apiculata*. 30
Figure 23. Good site for planting of *Rhizophora apiculata*. 31
Figure 24. Tree and flowers of *Lumnitzera racemosa*. 32
Figure 25. *The Ceriops tagal* (a) the tree, (b) fruit and (c) the flower. 33
Figure 26. Natural Mangrove regeneration and planting which mimics nature. 38
Figure 27. Schematic display of the six stages of natural gap creation and recovery. 38
Figure 28. Regeneration of *Rhizophora* in gaps 39
Figure 29. Nursery activities. 45
Figure 30. Two different temporary nursery types: (left) emerged nursery; and (right) submerged nursery. 46
Figure 31. Use zones of a nursery site 46
Figure 32. Marking boundary edges of planting areas with bamboo stakes. 51
Figure 33. (a) High sites, without tidal supply, are unsuitable for *Rhizophora* planting; (b) High sites, surface lowered to get tidal inundation, are suitable for *Rhizophora* planting 51

List of tables

Table 1. Changes in land area of the An Thanh Nam and An Thanh Ba communes in Cu Lao Dung from 1965 to 2008. 16
Table 2. Thinning of *Rhizophora apiculata and Ceriops tagal* plantation forests. 42
Table 3. Fruit and propagule material for mangrove planting in Soc Trang. 47
Table 4. Identification of fruit/propagule maturity based on colour. 47

Acknowledgements

Special thanks go to Mr. Phan Van Xe, Director of Forest Protection and Sub-department of Soc Trang and Project Director and to Mr. Ly Hoa Khuong, Project Coordinator, for their assistance, sharing of information, organising of field surveys and participating in preparing the toolbox.

Dr. Klaus Schmitt, Chief Technical Advisor of the project, supported all aspects of the preparation and printing of the tool box and contributed chapter 3 of this manual.

Thanks also go to technicians from the Forest Protection Sub-department and people from the coastal districts in Soc Trang, Mr. Châu, Mr. Tường, Mr. Lạc, Mr. Thạch Kiên, Mr. Triệu Di, Mr. Sỹ, Mr. Quốc and Mr. Tài, who took part in the field surveys and discussions, and to staff of the GTZ project, Dr. Luong Thu Thuy and Mrs. Nguyen Thi Van Kieu, for organising the workshop where this manual was discussed.

Special thanks go to the following people for their contributions:

Dr. Norman Duke from the University of Queensland, Australia, for the review of the manual and permission to reproduce Figure 27.

Master Sơn Vi Róth, a 14 year old pupil from Vĩnh Phú Middle School, drew the cover illustration entitled “Planting mangrove for flood control”.

Mr. Le Trong Hai from the Agriculture Institute of Ho Chi Minh City for the drawings in Figures 7 and 29.

Most pictures have been provided by staff from the Southern Sub-Institute of Forest Inventory and Planning. Dr. Norman Duke provided the picture in Figure 28 left; Mr. Dominc Meinardi provided the pictures in Figure 26 and 28 right and Dr. Klaus Schmitt provided the picture in Figure 26 left.

Dr. Pham Trong Thinh

Acronyms

Atonik 1.8 DD, 5 G	Nitrophenolate 0.9%
ACTMANG	Action for Mangrove Reforestation, Japan
Benlat	1-(butylcarbamoyl)-2-benzimidazol-methylcarbamat
BQLDA	Project Management Board
Captan	Thiophthalimide
Cm	Centimetre
CWPD	Coastal Wetlands Protection and Development
DAP	Dissolved Ammonium Phosphate
ETM	Eastern Topographical Map
FAO	Food and Agricultural Organisation of the United Nations
FPSD	Forest Protection Sub-department
RMFP	Rehabilitation of Mangrove Forest Project (Vietnam)
GTZ	German Technical Cooperation
H	Total height of a tree
Ha	Hectare = 10,000 m^2
IDA	International Development Association
km	Kilometre
m	Metre
m/s	Metre per second
mhsl	Mean highest sea level
MILIEV	A Mangrove Planting Project Funded by The Netherlands
mlsl	Mean lowest sea level
mm	Millimetre
N	Number of individual tree
NPK (16:16:8)	nitrogen-phosphorus-potassium; N_2O 16% + P_2O_5 16% + K_2O 8%
PNAS	Proceedings of the National Academy of Science
QĐ-TTg	Decision of Prime Minister
RMFP	Rehabilitation of Mangrove Forest Project
SIWRPM	Southern Institute of Water Resources Planning and Management
TEV	Total Economic Value
UBNDTST	Provincial People Committee of Soc Trang
Vipac 88	α-Naphthyl Acetic Acid (α - N.A.A) + β - Naphthoxy Acetic Acid (β - N.A.A) + $ZnSO_4$ + $MgSO_4$ + $CuSO_4$ + NPK
WB	The World Bank

1 Introduction

1.1 Soc Trang Province

Soc Trang Province is one of thirteen provinces in Viet Nam's Mekong Delta and is located south of the Hau River, which is the southern-most of the nine arms of the Mekong that form in the delta. The province has a 72 km coastline with a total land area of about 322,330 ha. It lies at 9°14'-9°56' N latitude to 105°34'-106°18' E longitude and is bordered by the provinces of Hau Giang to the northwest, Bac Lieu to the southwest, Tra Vinh to the northeast, and the East Sea (Figure 1). The distance from Soc Trang City to Ho Chi Minh City is 231 km.

Figure 1. Location of Soc Trang Province.

Soc Trang has a young alluvium terrain created by the interaction of hydrological regime of the Mekong River and marine geo-morphological processes. Generally, the province is a vast flat plain, of which shallow depressions lie at the backward margin of sandy ridges, parallel to the coastline. Those sandy ridges have an elevation of about 0.5 to 1 m descending from the northeast to the south.

The mean annual temperature is about 26.8°C, warmest in April (31.1°C) and coldest in January (23.8°C). The average humidity is about 83.4% varying from 96% during the rainy season to about 62% during the dry season. Annual rainfall is about 1,840 mm (Figure 2). The highest monthly value is observed during the rainy season with 335 mm. During the dry season, rainfall is completely absent, limiting the supply of fresh water for domestic and agricultural uses. The total annual solar radiation is about 140 - 150 kcal/cm^2. The annual sunshine quantity totals about 2,372 hours. Monthly sunshine reaches a maximum value in March (299.2 hours) and a minimum in October (99.3 hours).

The coastal zone comprises vast estuaries coming from the Hau and My Thanh tributaries. The coastal zone contains rich marine resources providing a high potential for integrated economic development. Mangroves are located along the Long Phu, Cu Lao Dung and Vinh Chau districts. Mangroves act as a protective belt for coastal zones against natural disasters and provide a high potential for human use.

1.2 The Coastal Zone of Soc Trang Province

The coastal zone of Soc Trang Province stretches from the Dinh An branch of the Hau River to Vinh Chau at the border of the Bac Lieu Province (Figure 3). It is comprised of three districts and 11 communes: An Thanh Ba, An Thanh Nam (Cu Lao Dung District), Trung Binh, Lich Hoi Thuong (Long Phu District), Vinh Hai, Lac Hoa, Vinh Chau, Vinh Chau town, Vinh Phuoc, Vinh Tan and Lai Hoa (Vinh Chau District).

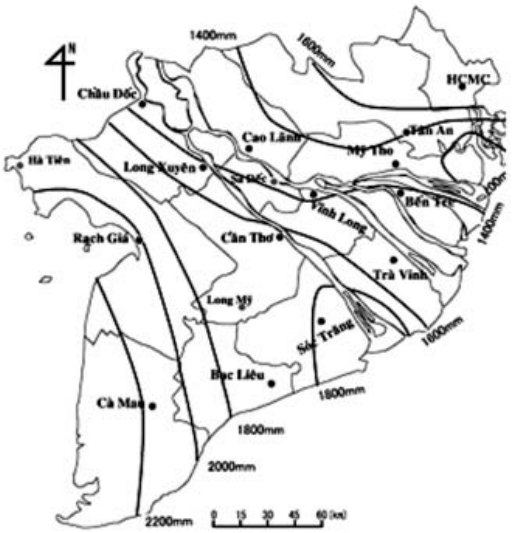


Figure 2. Isohyets of the Mekong Delta (Source: SIWRPM 1997).

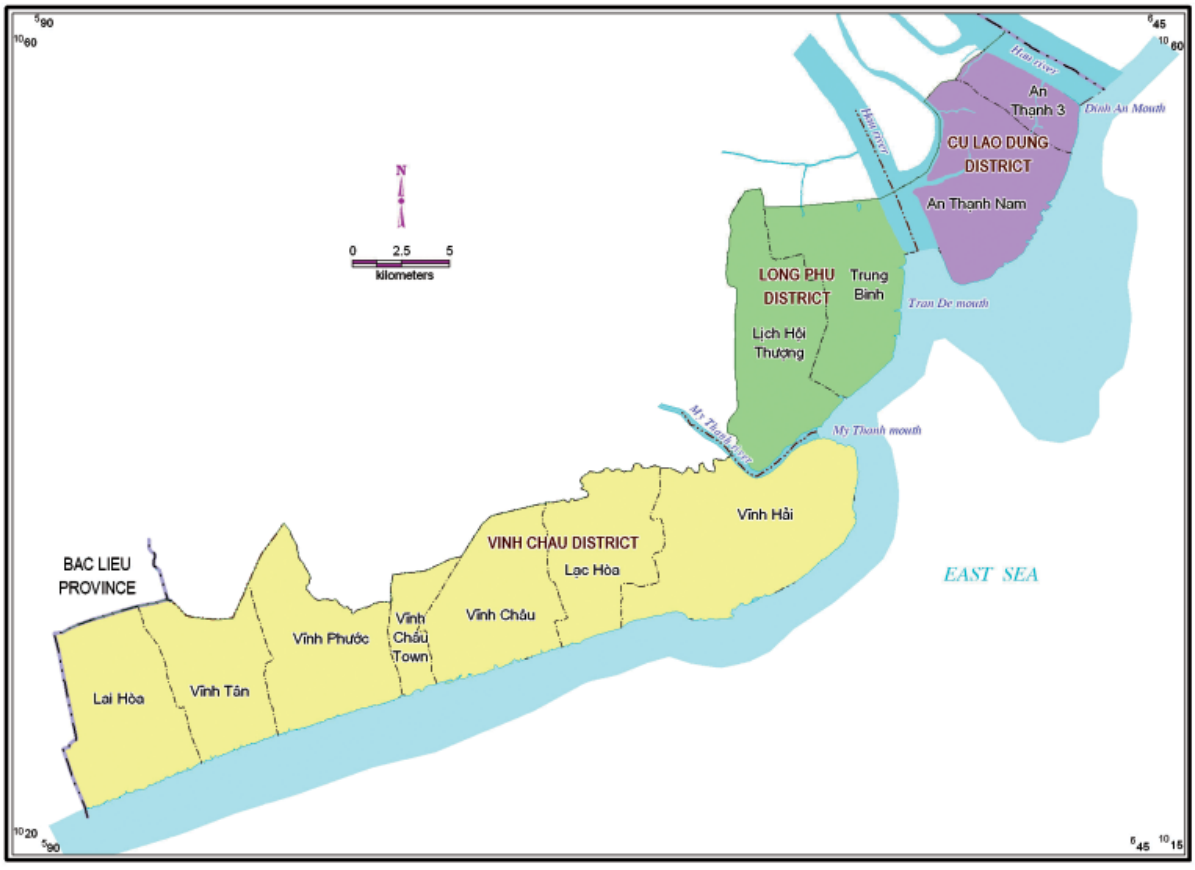


Figure 3. Coastal area of Soc Trang Province.

The climate is basically equatorial, characterised by long daylight periods with high, steady temperatures. This climate is suitable for the growth and productivity of various species.

The tides are uneven and semi-diurnal. The tidal amplitude varies from 3.6 to 4.2 m from August to January. The maximum peak occurs in October-November and the lowest values are recorded in April-May.

The wind regime changes seasonally from the northeast in the dry season to the southwest in the rainy season. There are north-easterly winds with high velocity during the dry season. The maximum wind speed varies from 3-5 m/s and may reach 10 m/s in March, November or December. There are south-western winds with low velocity during the rainy season.

The southwest monsoon, with its low wind speeds, coincides with the rainy season. During this season, the Mekong River carries sediments to the Delta, and accretion occurs in coastal areas leading to the expansion of mud and sand flats in Cu Lao Dung Island. Climate change and rising sea levels will intensify this process, particularly erosion, through increased intensity and frequency of storms.

The coastal area of Soc Trang Province is influenced by the flow regime of the Mekong River, the tidal regime of the East Sea and coastal long-shore currents driven by prevailing monsoon winds. The combination of these regimes creates a dynamic process of accretion and erosion along the coast. During the northeast monsoon (November to March), strong winds and currents cause coastal erosion. The coastline experiences a very dynamic process of erosion and accretion. Severe erosion occurs from Lai Hoa to Vinh Phuoc as well as along the coast of Vinh Hai, near the mouth of the My Thanh River.

In 1965, the entire coastline of Vinh Chau was bare of mangrove forests (Figure 4). By 1995 most areas were covered by mangrove forests. The coastline of Vinh Phuoc, in particular, had very large mangrove areas. These forests disappeared due to rampant cutting. The loss of mangroves resulted in severe erosion in Vinh Phuoc and Vinh Tan, which is clearly illustrated in the map showing the mangrove areas in 2008.

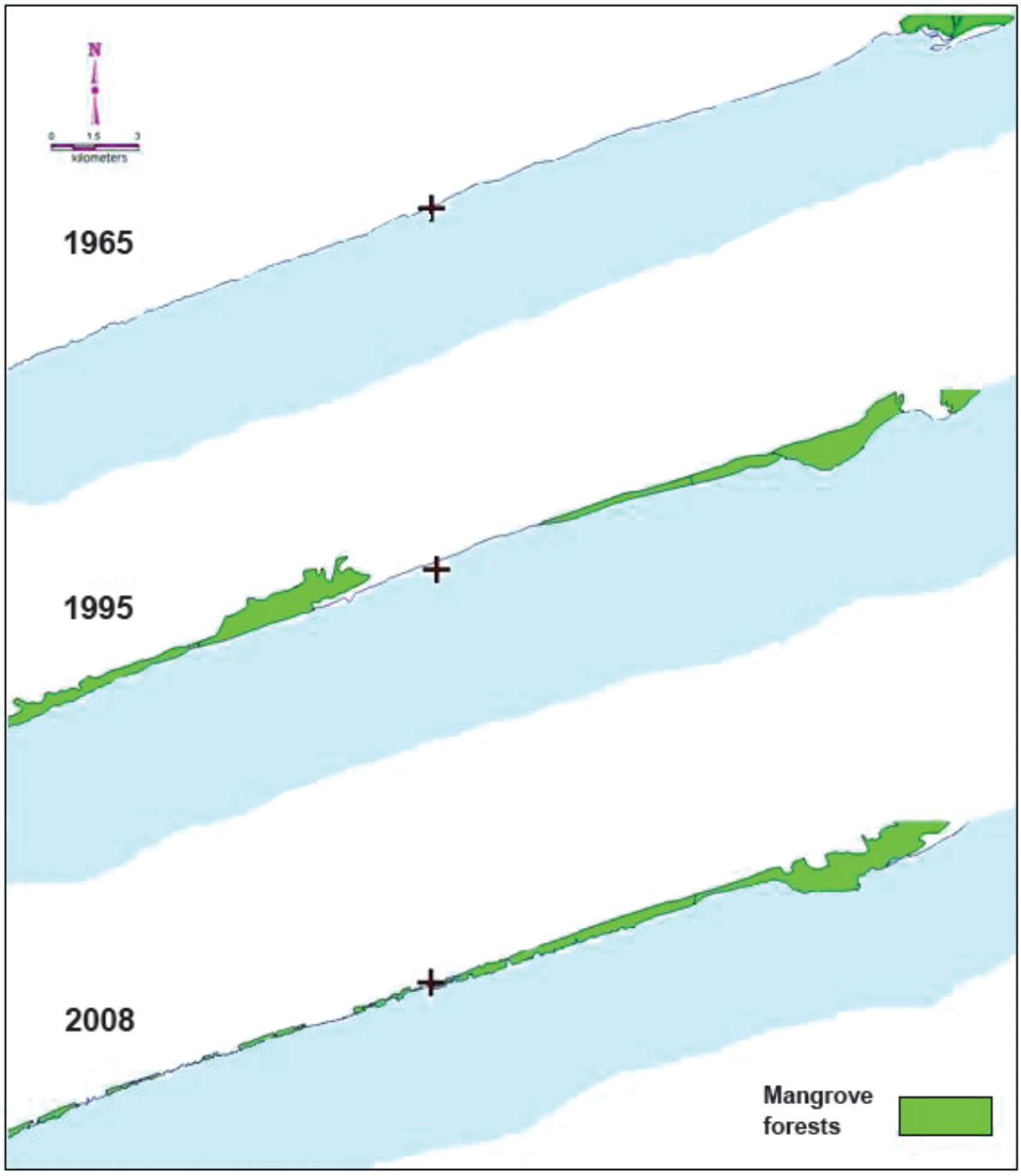


Figure 4. Variation of mangrove areas in Vinh Chau District. The cross marks the same geographic position for all 3 years (1965, 1995 and 2008).

Figure 5 shows the changes in mangrove forest cover on the eastern side of Vinh Chau District between 1965 and 2008. Overall accretion occurred to the north and south of the 1965 mangrove area, while at the same time the coastline to the east was slightly eroded. The mangrove forest cover declined overall during the last 43 years.

Figure 6 shows the variation in mangrove cover in Cu Lao Dung from 1965 to 2008. The two most striking features are the significant reduction in terms of mangrove forest area and the accretion. Changes in the land area of the An Thanh Nam and An Thanh Ba villages in Cu Lao Dung between 1965 and 2008 are

presented in Table 1. The total area of the two communes was about 5,498 ha in 1965, 6,726 ha in 1995 and 7,559 ha in 2008. From 1965 to 2008, the area of the two communes increased by 2,061.7 ha, which is an average increase of almost 48 ha per year. The mangrove forest area decreased from 1,791.9 ha in 1965, to 719.3 ha in 1995, and increased to 1,107.2 ha in 2008. This is an overall reduction in the area of mangrove forest of just over 38% in 43 years.

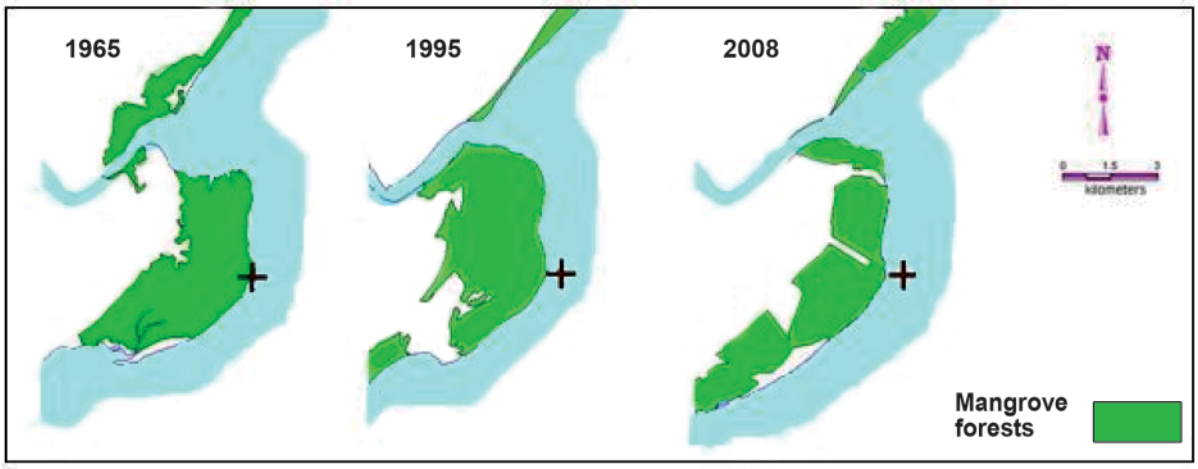


Figure 5. Variation in mangrove areas in the Lich Hoi Thuong and Vinh Hai communes. The cross marks the same geographic position for all 3 years.

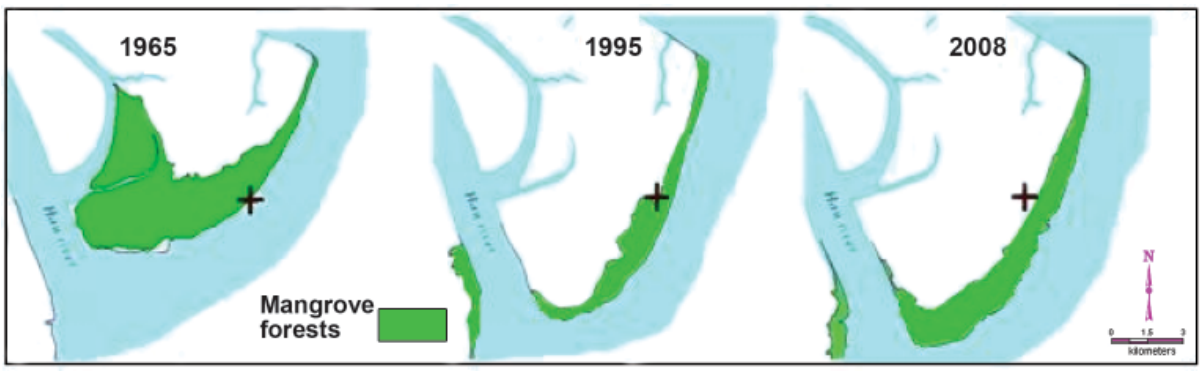


Figure 6. Variation in mangrove and coastline in Cu Lao Dung. The cross marks the same geographic position for all 3 years.

Table 1. Changes in land area of the An Thanh Nam and An Thanh Ba communes in Cu Lao Dung from 1965 to 2008.

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 2008)

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

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

1.3. Ecosystem Services and Benefits Provided by Mangroves

"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). In Viet Nam, they are usually called "Mangrove" or "Rừng ngập mặn" in Vietnamese.

Mangroves provide a wide range of benefits and functions:

Ecosystem Services

- 75% of all tropical commercial fish species spend part of their lives in the mangroves (nursery grounds, shelter, food)
- sequestration of atmospheric carbon
- protection from strong winds and waves
- stabilisation of soil and protection from erosion
- mitigation of floods, intrusion of sea water, and waves
- retention of nutrients and improvement of water quality
- protection of associated marine ecosystems by cleaning coastal waters

Goods

- Supply of timber, fuel, and various non-timber products including medicinal materials;
- Natural plant and animal resources

Attributes

- Biodiversity conservation
- Preservation of human and cultural heritage

A well managed mangrove shoreline protects the coast from erosion, winds and waves (Figure 7). This saves significant costs for dyke construction and maintenance.

(a) Coast with forest protection belt (b) Coast without forest protection belt

Figure 7. Forest protects communities in the coast.

1.4 Short History of Mangrove Destruction and Management in Soc Trang Province

During the Vietnam War (between 1962 and 1971), the United States military sprayed 77 million litres of chemical defoliants in South Vietnam destroying large areas of mangrove forest. After 1975, the destruction of mangrove forests continued as the land was converted into shrimp farms and land for cultivation.

Since 1990, the government has implemented various mangrove rehabilitation programmes to improve environmental and social conditions. From 1990 to 2000, Soc Trang Province planted about 1,900 ha of mangroves. From 2000 to 2007, rehabilitation and protection activities were carried out under the project "Coastal Wetlands Protection and Development" (CWPD) sponsored by the World Bank and Vietnamese Government (CWPD 2007) along with other projects. During the 8-year period, the CWPD rehabilitated 1,086 ha. Survival rates, observed one year after planting, were around 54% in 2000, 96% in 2003, 78% in 2005 and 80% in 2007. The CWPD contracted farmers to tend young plantations less than three years old. From 2004 to 2007, about 482.82 ha of mangroves were cared for under tending contracts financed by the World Bank project. Annually about 1,824 ha of mangroves were under protection through these schemes.

1.5 Lessons Learned from Plantation and Management Activities

As described in CWPD project documents, several factors impacted the planting programmes. These include natural processes and human activities. Cao *et al.* (2006) listed three main reasons that can result in the failure of planting programmes: (a) strong winds uprooted young trees and eroded substrate; (b) sediments filled up the new planting areas; and (c) barnacles adhered to the stems and branches of young trees, resulting in the deaths of the plants.

During the northeast monsoon season (November to March), severe erosion occurs, taking away many young trees. During the flood season (June to October), sediments accumulate at the mouths of Mekong River tributaries and these sediments bury newly planted seedlings. Another threat is barnacles, which, during the early rainy season (March to June), cling to the stems of newly planted trees and kill them (Figure 8).

Figure 8. Young trees killed by barnacles.

Figure 9. Using trawling nets for fishing may destroy regeneration.

Planting should be completed by early June, which should help to avoid such threats. In order to produce young seedlings in time for planting, the nursery setting is very important. The most suitable seasons for planting mangrove trees are shown in Chapter 7.4.

Human activities can also be a threat to the success of planted mangroves. In 2004, from the 29 ha of *Rhizophora apiculata* planted in Vinh Chau village, about 7.9 ha (just over 27%) were lost, and the survival rate of the remaining forest was only 55%. The low survival rates can be attributed to the fishers, who pull ground nets through the planted areas to collect crabs and shells - a process that disturbs plant growth and survival in these plantations (Figure 9, CWPD 2007).

Promoting natural regeneration is a good approach to re-greening the coastal zone. One of the measures taken is to improve the awareness of local people in order to prevent or limit fishing activities in areas where planting has taken place. Therefore, one solution in terms of designing a planting site is to leave empty spaces parallel to the coastline to provide areas for local fishers.

Afforestation is a very important activity for enhancing mangrove forest areas along the coast. In planting programmes, *Sonneratia caseolaris* is the best species for planting in estuarine mudflats. Furthermore, seedlings must be twice as tall as the height of the inundation level, and planting should only be carried out at sites where the average inundation level is less than 0.5 m.

Seedlings that are less than 2 m high are easily uprooted by strong waves. In 2006 and 2007, about 20 ha of *Sonneratia caseolaris* planted at Trung Binh (Long Phu District) with heights ranging from 1.5 – 2 m were completely uprooted by waves. As shown in Figure 10, almost all the seedlings planted in deeply inundated sites had disappeared after less than 2 years. A survey by the team in May 2008 found that only about 10% of the originally planted trees remained. Those lost were destroyed by strong winds and waves.

Figure 10. Only 10% of trees planted in 2006/07 in deeper inundation survived by May 2008.

Figure 11. High and hard surface sites are not suitable for mangrove trees.

The value of post-planting monitoring and site maintenance should not be under-estimated. Investments for replanting, tending, and managing mangrove plantation must be realistic and adapted to each particular site. For example, in eroded sites, seedlings must be supported by structures that consolidate sediments. And, in high and hard surface areas, substrate might be lowered to allow tidal flows to get into the site. Figure 11 shows a high and hard surface site, which is not suitable for mangrove trees unless land improvement activities are applied.

The relationship between rehabilitation with people's livelihood, and environmental concerns in the coastal zone should also be monitored. Adequate measures to prevent erosion and to facilitate natural accretion and reforestation in high lands must be put in place. This must be supported by appropriate scientific studies and monitoring. In addition, cooperation among local farmers, who are engaged in planting programmes with people who depend on mangrove forest and other stakeholders, must be promoted and encouraged.

In summary, the main factors affecting the success of plantation programmes include:

- Selection of species adapted to the sites;
- Quality of seedlings;
- Planting seasons which avoid sediment accumulation (June to October);
- Planting seasons which avoid the threats of strong wind and erosion (from November to March);
- Prohibition, or better management, of fishing activities in newly planted and regeneration areas;
- Maintaining of tidal current flows in plantations;
- Adequate investment for planting and post-planting management activities;
- Participation of local communities in the management and protection of plantations; and
- Cooperation of various sectors at all social levels.

1.6 Selecting Species Suitable for the Site

The selection of species suitable for a particular site is one of the essential factors in planting. There are about 26 real mangrove species occurring in the coastal area of Soc Trang Province.

In estuarine sites, salinity is diluted by fresh water coming down the Mekong River, and sites are inundated by normal daily tides. The most suitable species in these sites are *Sonneratia caseolaris* (Bần chua) and *Nypa fruticans* (Dừa nước).

Medium elevation sites with daily inundation, as shown in Figure 12, are suitable to many mangrove species such as *Rhizophora apiculata* and *Avicennia marina.*

On middle inundated mudflats, with high and hard substrate, higher salinity levels and monthly inundation, the most suitable species are *Avicennia marina* (Mấm trắng), *Rhizophora apiculata* (Đước), and *Lumnitzera racemosa* (Cóc) and *Ceriops tagal* (Dà).

Based on the suitability of mangrove species and lessons learned from previous planting programmes, the best-suited species for planting in the coastal zone of Soc Trang Province are *Sonneratia caseolaris, Avicennia marina, Rhizophora apiculata, Lumntizera racemosa*, and *Ceriops tagal.* Planting techniques for these species are presented in the following chapters.

Figure 12. Plantation of *Rhizhophora apiculata* on middle inundation site.

2 Producing Seedlings for Planting and Tending Mangrove Forest Plantations

2.1 *Sonneratia caseolaris* (Bần Chua)

Sonneratia caseolaris (L.) Engl is an evergreen tree 5–20 m high without buttresses or stilt roots, with a rather open spreading crown, and glabrous throughout. Pneumatophores are 50–90 cm high with a 7 cm diameter (Little 1983). Bark is grey and coarsely flaky (Figure 13). The leaves are opposite, without stipules, nearly sessile, elliptical, oblong or ovate, 5–13 cm long, 2–5 cm wide, with a broad or tapering base and blunt or rounded tip, entire, with 8–12 widely spreading fine side veins on each side, and leathery. Flowers occur in groups of 1–3 at the end of drooping twigs, are malodorous and nocturnal (Little 1983). Hypanthium have 6–8 calyx lobes; there are 6-8 petals measuring 2–3.5 cm in length and 1.5–3.5 mm in width with a dark or blood-red colour, stamens numerous, with threadlike filaments 2.5–3.5 cm long, a pistil with 16–21-celled ovary with many ovules; style long, stout (Little 1983).

Sonneratia caseolaris (bần chua) is common in brackish estuarine zones, mudflats, soft substrates, areas inundated for 6-12 hours/day and less than 1 m in depth. Such sites occur along estuaries in the Long Phu and Cu Lao Dung districts.

a b c

Figure 13. *Sonneratia caceolaris.*

(a) *S. caseolaris* forest in Trung Binh Soc Trang (b) and (c) fruit of *S. caseolaris.*

2.1.1 Collecting, maintaining and processing seeds

Collecting fruits

- Existing *Sonneratia* forests in Trung Binh village (Long Phu District) are available for the collection of seeds (Figure 14).
- Fruits of *S. caseolaris* ripen mostly from September to December.
- October and December are good months to collect ripened fruits.

Figure 14. Selecting trees to collect seeds in Trung Binh Commune.

Maintaining and processing fruits and seeds

- Fruits collected from the forest decompose and break up within 5-7 days - as the mesocarp disintegrates. Sieves can be used to collect the grain-like seeds.
- Seed grains can be cleaned with fresh water - keep them under shade, leave them to drain, and then sow them into prepared ground.

2.1.2 Producing seedlings with root bags

Sowing season

- From October to November.
- Sow seeds two to three times to let grains distribute evenly on the bed surface.
- Regularly schedule maintenance activities of transplanting, watering, weeding, and breaking scum on the bed.

Preparing the bed for sowing and cultivating seedlings

- Beds should have flat ground, dispersing flabby mud 5 cm thick; soil mixed with NPK fertiliser with about 20 kg/1,000 m² and then levelled.
- Beds are laid out in an east-west direction to evenly distribute sunshine on the bed surface.
- Limit and control ulcerated and rotten roots by applying Benlat one day before sowing. A dosage justify 6 g Benlat diluted in 10 litres of water is good for a 100 m² bed. Alternatively, 4 spoons of Captan diluted in 5 litres of water is good for a 100 m² bed.
- Beds suitable for keeping seedlings must be 10 cm thick, 1 m wide, and 10–20 m long.

Transplanting young seedlings into bags

- Pull up germinants (seedling sprouts) for transplanting into the bag when they are 20 – 25 days old with 8-10 leaves, and 0.5-1 cm tall. Water the beds heavily before pulling the germinants. Gently pull young seedlings at the base; then lay them on trays with their roots under water.
- Transplant young germinants into bags. Use a chopstick to make a hole in the middle of the bags. The hole should be as deep as the root length. Place the seedling directly into the hole, fill and press the hole lightly to keep the seedling firm and erect. Transplanting should be done under shade and in cool weather.

Standards for acceptable seedlings

- Acceptable seedlings are about 8 – 10 weeks old after transplanting into the bag.
- Height of 0.8 - 1.0 m with a stem diameter of about 1 cm.
- Straight stem with good root system and verdant foliage.
- Sturdy stems should not have pestilent insect damage.

2.1.3 Producing bare root seedlings of *Sonneratia* spp.

Preparing land for sowing

- Land for sowing must be ploughed deeply and raked carefully, refined after 15-20 days, mixed with fine ash and fertiliser (NPK).
- Water the bed 10-15 cm deep after 3 days; then level it with a rake.

Sowing

- Sow the seeds on a saturated water bed.
- Sow several times to evenly distribute grains on the bed surface.
- A day before sowing day, waters on the bed should be drained.
- Good times for sowing are days with cool and windless weather, during the early morning or late afternoon.
- Figure 15 shows the bare root seedlings of *Sonneratia caseolaris* produced in Vinh Chau, Soc Trang Province.

Tending young seedlings

- Grain-like seeds germinate 7 days after sowing, with two cotyledons after 0-10 days, and 8-10 leaves after 1 month.
- Water is pumped daily into the sowing bed, keeping the depth of water level above the bed surface.
- Apply fertilisers in the second and fifth months. Stop fertiliser application at about 1.5 months before pulling the seedlings for planting.
  - First fertilisation - 30–35 days after sowing with 4-6 kg urea/ha.
  - Second fertilisation - 15–20 days after the 1st application with 6–8 kg urea/ha.
  - Third and fourth fertilisations follow in a sequence of about 10–15 days after the second fertilisation with 10 kg urea plus 500 cc Atonik (foster)/ha.
  - After 20 days, apply 15 kg urea plus 7 – 9 kg DAP/ha

Figure 15. Producing bare root seedlings of *Sonneratia caseolaris.*

Collecting bare root seedlings

Standards of accepted bare root seedlings for planting:

- Stem diameter: 1.0 cm
- Stem length: 80–100 cm
- Seedling age: 6–9 months
- Vitality: stem and root systems are well developed and without pestilent insect damage.

Method for collecting seedlings

- Select 40% of good seedlings during the first re-planting (pull-up).
- After 3 days, apply mixed DAP + NPK + Vibac 88 to rehabilitate the remaining seedlings. Fertilise using about 30–50 kg/ha depending on the quantity of the remaining seedlings.
- A second collection occurs about 1.5 months after the first fertilisation.
- Stop fertilisation at least 30 days before collecting seedlings.
- The seedlings are pulled upright and handled at one-third of the length of the stem from the bed surface.
- Bundle 100 seedlings for easy transport and maintenance.

2.1.4 Planting and tending *Sonneratia caseolaris* seedlings

Choosing an acceptable site for planting *Sonneratia caseolaris*

- Estuarine mudflats, with little or no sandy composition are suitable sites for planting *Sonneratia caseolaris*. In Soc Trang, suitable sites are found in Cu Lao Dung District, Long Phu and Vinh Hai Communes, and Vinh Chau District (Figure 16a).
- Inter-tidal or sub-tidal sites inundated below 1 m.
- Adaptable sites are recognised by new mudflats with scattered natural regeneration, about 50 m belt wide, surrounding existing mangrove forests.
- Water should have low salinity of about 4-5‰, and the site should be getting fresh water from rivers.
- Sites that are not suitable include those that are eroded, deeply inundated, without natural regeneration, far from the river mouth, and highly saline (Figure 16b).

Planting materials

- Planting of seedlings with bags or bare roots.

Density of planting

- Density of seedlings with bag root is 3,300 seedlings/ha.
- Density of bare root seedlings is 5,000 trees/ha, to compensate for expected greater losses.

Suitable season

- The best planting season is from May to June.
- After this period, seedlings would just be buried by sedimentation and damaged by strong waves and wind.

Planting Techniques

- The ideal planting time is during low tide.

Seedlings with bagging roots:

- Plant seedlings in holes 20 x 20 x 20 cm in size.
- Tear the root ball cover before planting.
- Place the seedlings with the whole root submerged in the hole; then bury it in mud by pressing around the hole.

For bare root seedlings:

- Hold the base of the stem and plant the seedlings in the substrate at a depth of 10-12 cm.
- Bury the root with mud and press it to keep the seedling upright.

Carry on maintenance:

- 3-4 weeks after planting, check the plantation areas. If mortality is below 15%, fill the areas with seedlings from the nursery.

a

b

Figure 16. *Sonneratia* caseolaris planting sites

(a) acceptable with natural regeneration (b) unsuitable, deeply inundated sites.

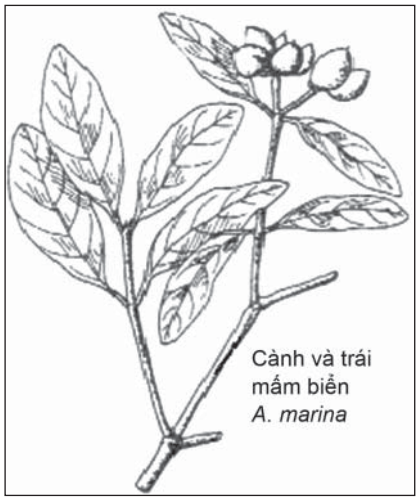
2.2 *Avicennia marina* (Cây Mấm Biển)

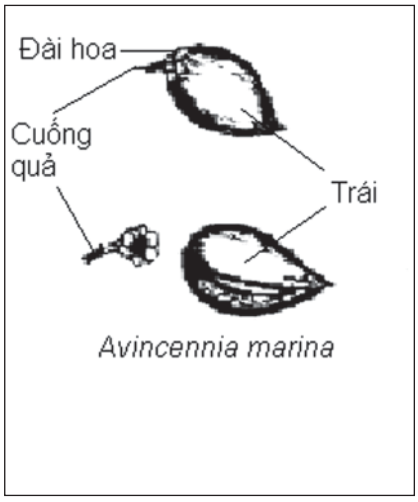
Avicennia marina (Forsk.) Vierh is an evergreen shrub or small tree 1–10 m high with a trunk up to 40 cm in diameter. Pneumatophores are numerous with a height of 10–15 cm and diameter of 6 mm. Trunks often have masses of small air roots, but no prop or stilt roots. The bark is whitish to greyish or yellow-green, smooth, often powdery with raised dots, scaly, exposing greenish inner bark (Little 1983). The branches, fruits and flowers of *Avicennia marina* are shown in Figure 17.

Leaves are opposite, ovate, lanceolate to elliptical, 3.5–12 cm long, 1.5–5 cm wide, mostly acute at both ends, entire, thick leathery, shiny green and hairless upper surface, pale whitish-grey and finely hairy underneath.

Petiole 5–10 mm long, hairy. Heads or cymes ball-like, upright on long stalks at ends and sides of twigs. Flowers few to many, sessile, 4 mm long, 5 mm across. Calyx 5-lobed, green, hairy, persistent; corolla tubular, white; turning yellow or orange with 4 nearly equal, short lobes (Little 1983).

Avicennia marina is adapted in mudflat sites along the coast, located far from river mouths such as Vinh Chau coast. Those sites are flabby or soft receiving daily tidal inundation below 100 cm for 6 to 18 hours.





a b c

Figure 17. *Avicennia marina*

(a) foliage (b) flower and (c) fruits.

2.2.1 Collecting fruits for seedling propagation

- *Avicennia marina* flowers from March to May and its fruits ripen from June to July. The best time for collecting fruits is in June.
- Good fruits are undamaged and free of pestilent insect damage.
- Fruits can also be collected from the ground.
- Ripened fruit is yellowish (Figure 18).

Figure 18. Ripening fruits of *Avicennia marina* (Forsk.) Vierh.

Protection of ripened fruits

- Good fruits should be planted after collection.
- If seedlings are not planted immediately, the fruits must be protected under shade, spread 20 cm thick, and regularly watered to keep cool. Storage should not exceed ten days.

Standards of seedling quality

Six to eight months after transplanting into the bags, good quality seedlings should bear the following characteristics:

- 35-40 cm tall.
- With 8-10 leaves.
- Straight stem with undamaged roots.
- Vigorous stem free of pestilent insect damage.

2.2.2 Planting and tending *Avicennia marina* seedlings

Site selection

- Suitable sites for *Avicennia marina* are tidal mudflats with scattered regeneration, flabby to hard mud or firm clay (Figure 19).
- Daily inundation from low or medium tides, with average inundation level of 50-60 cm.
- Salinity of about 15-30‰.

In Soc Trang, suitable sites for *Avicennia marina* are found on the accreting tidal mud flats along the coastline of Vinh Chau District.

Figure 19. Suitable sites for planting *Avicennia marina.*

Materials for planting

- Seedlings can have roots with or without bags.

Planting distance

- Density of about 3,300 seedlings/ha (i.e. about 1.5 m between trees and 2 m between rows).

Planting season

- The planting season is during the early rainy season from April to May.
- Outside this time, seedlings are threatened by sediment accumulation, strong wind and waves.

Planting techniques

- Before planting, make a hole 20x20x20 cm in size.
- Tear the bag cover.
- Carefully place the seedling with the bag straight into the hole, filling the hole with soil and pressing it in to keep the seedlings firm and erect.

Filling after planting

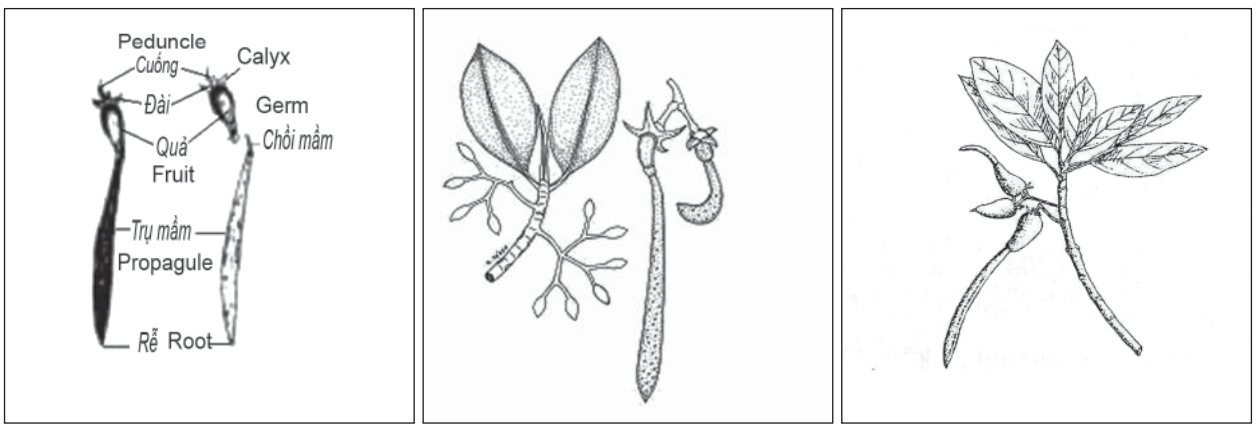
- 3-4 weeks after planting, check and replace seedlings if mortality levels are less than 15%. In instances of higher mortality, complete replanting of the site is necessary.

2.3 *Rhizophora apiculata* (Cây Đước)

Rhizophora apiculata Bl. is a dominant mangrove species in the coastal areas of Mekong Delta. These are medium to tall trees that may reach 30–40 m in height. Stem diameters taken just above the highest prop root are often about 15–35 cm.

Leaves are opposite, simple, light or dark green, obovate, leathery, margins revolute, bluntly acute apex with a distinct mucronate tip, 1–7 mm long. The leaves and propagules of *R. apiculata* and *R. mucronata* are shown in Figure 20.

Flowers are perfect. Inflorescences have few to many joints with 1,2-dichotomous branching and one to many buds per inflorescence. Calyces are typically pale yellow at maturity with 4 lobes, rarely 3. Buds are obovate, green when immature to pale yellowish green as they mature, dimensions 1–2 cm long and ~1cm wide (Tomlinson 1986).



a b c

Figure 20. (a) Fruit and (b) branch and fruit of *R. apiculata,* (c) branch and fruit of *R. mucronata.*

Petals, usually 4, are lanceolate to linear, creamy white, woolly (*R. mucronata*) to hairless (*R. apiculata*), ~10 mm long and ~2 mm wide. Stamens are pale yellow numbering 7-8 (*R. mucronata*) 7-12 (*R. apiculata*). Style is pale green, terete, 0.5–6 mm above base, with dichotomous tip. Bracts and bracteoles vary depending on species. Bracts are swollen, brown and corky for *R. apiculata.*

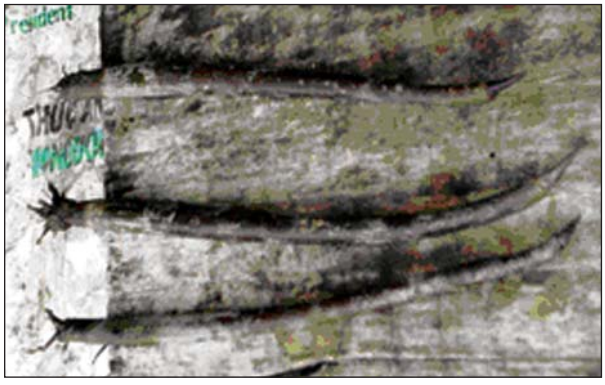
Fruits, when mature, are pear-shaped, elongate, waist constricted, smooth brown surface, calyx lobes elongate are spreading (when hypocotyl are ready to emerge).

Rhizophora apiculata and *R. mucronata* usually occur at the back of *Sonneratia caseolaris and Avicennia marina.* The substrate usually ranges from soft or hard mud to sand, occasionally in rock and coral. The period of daily inundation is about 6 hours. High and hard surface areas must be channelled to allow tidal penetration and water circulation.

2.3.1 Collecting and maintaining propagules for planting

Collecting propagules

- Propagules collected from vigorous forests at least 10 years old usually yield the most fruits.
- Forests are located at suitable sites for collecting propagules and for easy transportation.
- Good parent trees are straight, long stemmed, without defects, with large and thick root systems, large leaf canopy, stem diameter above 6.5 cm, and over 10 m tall.
- In Soc Trang, propagules are best collected from *Rhizophora* forests in Vinh Hai Commune in Vinh Chau District.
- The flowering season for *Rhizophora apiculata* is from March to May. Propagules ripen from July to December. Propagules are best collected in August and September. During this time, propagules are of good quality without pestilent insect damage.



a) Acceptable propagules without roots or leaves.

b) Unacceptable propagules with long roots and emergent leaves.

Figure 21. Selecting propagules of *Rhizophora apiculata.*

Standards of acceptable propagules

- Undamaged propagules, without pestilent insects, at least 1 cm in diameter, over 23 cm in length, over 20 g in weight, without roots and leaves.

Protection of propagules

- Keep propagules in a shady place, spread 20 cm thick, water regularly.
- Maintenance should not exceed beyond 10 days.
- If propagules are to be transported to distant locations, regular watering is essential.

Standards of good propagules cultivated in the nursery

- About 4-5 months after transplanting into bags, good propagules are 40-50 cm tall, with 8 -10 leaves.
- Root is straight and strong, without pestilent insects.
- Good and bad propagules are shown in Figure 21.

2.3.2 Planting and tending

Site selection

Sites suitable for planting *Rhizophora apiculata* are shown in Figure 22 and Figure 23.

Suitable sites for *Rhizophora* have:

- Hard mud and soft clay.
- Receive regular tidal flooding with inundation levels of 30-40 cm.
- Mud flats at the back of *Avicennia* and *Sonneratia.*
- Salinity levels around 15-30‰.

In Soc Trang, suitable sites lie along the coast of Vinh Chau District.

Sites not suitable for *Rhizophora* have:

- Low elevations permanently inundated by tide, or mudbanks seaward of pioneer species such as *Avicennia* or *Sonneratia.*
- High elevations, hard substrate surfaces, occasional or non-inundated lands.

Land preparation

- Before planting, the site must be free of weeds and cleared of other vegetation.
- Clear away all branches and litter perpendicular to the direction of tidal flows.
- Land preparation must be completed 20 days before planting.

Channelling

- Higher elevation sites must be lowered to allow suitable tidal inundation across the planting area. Ditches are 1-1.2 m wide, 0.5-0.8 m deep, with a distance between channels of about 50–100 m, depending on topography.

a

b

Figure 22. Site selection for planting *Rhizophora apiculata.*

a) Suitable sites b) Not suitable sites.

Lower land surface

- Decrease the land surface elevation in hard and high topography sites using ditches. These ditches should be 0.25 to 0.5 m deep.
- Ditches should be completed 1 month before planting to get a 3-5 cm layer of sediment on the bottom of the ditches.

Materials for planting

- Planting of propagules or seedlings with a bag from the nursery.

Planting distance

- 10,000 individuals/ha (1 x 1 m distance between seedlings).

Planting season

- Best planting season is August to October.
- After this period, new plantations are threatened by strong north-easterly winds and waves.

Planting techniques

- Young seedlings with bags are planted in holes 20x20x20 cm in size.
- Tear bag cover, but do not damage the root system. Ditch hole for planting.
- Place seedling with bag into the hole, bury with mud and press it to make the seedling firm.
- Propagules without bags can be planted in mud up to 1/3 of the propagule length to keep them straight and firm.

Figure 23. Good site for planting of *Rhizophora apiculata.*

Filling after planting

Three to four weeks after planting, check and replace seedlings where mortality levels are less than 15%. In instances of higher mortality, it may be necessary to completely replant the site.

2.4 *Lumnitzera racemosa* (Cóc Trắng, Cóc Nghệ)

The tree, flowers and leaves of *Lumnitzera racemosa* Willd are shown in Figure 24. Its leaves are succulent and small (up to 4 cm in length, 2 cm in width). The leaf shape is obovate (broadest above the middle of the leaf), the apex is rounded or emarginate (having an indent at the leaf tip). The petiole is often absent and leaves are often sessile. A notable characteristic is the serrated edge of the leaf (Tomlinson 1986).

Flowers are up to 1 cm long and have 5 small white petals. The fruit is fleshy and flattened while on the tree, but becomes fibrous after floating in water (Tomlinson 1986).

The above ground root system is not well-developed, as observed in coastal sites along the Mekong delta.

Lumnitzera racemosa is adapted to inter-tidal, hard mud substrate. The species can also tolerate fresh and saline waterlogged sites. Medium to high intertidal sites are most suitable for planting.

a

b

Figure 24. Tree and flowers of *Lumnitzera racemosa.*

(a) *Lumnitzera racemosa* tree (b) *Lumnitzera racemosa* flower.

2.4.1 Collecting and maintaining seeds

- Fruits of *Lumnitzera racemosa* ripen from August to October. Seeds are best collected in September.
- After collection, the fruit is dried to get seeds which are then stored in dry conditions.

Cultivating seedlings

- Seeds are soaked in water for 24 hours, sown in trays, and sprouted seedlings are transplanted after germination into bags.
- Seeds may also be sown directly into beds.

Maintenance after transplanting

- Seeds sown into beds must be watered daily by hand or by tidal flows.
- High elevation plots should be ditched to get tidal waters into the site.
- About 8-10 months after sowing, 30-40 cm long young seedlings are ready for planting.

2.4.2 Planting and tending *Lumnitzera racemosa*

Land preparation

- Highly saline sites (50‰) with hard mud or clay, should be mounded 30-40 cm thick to reduce salinity during the dry season.
- Ditched holes in the mound 20 x 20 x 30 cm in size.
- Seedlings can be planted with or without bag.
- Seedlings should be nursed in bags.
- Plant *Lumnitzera racemosa* on mud or soft clay. If salinity is 25 – 45‰, mounding is not required, and planting seedling without bags is possible.

Planting techniques

- Planting season is from August to October.
- Density is 5,000 seedlings per ha.
- Planting distance is 1 x 1m between seedlings, and 2 x 2 m between rows.

Lumnitzera racemosa is slow growing with an annual average growth of 0.4 cm stem diameter and 0.6 m height.

In highly saline hard surface lands or high salinity content, tree growth may be even lower. However, this species is effective in protecting the coastal environment.

Tending young forests

- Filling and replacing dead trees.
- Mound up stump.
- Removing climbers.
- Preventing damage by people and animals.

2.5 *Ceriops tagal* (Cây Dà Vôi)

The tree, fruits and flowers of *Ceriops tagal* (Perr.) C.B. Robinson are shown in Figure 25. This species is distributed from East Africa to the islands of the West-Central Pacific. Leaves are obovate (broadest above the middle of the leaf), with a rounded apex and light green in colour. The stem of *Ceriops tagal* is usually buttressed. The pneumatophores often develop as knee-roots, originating from a looping pneumatophore (Tomlinson 1986). Flowers are very small (<1 cm, usually 0.5 cm). Like all mangrove trees of the family Rhizophoraceae, *Ceriops tagal* is also viviparous. Propagules are slender and long, but can easily be recognised from the fatter propagules of *Rhizophora mucronata*.

a b c

Figure 25. The *Ceriops tagal* (a) the tree, (b) fruit and (c) the flower.

The timber of *Ceriops tagal* is very strong; it can be used for house posts, pillars propping up the roof, etc. The timber is fine grained and the bark contains a high concentration of tannins. Forests are only poorly capable of protecting the coast from erosion, storms and other natural disasters.

Ceriops tagal is adapted in the back of *Avicennia* and *Sonneratia* with soft to hard substrates. Sites suitable for planting receive daily tidal inundation for about 4 hours with high topography and hard substrates. In recent years, *Ceriops tagal* has been introduced largely in higher areas where tidal inundation is rare.

2.5.1 Collecting and protecting seedlings

- The fruits of *Ceriops tagal* ripen during August and October. Mature propagules are greyish brown. The best time to collect propagules is during September.
- Direct planting after collection of propagules is possible, or propagules may be kept in a waterway and watered occasionally.
- Storage under these conditions should not exceed 15 days.

Standards of acceptable propagules for planting

- Undamaged propagules without roots.
- 15–25 cm long propagules.
- 0.5-1.0 cm fruit diameter.
- About 80-120 individuals per kilogram.

2.5.2 Planting and tending *Ceriops tagal* seedlings

Land preparation

High topography inundated occasionally, hard clay with associated plant indicators known as Cóc kèn (*Derris trifolia* Lour), Sam biển (*Sesuvium portulacatrum* L.), Mái dầm (*Crytocoryne ciliate* (Roxb.) Scott) must be lowered using ditches. Ditches should be 0.4 m wide and 0.3 m deep to get tidal waters to occasionally inundate the site.

Planting method

- Planting season is from August to October.
- Density is 10,000 propagules per hectare.
- Planting materials are seedlings with or without root balls.

Planting of propagules with bare roots

- Propagules are planted in mud at a depth of 5–8 cm (about 1/3 of propagule length).
- During the first year, tending activities include regular watering, occasional filling, removal of barnacles and crabs, and control of human activities.

Planting of propagules with root balls

- Seedlings with root balls are grown in the nursery for 8–12 months.
- Hole for planting is 20 x 20 x 20 cm in size.
- Tear ball cover.
- Place seedling in the hole, bury the stump, and press around the seedling to make it firm.

3 Mangrove Planting and Management with Considerations for Increasing Stand Resilience to Climate Change

Chapter 2 provided a comprehensive overview of planting techniques and emphasised the importance of well-considered site and species selection as well as the right planting time and technique. These techniques are often used successfully for rectangular shaped monoculture plantations. Such plantations, particularly those using *Rhizophora,* are suitable for timber production, but they only provide limited protection to the coast and dykes from strong winds and waves. The need for this kind of protection will become more and more important as the frequency and intensity of storms increases as a consequence of global warming.

During heavy storms, tall trees with brittle (inflexible) stems tend to snap, particularly *Rhizophora* which, if planted in plantations, often has tall, thin stems. In monoculture plantations, all trees have almost uniform heights and could, to a large extent, be destroyed by a single heavy storm[1]. In contrast, a natural mangrove ecosystem is more diverse, both in terms of species composition as well as horizontal and vertical structure and therefore could be more resilient to the negative impacts of climate change.

In order to maintain the coastal protection function of mangroves, it is necessary to create and promote diverse coastal forests that are resilient and have a natural capability of regeneration. A greater knowledge and understanding of mangrove reforestation and afforestation techniques is needed to achieve such a goal.

In this chapter, new approaches are proposed for the planting and management of mangroves with an emphasis on promoting stand resilience to climate change. This might be achieved by:

- Applying risk spreading strategies to address the uncertainties
- Protection of mangrove areas that have shown persistence over time
- Restoration of degraded coastal areas
- Establishment of upland buffer zones to allow migration of mangroves in response to rising sea-levels
- Effective management/protection strategies to reduce human threats
- Development of alternative livelihoods for mangrove dependent communities
- Monitoring the response of mangroves to climate change

This chapter will only cover the practical approaches to improved planting. While the establishment of buffer zones is recommended to allow for the migration (with natural or assisted dispersal upland) of mangroves in

[1] Larger trees are commonly killed because the leaves and terminal growing shoots are blown off. These species do not possess epicormic buds beneath stem and branch bark, and are unable to re-shoot after the terminal shoots have been lost.

response to rising sea-levels, such topics extend beyond the scope of this manual and would be part of an integrated coastal area management plan. Management and protection from human threats and providing alternative livelihood projects will be covered briefly in Chapter 4.3, while monitoring will be covered in a separate manual.

Given the threats of climate change in coastal areas, and considering the failures of previous mangrove rehabilitation programmes, there is a need to test new approaches to mangrove planting. This entails adhering to the *precautionary principle,* in the first instance. In the context of environmental protection, this is essentially about the management of scientific risk. It has been defined in Principle 15 of the Rio Declaration (1992)[2] "Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation."

3.1 Testing new Approaches for Mangrove Reforestation and Afforestation

During the long process of natural evolution, mangrove plants have adapted effective characteristics and strategies for their amazing survival and success in the coastal zone. In order to improve upon natural mangrove survival, we should first learn more about the successful approaches already used by nature. We need to support natural processes, rather than fight them. Where practical, it might be best to imitate or mimic nature when it comes to planting or re-establishing mangroves in difficult sites.

When doing so, it is important not to depend on a single solution. In this way also, it would be prudent to spread the risk by using a number of strategies to address uncertainty. For example, it would be useful to protect representative species and habitats while testing different methods of mangrove planting that mimic nature. What we need to avoid is having a strategy that puts "all our eggs in one basket".

Techniques that mimic nature

This approach begins by learning how mangrove forests regenerate naturally, and then applying this knowledge to future regeneration projects. In natural forests, young plants often congregate around parent trees in higher numbers (see Figure 26 left). These are added to every year - not just once, as occurs in monoculture plantations.

- **Dense planting close to established (mature) trees.** Based on the natural regeneration of different species, we can implement a strategy of small-scale planting that mimics nature (Figure 26 right). In doing so, we might achieve greater ecosystem resilience while maintaining the natural community structure and forest composition. This approach might also be suitable for small-scale planting in sites with high wave energy, because experience drawn from many mangrove afforestation projects has shown that in such sites only those seedlings planted close to mature trees had survived.

[2] United Nations Conference on Environment and Development, Rio, 1992 (the "Rio Declaration").

Figure 26. Natural Mangrove regeneration and planting which mimics nature.
Left: Natural regeneration of *Rhizophora* seedlings amongst established root systems of mature trees. Right: planting of *Rhizophora* and *Ceriops* in Vinh Chau Commune which mimics natural regeneration.

A second approach to be tested is the transformation of existing even-aged plantations into more diverse forests, both in terms of structure and species composition. This approach mimics the natural occurrence of canopy gaps and the natural regeneration which takes place in such gaps (for an example see Figure 27).

- Creating gaps for natural regeneration or planting. Through creating canopy gaps in old stands either natural regeneration will take place (see Figure 28 left) or mangroves can be planted mimicking natural regeneration (see Figure 28 right). This is also a small-scale approach in which creation of large gaps must be avoided, thus maintaining the protection function of the mangrove forest. Field testing, in combination with systematic monitoring, will show what the best gap sizes and spacing of gaps will be. Again, this approach to planting is not a one-off activity. It must be carried out periodically within the same area, thus creating a constantly tapering continuous forest, in which trees of all dimensions are mixed.

It is important to constantly monitor the success or failure of these small-scale planting approaches that mimic nature. Only then will it be possible to come up with suitable regeneration strategies for each site.

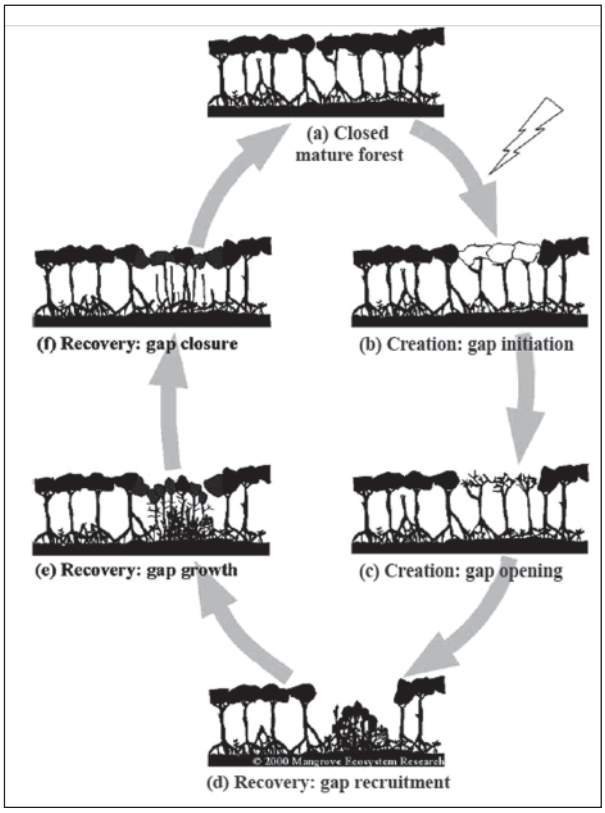


Figure 27. Schematic display of the six stages of natural gap creation and recovery (reproduced with permission from Duke 2001).

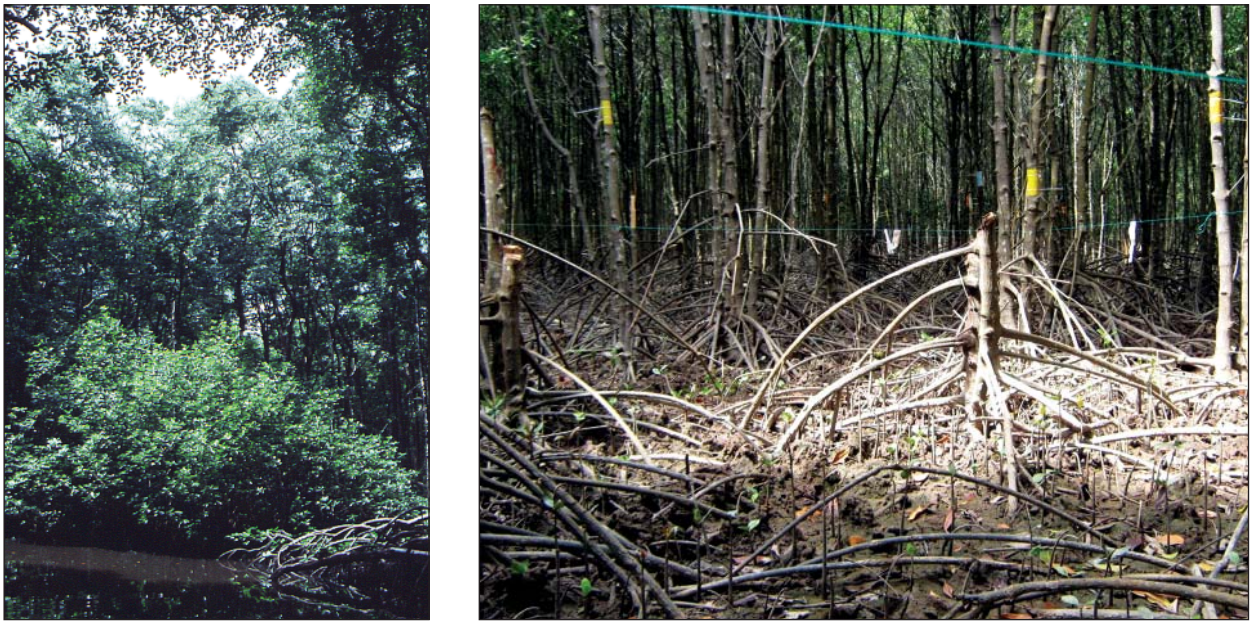


Figure 28. Regeneration of *Rhizophora* in gaps.
Left: *Rhizophora* seedlings grow rapidly in naturally occurring gaps amongst mature trees. Right: Dense planting of *Rhizophora* and *Ceriops* in gaps, Lai Hoa Commune.

3.2 Physical Measures to Support Mangrove Rehabilitation

Planting by mimicking nature can be supported by additional physical measures in areas along high-energy shorelines where natural recruitment no longer occurs and where conventional planting methods are ineffective.

This is the case in several locations along the coast of Soc Trang Province. Here, the flow regime of the Mekong River, the tidal regime of the East Sea, and coastal long-shore currents driven by monsoon winds create a dynamic process of accretion and erosion (see Chapter 1.2).

In sites with severe erosion, the project is testing a model for mangrove rehabilitation which combines:

- appropriate dyke design,
- use of barriers to break waves, limit erosion and increase sedimentation, and
- rehabilitation of mangroves by mimicking nature under relatively sheltered conditions behind the wave breaking barrier.

Barriers placed offshore can break waves, reduce shoreline erosion, and increase sedimentation. This can provide an environmental setting where mangrove saplings can get established in relatively sheltered conditions.

The design and placement of such barriers must be planned very carefully. The project is therefore developing a numerical model, which simulates hydrodynamics and shoreline development with the aim to design breakwaters (wave breaking barriers), which will decrease erosion, increase sedimentation and at the same time avoid downdrift erosion (lee-erosion) as far as possible.

The numerical model will be developed for the entire coast of Soc Trang Province. The design and construction of a wave braking barrier will be tested in the pilot site in Vinh Tan Commune together with rehabilitation of the sea dyke. Methods of mangrove planting in front of the dyke will be tested once sedimentation has occurred.

This model, which combines mangrove rehabilitation with engineering measures, could become part of an integrated coastal area management strategy, which will look at the coastal zone as a whole - and not only at isolated erosion sites - and will consider different options depending on site-specific conditions and expected impacts from climate change.

4 Maintenance, Management and Protection of Mangrove Plantations

Maintenance (tending) is usually applied in new plantations that are less than 3 years old. Activities to be achieved in this period include replanting dead and lost seedlings, and dieback areas where mortality rates exceed 15% (computed from initial planting density). Regular monitoring of plantation sites is very important for supplementing the site's regenerative capacity, preventing destructive human activities, and assessing infestations or natural damage. This chapter provides guidelines for tending new mangrove plantations.

4.1 Plantation Maintenance

First year

Carry out filling in sparse areas of the new plantation. Depending on the mortality rate, apply the following measures:

- In new plantations with mortality rates below 30% - replace lost seedlings in vacated areas larger than 2 m^2.
- Replant patch areas where mortality rates are between 30-60%.
- Replant affected sites where mortality rates exceed 60%.

Check and monitor the plantation regularly to carry out timely management interventions.

Second and third year

- Continue replacement of dead trees with new seedlings.

4.2 Controlling Disease

- Plantation forests are sensitive to negative impacts and unusual weather that may reduce tree resistance, causing epidemic diseases.
- Severe disease observed in the *Sonneratia* forest along Cu Lao Dung is not treated.
- Regular monitoring of diseased trees is necessary.

4.3 Protecting Plantations

Protection measures

- Institutionalise patrolling arrangement and regulate forest protection activities.
- Involve people in the sustainable management and protection of mangrove forests (for details, see section on co-management below).
- Prevent people from entering newly planted forest areas and reduce the use of destructive fishing gear in the collection of aquatic products.
- Promote participation of community and all stakeholders (forest organisations, foresters, local government, etc.) in forest protection.
- Strengthen information campaigns and mobilise people to improve public awareness about forest protection through meetings, workshops, research, and advertisements on television, signboards, and posters.
- Monitor ground condition of plantations and check for normal tidal circulation and site inundation.
- Clear embankments that prevent tidal circulation. Do channelling in case of sand burying.

The use of co-management in plantation protection

Co-management[3] can significantly contribute to the protection of mangrove forests. Co-management involves fairly large areas of land, which can be divided into zones (areas) in which different management regimes are applied. This increases the effectiveness of management and protection.

In a co-management scheme, the resource users and local authorities jointly identify zones where certain resources are in need of some level of protection, conservation and rehabilitation, and where sustainable use is possible. Specific rules are agreed on in each of the identified zones in terms of who can do what, where, when, how, and how much. This will ensure the successful protection, conservation and sustainable use of natural resources and thus contributes to a better protection of the coast from the negative impacts of storms, flooding and erosion.

For co-management to be used in the context of plantation protection for example, it must first be agreed that degraded mangrove forests threaten coastal protection. Degraded areas must be identified, such as areas where people inadvertently destroy mangrove seedlings when gathering resources, particularly by using trawling nets when catching crabs and shellfish and long nets for catching gobi fry. It needs to be agreed through negotiations that the degraded area should become a rehabilitation zone to ensure the plantation's success and better protection of the land behind the forest. Rules are developed for the zone, which ensure that the seedlings are protected and allowed to grow undisturbed for a period of time through certain restrictions including limiting who can enter the zone, when it can be entered and what types of fishing gear can be used there. In some places, this may include a ban on fishing for the first two years after replanting. As part of the agreement, all the resource users are responsible for ensuring compliance with the rules of the zone. Only after this has been agreed and adhered to will the mangrove forest area be successfully rehabilitated over time. Once the seedling trees have matured enough so as not to be threatened by fishing activities, the area can then be rezoned to perhaps a sustainable use zone where the resource use rules are less restrictive. Monitoring of seedling establishment and forest growth will show when the objective of rehabilitating the degraded forest area has been achieved.

[3] Co-management in the context of natural resource management is a partnership arrangement in which a resource user group gets the right to use natural resources on state-owned land (a defined area) and the responsibility to sustainably manage the resources (including protection). Resource users and local authorities jointly negotiate an agreement on who can do what, where, when, how, and how much in a particular area of resources, which is then implemented and monitored primarily by the resource users themselves.

For a more comprehensive report on the benefits of co-management and how co-management contributes to the protection of mangrove forests, while at the same time providing livelihoods for local communities, see the report "Co-management in Au Tho B Village: A Pilot Test for the Coastal Zone of Soc Trang Province" which will be published in 2010.

4.4 Plantation Management

4.4.1 Thinning

- After 3-4 years, the forest canopy will close. Pruning and thinning are suggested to eliminate disease and strengthen tree vigour.
- These activities should be carried out during the rainy season.

4.4.2 Pruning the forest crown

- Competition between planted trees becomes severe 3-4 years after the forest canopy closes. Natural elimination may cause irregular tree growth.
- Thinning should be applied to *Rhizophora* forests at the back of the *Avicennia* and *Sonneratia* belt.
- These activities aim to provide more space and strengthen the remaining trees.
- Thinning systems and other useful methods applicable to *Rhizophora* and *Ceriops* plantations are presented in Table 2.

Table 2. Thinning of *Rhizophora apiculata* and *Ceriops tagal* plantation forests.

Thinning sequence	Forest ages (years)	Density before thinning (tree/ha)	Intensity of thinning (%)	Spacing (m)	Remaining density (tree/ha)
First	8-10	8,000	35	1.42 x 1.42	5,000
Second	15-20	4,000	30	1.8 x 1.8	3,000

4.4.3 Thinning method used in plantations

Mechanical thinning is based on a distance established using a set cane length to control density.

Cutting objects

- Trees to be eliminated by thinning start with those damaged or infected by disease.
- For two-trunked trees, the sick or stunted trunk should be cut.
- For crowded of chaotic trees, 50% must be eliminated.
- Thinning should not create large barren spaces in the forest.

Marking thinned trees

- Before thinning, mark trees to be thinned with red paint.
- Experienced technicians should be consulted to provide guidance.

Thinning techniques

- Before thinning, farmers must be trained in all aspects of thinning techniques, so they can recognise trees to be cut and spare the healthy trees.
- Cutting at the stump of thinned trees.
- Thinning should not damage the remaining trees.

Cleaning after thinning

- Collect all branches and litter created during thinning; cut it into small portions; spread it evenly throughout the forest, or mound it perpendicular to the direction of sea currents.

Please note that the above does not apply to new approaches to mangrove planting and management described in Chapter 3.1 – mimicking nature and creating light gaps to stimulate natural regeneration and a diverse forest structure.

5 Nursery Setting and Seedling Cultivation

5.1 Rationale of Nursery in Mangrove Planting

Mangrove species are easily capable of regenerating naturally in suitable sites. In the coastal zone of Soc Trang however, most of the sites are not suitable (i.e. those that are eroded or uncultivated lands) for natural regeneration of mangrove. In addition, the flowering and fruit maturation period of mangroves does not coincide with the best seasons for establishment.

For example, the ideal planting season of *Sonneratia caseolaris* is from May to July to avoid burying of seedlings by alluvium deposits and strong waves. The fruits of *Sonneratia caseolaris*, however, mature from September to December. A mangrove nursery can provide good quality seedlings of the desired quantity at a time that is best-suited for planting.

This chapter provides guidelines for nursery management and planting that will maximise mangrove rehabilitation along the coast of Soc Trang Province.

5.2 Selecting the Location for Establishing a Mangrove Nursery

Selecting the location of the mangrove nursery is the first step towards determining the success of the planting project, by helping lessen seedling mortality. For example, a nursery established by the CWPD project at Vinh Chau that produced *Rhizophora apiculata* was located too far from the planting sites. The site is currently rehabilitated with *Casuarina*.

Dos and don'ts when establishing a mangrove nursery:

a. Avoid placing the nursery in the following locations: ▪ Too far from a water source; ▪ A depression area or highland; ▪ Far from the village, creating difficulties for daily management; ▪ Near cattle grazing areas; ▪ Not enough soil for potting.	**b. Preferred nursery locations:** ▪ Near fresh water and/or salt water sources; ▪ Access to a road or creek to assist transport; ▪ Near planting sites; ▪ Flat land; ▪ Availability of soil for potting.

c. Size of nursery

The nursery should be large enough to hold materials for potting, such as soil and fertiliser, and have space to prepare potting, lay the bed to cultivate saplings and other activities. Schematic zones of a nursery are shown in Figure 29.

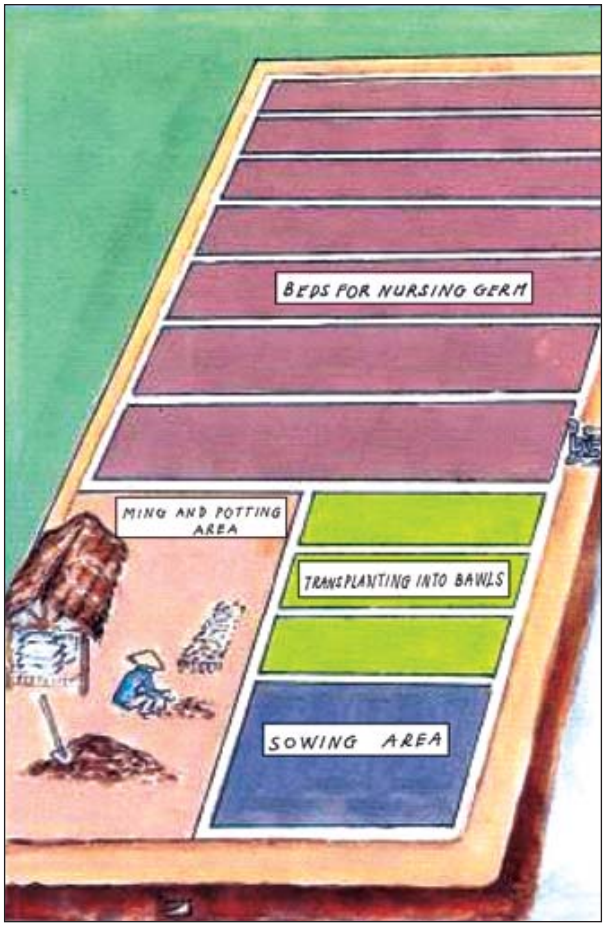


Figure 29. Nursery activities.

In general, the size of the nursery varies from 1-10 ha depending on the number of seedlings required. For example:

- To produce seedlings for planting one hectare of *Rhizophora apiculata* with 10,000 seedlings, the seed area should be 350 m^2 plus 150 m^2 of spare space, for a total area of 500 m^2.
- To produce 100,000 seedlings of *Avicennia marina*, an area of 2,000 m^2 is needed, of which 65% should be allotted for cultivating saplings, and the rest for potting, soil preparation, walking, watering lines, etc.
- To produce 1,000,000 bare-root seedlings of *Sonneratia caseolaris*, an area of 5,000 m^2 beds is needed, of which 70% will be allotted for cultivating seedlings and the rest for other activities.

5.3 Designing Different Types of Nurseries

5.3.1 Different types of nurseries

There are different types of the nurseries for producing mangrove seedlings.

Permanent nursery. This type of nursery aims to produce seedlings for long-term and large-scale planting programmes.

Temporary nursery. This type of nursery is constructed on a small scale and may be used over short periods of about 1-2 years. Temporary nurseries can be broken down into two sub-types (Figure 30):

- Emerged nursery - constructed on high surface, regularly watered.
- Submerged nursery by ditches - the ground is lowered to favour tidal flooding, watering is conducted occasionally.

Figure 30. Two different temporary nursery types

(left) emerged nursery; and (right) submerged nursery.

5.3.2 Zoning of the nursery

In general, a nursery is comprised of the following sections (Figure 31):

- Area for holding materials – storage room for soils, fertilisers, chemicals, rice hush, ash, humus, and other potting materials.
- Area for preparing - soils and other materials are prepared in this area.

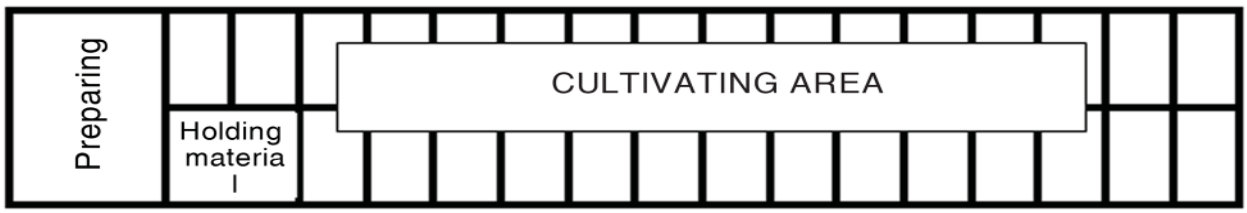


Figure 31. Use zones of a nursery site.

- Area for cultivation of seedlings covers 60% of the total area.
- Irrigation system - an embankment made around the nursery to control tidal flows and used to transport materials.
- Shading system protects the seedlings from strong winds and severe sunshine. Bamboo poles are used to support the roof. The shading crown is at least 1.5 to 2.0 m above the ground to allow for easy walk-in access. The shading cover is made of black or green nets or Nypa thatch.

5.3.3 Designing a submerged nursery

Looking after seedlings with bowls

- Beds for cultivating seedlings are dug about 15-20 cm into the ground.
- The beds are 1.2 m wide and 20-25 m long.

- Beds are separated by 30 cm high embankments for footpaths.
- Nursery beds are connected with each other to facilitate site irrigation.

Looking after bare root seedlings

- Land is ploughed and the weeds, grasses and other vegetation are removed.
- The nursery is divided into small beds of 6 x 20-50 m each.
- An embankment surrounds the nursery to control tidal inundation. Channels are connected to irrigation canals located around the perimeter. The submerged nursery is suitable for most mangrove species.

5.3.4 Designing an emerged nursery

An emerged nursery is designed in a similar way to the submerged nursery. However, the emerged nursery is located on higher elevation sites that are rarely inundated by tidal waters.

5.4 Methods for Planting and Selecting Mature Fruits

Mature and healthy fruits or propagules are best collected from nearby forest plantations. *Rhizophora* propagules may be collected from tidal canals with hand nets; *Avicennia* fruits may be collected from the ground beneath trees during low tide; *Sonneratia* fruits can be collected directly from mature trees.

Tables 3 and 4 show the planting methods and key identification characteristics of mature fruits for the five main mangrove species of Soc Trang Province.

Table 3. Fruit and propagule material for mangrove planting in Soc Trang.

No	Species	Materials	Planting methods
1	Mấm biển *(Avicennia marina* (Forsk.) Vierh.)	Fruit	Mixed or mono-planting
2	Đước (*Rhizophora apiculata* Bl.)	Propagules	Mono-planting
3	Dà vôi (*Ceriops tagal* Pers)	Propagules	Mono-planting
4	Bần chua (*Sonneratia caseolaris* (L.) Engl.)	Grain	Mono-planting
5	Cóc trắng (*Lumnitzera racemosa* Wild)	Grain	Mixed or mono-planting

Table 4. Identification of fruit/propagule maturity based on colour.

No	Species	Colour	
		Middle age	Mature
1	Mấm biển (*Avicennia marina* (Forsk.) Vierh.)	Green	Yellowish fruit skin
2	Đước đôi (*Rhizophora apiculata* Bl.)	Dark green	Pale to red brown
3	Dà vôi (*Ceriops tagal* Pers)	Green	Pale to red brown
4	Bần chua (*Sonneratia caseolaris* (L.) Engl.)	Pale green	Deep green
5	Cóc trắng (*Lumnitzera racemosa* Wild)	Green	Red brown

The fruiting season for most mangrove species in Soc Trang is between August and December.

5.5 Producing Seedlings with Root Bags

5.5.1 Preparation of soils

Soils from nearby creeks should be collected, dried and ground. Soils are mixed with the fine ash of rice husks or plant sweepings at a 5:1 ratio. About 0.5% of mixed fertiliser N:P:K (16:16:8) and cow dung is added with loam.

5.5.2 Preparing nursery beds

Emergent beds. 1.2 x 20–25 m beds are prepared. The sides of beds are made from wooden planks. A pathway of 0.3-0.4 m between beds is maintained for watering the seedlings.

Submerged beds. These are similar to emerged beds and are also 1.2 x 20–25 m in size. Nursery bags are placed inside the beds, which are buried at a depth of 15-20 cm, and flooded to a depth of about 10 cm. A 0.3-0.4 m wide path is constructed along the beds for watering the seedlings.

5.5.3 Filling bag

Bags covers are made from 10 x 18 cm polythene. Small holes are made in the bottom to help drain excess water.

After the mixing of soils and fertilisers, nets with a 5 x 5 mm mesh size are used to screen weeds and other debris before filling the bags. Polythene bags filled with the above mixed materials are kept cool and dry under shade.

5.5.4 Sowing

Before sowing beds, the bags are watered. Propagules of *Rhizophora apiculata*, *R. mucronata* and *Ceriops tagal* are planted directly in the bags, then placed on the beds. Two or more seeds of *Sonneratia caseolaris* and *Lumnitzera racemosa* or *Avicennia marina* are sown into the bags (or as young saplings with a height of 5-7 cm).

5.5.5 Nursery maintenance

Maintenance activities include creating a shading system for protecting saplings from severe sunshine and strong winds. Shade materials consist of black netting (shadecloth) or *Nypa* thatch. Initially, shade is set at 60- 70%, then gradually reduced to 30-50%, and 20-30% after one and two months, respectively.

Watering. During the initial stages, watering occurs twice a day using rose-head watering cans - in the morning and again in the afternoon. When seedlings are larger, more water is required, so an irrigation system with tidal water can be used.

Application of fertiliser. Inorganic fertilisers with N:P:K at a 16:16:8 ratio should be applied after 30 days to increase the growth of mangrove seedlings. It is mixed with 3-4 grams of fertiliser in 1 litre of water for 1 m^2 seedling beds.

Weeding. Weeds are regularly removed to keep seedlings free from competition. Regular checking of all beds at least once a week will prevent other plants from invading the nursing beds.

Shifting seedling bags must be carried out after 3 months to prevent seedlings from rooting into the ground.

5.6 Producing Bare Root Seedlings

5.6.1 Preparation of soils

- Step 1: The nursery site is carefully ploughed and harrowed.
- Step 2: All weeds, grasses, debris and other vegetation is removed.
- Step 3: The water is pumped in to inundate the plot by 10-15 cm for 3-5 days.
- Step 4: About 0.2 m^3 of risk husk ashes and 10 kg of fertiliser N:P:K at a ratio of 16:16:8 is applied on 100 m^2 beds and then harrowed and raked level with the bed surface. Pesticides can be sprayed on the bed surface, if necessary. One litre of formalin is diluted in 15 litres of water (38%) then sprayed on 40 m^2 of bed area to control pests and diseases.

5.6.2 Sowing

- The number of seeds is divided into three parts to be sown three times in order to evenly distribute them on the surface of the bed.
- The water on the beds should be drained completely a day before sowing.
- The best time for sowing is in the morning or evening.

5.6.3 Nursing

Watering. Daily watering by tidal inundation. The level of inundation depends on the height of the seedlings. Daily watering is suggested in order to maintain the moisture level within seedling beds.

Application of fertiliser. Urea is applied 30 days after sowing as follows:

- Stage 1: 4 – 6 kg/ha 30 days after sowing.
- Stage 2: 6 – 8 kg/ha 60 days after sowing.
- Stage 3 & 4: 10 kg/ha 85 and 110 days after sowing.
- Stage 5: 15 kg/ha and 7-9 kg/ha of DAP 135 days after sowing.

6 Planning, Monitoring and Assessment

6.1 Planning

A general planting plan must be formulated for each three-year period and reviewed annually during the execution period. Work conducted during each annual planting period will be based on the approved plan. Planning for each plantation project must be comprehensively prepared. It must be practical and realistic, corresponding to actual site conditions, especially when planting materials are produced in nurseries. Unworkable and unrealistic plans are a waste of money and effort and sometimes carry dramatic social consequences.

Local technicians with the Provincial Forest Protection Sub-department (PFPSD) will be in charge of preparing the planting plans. In some cases, the PFPSD may cooperate with forestry research institutes and universities to prepare the most beneficial planting plans.

a. Three year planting plans

The three year planting plan provides the overall schedule and details. It must contain the following sections:

- Actual location and area of planting plots.
- Site characteristics of planting plots.
- Vegetal species corresponding to particular sites.
- Requirement for propagules, fruits, seedlings and their standard characteristics.
- Planting techniques.
- Requirements for the nursery setting.
- Schedule of planting activities.
- Organisation and arrangement of planting activities.
- Requirements for budgets, equipment, and materials required for each year of the three year period.
- Current land-use and vegetation of planting plots must be accurately described and pinpointed on the site map. A minimum area of 0.5 hectares should be indicated.
- A site map is required that shows the locations of planting plots. Site characteristics such as soil, mean tidal inundation, accretion, erosion, vegetation, land use, and other special spots must be described and presented on the map.
- Each three year planting plan will be submitted and approved by the relevant authorities for implementation. The following offices will be involved in the planning process: Department of Agriculture and Rural Development, Department of Planning and Investment, and Department of Finance.

b. Annual planting periods

Based on the three-year planting plan, each annual period should be described and prepared for implementation. The PFPSD will review and update the annual planting plan for implementation. Aspects needed in each annual review include the following:

- Survey of the location and planting area.
- Preparation of human resources, seedlings, materials, equipment, and tools for planting.
- Budget allocation.
- Land use and site maps.
- Detailed annual planting plan must be prepared corresponding to site characteristics, weather, and current pricing.
- This plan must be approved and budgeted two months prior to the planting season.

c. Field planting design

- After the annual planting period plan is approved, a field planting design should be prepared. The field design includes marking the boundary with posts (Figure 32) and a fence, marked rows, and a description of the planting schedule.
- For planting *Sonneratia* or *Avicennia* in sites along estuaries and the coast, a planting buffer zone of 50 meters should be kept along the existing forest to provide access for boat passage. At the upland margin, land preparation must be lowered or ditched to facilitate the entry of tidal waters (Figure 33).

Figure 32. Marking boundary edges of planting areas with bamboo stakes.

a **b**

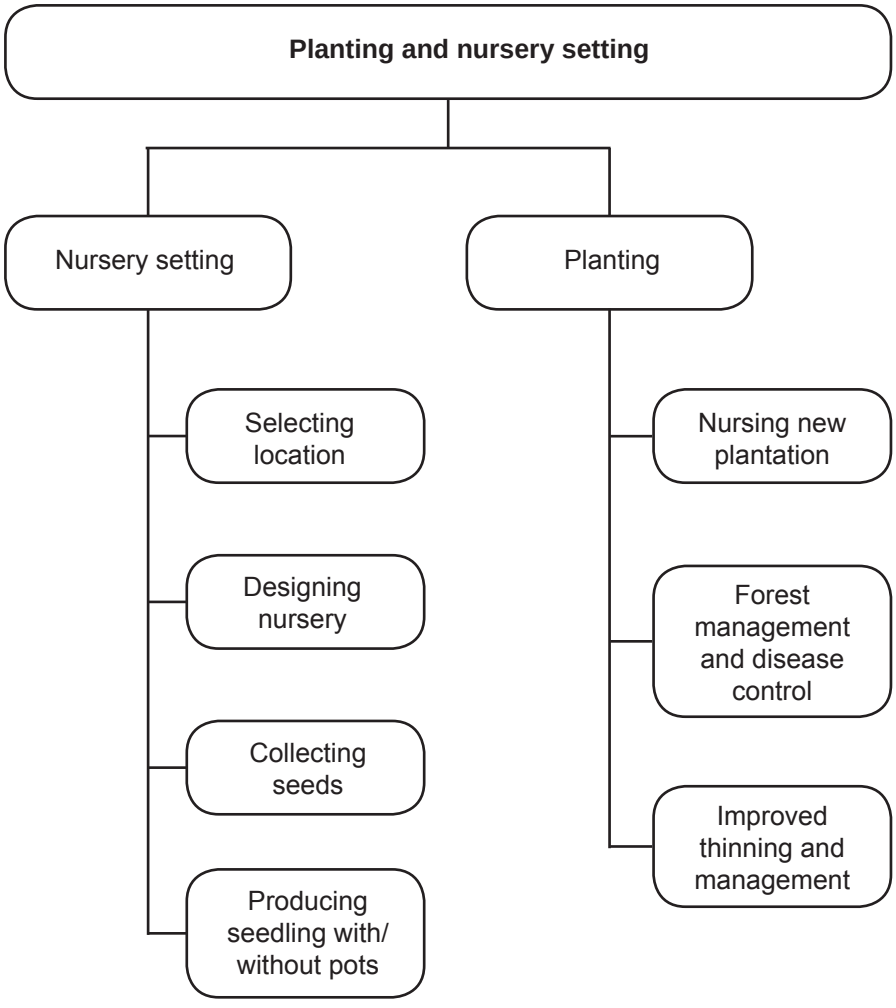
Figure 33. (a) High sites, without tidal supply, are unsuitable for *Rhizophora* planting; (b) High sites, surface lowered to get tidal inundation, are suitable for *Rhizophora* planting.

6.2 Monitoring and Assessment

The PFPSD will be in charge of arranging the monitoring and assessment of planting activities. Details about monitoring are provided in a separate manual.

7 Summary

7.1 Flowchart for Planting and Nursery Activities



7.2 Seed Characteristics, Planting Methods and Nursery Maintenance

Species	Characteristic of seeds					Planting method	Nursery Maintenance
	Collecting time (month)	Number of seeds per fruit	Number of seeds per kg	Sowing materials	Initiation of germination		
Bần chua *(Sonneratia caseolaris)*	8-11	500-1,500	10-12	seeds	4 days	Push seed into soil	Watering once a day and removal of crabs
Mấm biển *(Avicennia marina)*	7-9	1	300	fruit	3 days	On top of soil	Watering once a day and removal of crabs and caterpillars
Đước *(Rhizophora apiculata)*	7-10	1	40	propagules	7 days	Sown 1/3 of length	Watering once a day and removal of crab
Cóc trắng *(Lumnitzera racemosa)*	8-9	1	8,000-10,000	seeds	7 days	On top of soil	Watering once a day and removal of caterpillars
Dà vôi *(Ceriops tagal)*	6-8	1	120	propagules	10 days	Sown 1/3 of length	Watering once a day and removal of crabs

7.3 Ecological Characteristics and Planting Methods for Key Mangrove Species in Soc Trang

Species	Natural distribution	Substrate	Tidal range	Planting methods
Bần chua *(Sonneratia caseolaris)*	Brackish estuarine zone	Mudflat, soft substrates	Inundation level <1 m at 6-12 hours/day	Potted seedlings or with bare roots
Mấm biển *(Avicennia marina)*	Saline mudflat zone, usually away from river mouths	Mudflat, soft substrates	Inundation level <1 m at 6-12 hours/day	Potted seedlings or with bare roots
Đước *(Rhizophora apiculata)*	Just behind *Sonneratia caseolaris* and/or *Avicennia marina*	Soft to medium substrates, with thick muddy, clay or light sandy layer	Daily inundation ~6 hours/day, natural circulated tide	Planting using propagules or potted seedlings
Cóc trắng *(Lumnitzera racemosa)*	Behind *Sonneratia caseolaris* and/or *Avicennia marina,* upland zone	Medium of steady clay substrates	Higher elevations affected by monthly high tides	Planting using propagules or potted seedlings
Dà vôi *(Ceriops tagal)*	Back of *Sonneratia* and/or *Avicennia* upland zone	Soft to hard clay or light sandy structure, wet substrates	Inundated a few hours per day	Planting using propagules or potted seedlings

7.4 Scheduling for Annual Planting and Monitoring Activities

Activities	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Application of requests for budget of planting activities												
Designing for planting												
Sonneratia caseolaris												
Collecting fruit and sowing												
Setting and management of nursery												
Planting												
Avicennia marina												
Collecting fruit and sowing												
Setting and management of nursery												
Planting												
Rhizophora apiculata												
Collecting propagules and sowing												
Setting and management of nursery												
Planting												
Lumnitzea racemosa												
Collecting propagules and sowing												
Setting and management of nursery												
Planting												
Ceriops tagal												
Collecting propagules and sowing												
Setting and management of nursery												
Planting												
Forest management												
Annual assessment of planting programme												

References

Cao, T.T., N.T. Binh, V.D. Huong, N.T. Le and Đ.X. Phuong, 2006. *Study for planting and growing of Sonneratia caseolaris at the deep and accretion coast along Trung Binh village, Long Phu district, and An Thạnh III, An Thạnh Nam villages, Cu Lao Dung district, Soc Trang province.* Southern Sub-Institute of Forest Science, HCMC.

CWPD 2007. *Project Completion Report: World Bank Coastal Wetlands Protection and Development.* Provincial People Committee of Soc Trang and CWPD Management Board.

Duke, N.C., 2001. *Gap creation and regenerative processes driving diversity and structure of mangrove ecosystems.* Wetlands Ecology and Management 9: 257-269.

FAO 1994. *Mangrove forest management guideline.* FAO forestry paper 117, Rome. 319 pp.

Little, E.L. Jr., 1983. *Common fuel wood crops: a handbook for their identification.* McClain Printing Co., Parsons, WV.

SIWRPM 1997. *Report on social and environmental study update for the Quan Lo Phung Hiep Project.* Ministry of Agriculture and Rural Development, Sub-Institute for Water Resources Planning and Management, Ho Chi Minh City, Vietnam.

Tomlinson, P.B., 1986. *The Botany of Mangroves.* Cambridge University Press. Cambridge Tropical Biology Series. 413 pp.

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

Management of Natural Resources in the Coastal Zone
of Soc Trang Province
134 Tran Hung Dao Street,
Soc Trang City, Viet Nam
T + 84 79 3622164
F + 84 79 3622125
I www.gtz.de
www.cmz-soctrang.org.vn