REHABILITATION & ECOLOGICAL RESTORATION R & D FOR MARGINAL & DEGRADED LANDSCAPES AND SEASCAPES

A Research Compendium
FOR DAMAGED COASTAL AREAS

Department of Environment and Natural Resources
Ecosystems Research and Development Bureau

A RESEARCH COMPENDIUM FOR DAMAGED COASTAL AREAS

COMPENDIUM SYNTHESIZERS

EVANGELINE T. CASTILLO
Program Leader

HONORATO G. PALIS
Project Leader

ERDB COMPENDIUM COMPILERS

CARMELA G. TAGUIAM

JOSE ALAN A. CASTILLO

LIZA C. RANES

EMILIANO B. RAMORAN

DANILO A. SABINIANO

MA. LOURDES Q. MORENO

MA. MARCIA M. SANTILLAN

JULIANA B. ZUÑIGA

Ecosystems Research and Development Bureau
Department of Environment and Natural Resources
College, Laguna 4031

May 2010

FOREWORD

Over the past decades, the Philippine mangrove ecosystems and beach forests have suffered severe degradation to the point that biological diversity is threatened. Based on statistics, the extent of mangroves in the country is now barely 117,700 hectares out from the reported 450,000 hectares in 1920. The continuous degradation of the fragile Philippine mangrove ecosystems stems from both the adverse effects of human activities and natural processes.

Mangrove and beach degraded coastal areas therefore need serious rehabilitation and restoration efforts. Coastal rehabilitation and restoration primarily start from greening the coastline using mangrove and beach plants and associated coastal species with meager scientific planning. To date, however, variable success rates (from very high to very low) have been achieved with different species in small-scale experiments. The likelihood of planting success in abandoned fishpond for instance, is severely limited by the reduction in soil quality as a result of increased erosion, activation of acid sulphate soils, and addition of chemicals.

This compendium hopes to provide insights and guidelines on successful rehabilitation based from updated research information and technologies gathered on a national scale, organized and synthesized by the Ecosystems Research and Development Bureau.

MARCIAL C. AMARO, JR.
Director

PREFACE

This Research Compendia on Rehabilitation and Ecological Restoration R & D Technologies for various Ecosystems was published through the efforts of the Ecosystems Research Development Bureau and its regional research field counterparts, i.e. Ecosystems Research and Development Sectors. Research information was gathered from all Regions including those from recent books and the internet. Ecosystems studied include: critical watersheds, degraded mine waste areas, volcanic debris laden areas, marginal grasslands and uplands, damaged urban and coastal sites.

While research and technology information generated in the past years have proliferated, the changing needs of time require that recent technologies be collated, integrated, analyzed and synthesized as a basis of decision-making in verifying the effectiveness and efficiency of said technologies. Managers and developers particularly in degraded areas need vital source of broad set information from which to choose from. This manual hopes to be a meaningful guide to hasten rehabilitation efforts in these areas.

EVANGELINE T. CASTILLO, *Ph. D.*
National Program Leader/Coordinator
Rehabilitation Banner Program

ACKNOWLEDGEMENT

This piece of work was made possible through the full support of the ERDB Management and the technical contributions of ERDB and ERDS research staff of the Department. Specifically, gratitude is also due to the following for providing valuable inputs especially on the silvics and silviculture of selected mangrove and beach forest species included in the compendium: Dr. Ma. Lourdes Q. Moreno, Ma. Marcia M. Santillan, Juliana B. Zuniga and the regional focal persons namely: Region 1, Cirilo M. Nuesca, Sr., Region 7, Aguinaldo C. Bueno and in Region 13, Jeremias B. Bruzon.

EVANGELINE T. CASTILLO, *Ph. D.*
National Program Leader/Coordinator
Rehabilitation Banner Program

HONORATO G. PALIS, *Ph. D.*
Project Leader

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

A "coastal ecosystem" encompasses estuaries, coastal waters and lands, and /or coastlines located at the lower end of drainage basins, where stream and river systems meet the sea and are mixed by seawater thru tidal actions. The coastal ecosystem includes saline, brackish (mixed saline and fresh) and fresh waters, as well as coastlines and the adjacent lands. In recent years, the ecological, biological and socioeconomic functions and values of the coastal habitats/ecosystems have been a growing concern inasmuch as impacts as a result of degradation have increased considerably. Any coastal resource management program cannot ignore this degradation and repair and rehabilitation of these degraded resources must be an element of any program.

In this context, the coastline represents different types of geographical, geological, and climatic conditions. Portions of critical coastal habitats and ecosystems include mangroves, sea grass beds, coral reefs, beaches and beach forests, coastal thickets, water sources, and cultural areas. These habitats are found in close proximity to each other and there is relationship among them. It is essential that that the habitats be viewed and managed as a system. Almost all coastal areas encountered have site-specific human practices and pressures on the ecosystems that need to be addressed Thus, this must always be considered when formulating rehabilitation and restoration strategies.

The Philippine coastal zone covers a coastline extent of 36,300 km (Primavera and Esteban, 2008) which encompasses a wide range of ecosystems and associated resources. Two (2) of the major coastal forest ecosystems, the mangrove and beach areas include an interface between sea and the land. These ecosystems occur mostly along coastal waters, tidal flats, extending along rivers, streams and its tributaries where the water is brackish. Mangrove and beach areas include a vast range of combinations of tidal regimes, climatic variations species composition and varying physical, chemical and microbial composition of soils and water. These influence the wide varying growth, productivity and reproduction.

Mangroves are critical components of the coastal zone in particular to the estuarine systems. These coastal forests play an important role in tropical coastal economies providing many goods and services for the human population. They are the source of major and minor forest products i.e. timber, charcoal, firewood, honey, alcohol, sugar and many others.

The environmental, social and economic values and functions of coastal forests have long been recognized. They act as buffer zones against strong waves and typhoons thus providing shoreline protection and stabilization. They

enrich near shore areas thus furnish a favorable habitat, breeding and nursery ground for marine fishes, crustaceans, and mollusks; Mangroves support genetically diverse communities of terrestrial and aquatic fauna and flora that are of direct and indirect environmental, economic and social value to human societies throughout the world. However, the unsustainable use and over exploitation, human settlements, the degradation of these zones has been a worldwide catastrophe.

Over the past decades, the Philippine mangrove ecosystems and beach forest, to some extent, have suffered severe degradation to the point that biological diversity is threatened. Like other tropical countries, the nation has confronted with environmental problems, which, by and large, stems from both the adverse effects of anthropological activities and natural processes resulted in the continuous decline in production of this fragile environment. Apart from the human impacts and natural threats to these ecosystems they were also subjected to various land uses. These once extensive and diverse assemblages of natural mangrove communities have substantially undergone physical and biological decimation where it has dwindled to less than one third of its original in the past decades. Based on statistics, the extent of mangroves in the country is now barely 117,700 hectares (Melana, *et al*. 2000) out from the reported 450,000 hectares in 1920.The degradation of the Philippine mangrove ecosystems continuous almost unabated for a number of reasons. However, statistics on the rate of beach forests in the country is wanting but the fact that the two (2) ecosystems are found side by side and in many occasions overlapping as to area coverage, it is therefore safe to assume threats and decimation are common to both of them. Among the reasons include: economic and development pressures; lack of public awareness and/or lack of the intrinsic value of the mangrove and beach system; conflict of uses; lack of an overall national conservation and management policy direction; and failure of the government to fully implement laws and regulations.

There were also threats to the mangrove ecosystem that cause the most extensive destruction such as: indiscriminate, large-scale and non-selective logging of mangrove forests; organized and large-scale conversion of mangrove forestland into salt beds, agricultural farms, commercial, industrial and human sites, garbage disposal sites; and capital intensive brackish water fishponds. The most destructive among these is brackish water pond culture, primarily for shrimp production that also included areas within beach forest areas. This view fails to appreciate the functions of the mangrove ecosystems. The beach forests on the other hand have also been increasingly under threat with rapid development of potential coastal areas into commercial beaches. Although management efforts are increasing, many problem areas still exist. The government policies and programs have contributed in most part to the rapid

destruction of the resource. For example, mangrove policies and program have favored short-term economic benefits of damaging developments and ignore the long term and sustainable use of resources. In addition the lack of alternative livelihood opportunities for coastal dwellers that depend on mangrove resources for a living has aggravated the ineffectiveness of the implementation of relevant policies and programs. It is worth to mention that about 55 percent of the total populations of the country live within the coastal mangrove areas and derive their livelihood from mangrove products aside from fishing and farming.

The problem is immense and complex and the negative impacts of such interventions are diverse and far-reaching with serious human and environmental economic and social consequences. The cumulative result of the impacts has been called ecosystems simplifications: large reductions in the life-supporting complexity and diversity of ecosystems. These disturbing impacts, might as well have contributed to the degradation and loss of mangrove and beach biodiversity of species and ecosystems. It is therefore imperative that a management and conservation of mangrove resources be based on sound information, knowledge-based policies and sustainable management principles. This must be given the highest priority in our efforts directed towards sustainable conservation, management and utilization of coastal ecosystems and its resources, in general.

1.1 Objectives of Coastal Forest Rehabilitation and Restoration

There are three main reasons for restoring coastal forests (mangrove and beach areas): (1) conservation of the natural system through ecosystem preservation, (2) restoration of a natural system for sustainable utilization and (3) protection of coastal areas. There are no distinct boundaries between the different approaches but in extreme cases the degree to which the ecosystem is restored will vary. In the case of conservation, as much of the disturbed pristine ecosystem will be conserved/restored in as much as possible and the success of restoration should be judged on how nearly the restored ecosystem emulates the original pristine system. This will involve maintaining most ecological processes and preservation of genetic diversity.

Where restoration is primarily for production purposes, less attention is paid to restoring as much of the ecosystem as possible and more is given to the cost and benefit of the product. The dilemma is how much of the original mangrove and beach forest ecosystems have to be restored to maintain sustained production. This is a critical question that needs to be investigated on pristine and disturbed mangrove and beach ecosystems. The very process of mangrove and beach forest ecosystem restoration is carried out with clear

objectives under carefully controlled conditions and with subsequent long–term monitoring.

1.2 The Problem Areas

Coastal forests, namely mangrove and beach, have been used unsustainably and therefore need serious considerable focus and are requiring rehabilitation and restoration efforts. Aside from planting mangrove and beach plant species, other environmental concerns have to be considered too. Other areas of concern affecting the whole ecosystems include : the quality of water in coastal streams, rivers and inshore waters; loss of riparian vegetation; loss of flora and fauna habitats in both terrestrial and marine areas; degradation and filling of wetlands; erosion of coastal dune systems and degradation of coastland; siltation of estuaries and inshore waters; and factors that interfere with ecological and geo-morphological attributes of the coastal systems both for mangrove and beach forests.

Degradation associated with these matters has occurred as a result of failure to properly manage the way in which coastal zone resources have been used for various human activities. There are significant costs associated with rehabilitation of these resources and failure to devote resources to rehabilitation and restoration will reduce the usefulness of these resources for a range of economic and social activities.

Coastal rehabilitation and restoration primarily start from greening of the coastline with mangrove and beach plants and associated coastal species through plantation establishment or simply enrich the sparsely or denuded stand. The target areas are those sites where natural regeneration is deemed difficult to perpetuate; devoid of mother trees and when regeneration potential is nil. For mangrove forests, in many cases these areas were subject to clear cutting in the 1960s to 70s when the government allowed massive clear cutting for fishpond development. After only 3 to 5 years the areas developed for fishpond are gradually been abandoned due to high cost of maintaining the productive state of the ponds. Accumulation of acid sulfate soil in pond substrates can substantially reduce the pond productivity hence abandoned the fishponds. Unproductive/ undeveloped/ abandoned areas covered by Fishpond Lease Agreement (FLA) but reverted back from the disposition of BFAR for fishpond being unproductive after the said term (PD 705 sec 33 and 43; PD 704 sec 24) are the target of massive restoration. The likelihood of planting success in abandoned fishpond is severely limited by the reduction in soil quality as a result of increased erosion, the activation of acid sulphate soils, and the addition of chemicals. To date, variable success rates (from very high to very low) have been achieved with different species in small scale experiments to plant

mangroves in disused shrimp ponds and in shrimp sludge cake areas.

Beach forest on the other hand is also subjected to pressures brought about by coastal development, particularly beach development. A good number of beach front and foreshore areas in the country have been titled illegally hence removal and cutting of beach plants are beyond government control. However, most of beach owners are open to rehabilitation especially when storm surges cut beach sand into the open sea. In many cases, least developed beach areas are oftenly dominated by coastal communities where extraction of biomass is prevalent primarily for fuel wood purposes. The harvest of biomass for fuelwood alone is one of the pressures responsible for decline of beach forest productivity and its accompanying biomass.

Government projects and programs in forestation have not always included beach restoration such that it aggravated beach forest degradation. The rise in sea level in many beach areas has further reduced the ability of the beach areas to recover and its resiliency is always in question.

Fig. 1. Pristine mangrove forest converted to aquaculture.

The conversion activities of prime mangrove forest to various land-uses become a common scene especially in built-up and urban areas (Figure 1). Expansion and construction of various structures such as jetties, markets, fishports, bridges, beach resorts, housing, agriculture and the like, have become unnoticed only to find out that mangrove stands have been depleted (Figure 2).

Mudflats and estuary areas that have been subjected to disposal of effluents loaded with chemical pollutants are also problem areas especially near urban and mining sites. Restoration of such areas requires ecological approach whereby plant succession for gradual reintroduction of plants is first considered.

Fig. 2. Gradual inching of built-up areas displaced productive mangrove stand.

Adoption of all types of plant lifeforms are encouraged to effect ecological succession before a seral stage can be achieved. Similarly, most often mudflats are always exposed to high energy waves that conventional planting with propagules always failed.

Selection of germplasm should be modified in such away that it could withstand the onslaught of high energy waves. The frequent movement of sandbar also poses a problem wherein planted propagules are often uprooted and inundated due to shifting sand in all directions.

Figure 3. A typical beach forest.

Continuous and unabated extractions of biomass from mangrove and beach forests (Figure 3) are common especially in areas near built-up and urban sites. The biomass removed from the forest are used as fuelwoods, poles for fence and lighthouse construction materials and charcoal making. The deforested sites now become devoid of plant life and biomass to affect normal exchange of materials and thus affecting nutrient cycling, hence need to be restored.

Problem areas mentioned need appropriate rehab protocols to address gradual site decimation and at the same time maintain its ecological integrity, economic productivity and achieve resilient ecosystems.

1.3 General Considerations on Mangrove and Beach Forest Rehabilitation

Rehabilitation strategies in general for mangrove and beach forests are highly dependent on its objectives and the nature and kind of problem areas. Normally, the planting protocol is more often dictated by the objectives of the rehabilitation. For coastal protection from direct impacts of storm surges, tsunamis, strong wave action and other coastal perturbations, pioneer species are planted such as the group of *Avicennia* and *Sonneratia* species. These groups of plants can withstand a high energy or exposed areas due to dimensional stability of its root systems and pliable stems. Spacing here is normally very dense e.g. 0.5 x 0.5 or 1.0 x1.0 meter. For semi- exposed areas or lagoon sites, *Rhizophora spp.* is recommended as it can accommodate coralline, sandy or muddy substrates with high survival rate. However, if the plan is to establish plantations for commercial purposes, a low energy areas are often selected and planted with fast growing mangrove species such *R. stylosa, R. mucronata* and *R. apiculata.*

Other restoration strategies are also based on many factors provided both by ecological and physical attributes that dominate and exist in the area. Foremost of all is site selection where minimum data sets should be considered. Some of these variables that to be avoided include: highly saline and inundated areas or sites submerged for more than1.5 meters to prevent and minimize barnacle infestations. In areas where barnacles abundantly thrive, the plantation may suffer 80-100% mortality; do not encroach or plant on sea grass beds because they are equally important ecosystem to maintaining the overall productivity of the coastal zone; Avoid areas exposed to rapid currents and shifting substrates as well as open areas except when the object is to stabilize the adjoining soil. Planting on these sites should have a closer spacing; consider compatibility of species with sites; select sites with stable soil; consider the zonation pattern of mangroves; select shallow grounds to keep the plants above water level for at least three hours daily for optimum photosynthesis.

Other consideration also include freshwater supply. Mangroves grow best on muddy coastal plains where adequate freshwater supply from river discharges are available. Water sources also come from rainfall, run-off from the land and flooding by tide from the nearest river systems. Similarly, areas which are not greatly influenced by tidal inundation or calm shorelines are most suited for mangrove plantation establishment; however, the area must be reached or submerged by saline water daily. Low energy areas (that are not directly exposed to open seas) are also priority sites and it includes bays, lagoons estuaries, and riverine areas.

Beach plants in general are not directly affected by changes in substrate physical attributes, tidal fluctuations, storm surges, sea level rise, among others as they are normally situated in the terrestrial portion of the coastal zone. Sandy areas are the common substrate where beach plants grow best. Nearly all beach forest plants can be propagated just like upland forest species. They only differ in few protocols wherein some species need to be raised near coastal areas for they need frequent salt spray to maintain robust and optimum growth.

Social considerations are also a variable to site selection and expansion of rehabilitation for both mangrove and beach forests. Avoid areas of conflict. These are areas with existing claims, questionable classification, areas with security problems, areas where people are indifferent to the cause on efforts restoration, and areas which provide livelihood to coastal resident such as open mudflats that often utilize for shell collection.

Attached are various species templates of selected mangrove and beach forest plants for ease of field identification. It also shows their silvics and

silvical information and attributes. Please refer to appendix with templates nos. 4 to 21.

2. MANGROVE AND BEACH FOREST REHABILITATION PROTOCOLS

Mangrove and Beach Plant Type Nursery Establishment

2.1 Nursery Site Selection

Selection of nursery site is crucial in the overall success of rehabilitation. Many difficulties may arise if improper site is selected (Table 1).

PROBLEM	PROBABLE CAUSE
Highly plant mortality rate due to under watering	Absence of nearby water source makes watering difficult
High plant mortality rate due to flooding	Site located in a floodplain, tidal range or an area subjected to intense runoff from rainfall
High plant mortality rate due to poor care and maintenance	Site too remote from the barangay
Loss of plants from theft	Site too remote from the barangay
High plant mortality rate due to absence of appropriate soil media for potting	Site too remote from a proper source of appropriate potting soil media
High plant mortality rate due to close spacing of plant resulting to over-crowding	Limited area for growing large plant population
High plant mortality rate due to long distance transport	Far distance of planting area from the nursery

2.2 Criteria for Nursery Site Selection

Supply of *water* - Determining a site for a nursery near a brackish water or freshwater source should be easy since mangroves are located in the coastal zone. Periodic watering is a basic requirement for a nursery thus it should be near to piped water or situate the nursery near a well. While locating the nursery close to a river is a good idea, it is necessary to keep a certain distance to avoid flooding during rainstorms or high tides.

Accessibility – Nursery should be located close to laborer house and mangrove area. If this is not possible, find a place close to the *barangay* or one where it can be easily reached by banca so that seedlings can be readily transported for planting and potting soil can be brought in for seed beds and

pots. The area should be open enough to ensure that the seedlings get enough light.

System of Drainage –The site to be selected must have good drainage and is relatively flat. Drainage is essential because plants become waterlogged when standing water is always present and working in the area becomes difficult. Therefore, when evaluating an area as a potential nursery, the surface of the ground should be examined.

Size of area – The size of the area is critical factor in nursery efficiency. As a general rule of thumb, about 325 square meters is needed for seed bed. Add another 100 to 200 square meters work space for potting, laying seed beds and other activities.

2.3 Types of Mangrove and Beach Nurseries

Permanent nurseries are for mangrove and beach planting over an extended period of time. They tend to have more developed working areas with small sheds to provide shelter from the sun and the rain.

Subsidiary nurseries are normally located at a distance from the permanent nursery, or for areas separated from the permanent nursery, or for areas separated from the permanent nursery by such natural features as large rivers, bays or rough water. It may operate for several years as in permanent nursery.

Temporary nurseries are the smallest in all nursery areas and are designed for targeted small areas for rehabilitation. Generally set up where there is small planting area (typically less than 5 hectares) which could be planted over a one-year period. These nurseries are not nearly as elaborate as permanent or subsidiary nurseries.

2.4 Nursery Infrastructure

Preparation of site- – The nursery site must be located in an open area to avoid the cutting of trees. If the cutting cannot be avoided, extra care should be exercised in trimming branches to let in more sunlight. It is not always required to clear all the trees and shrubs, they can be used to shade some areas of the nursery, land leaves and twigs form removed vegetation can be used to start the compost beds. Be sure to remove all stumps and pull up all grasses including the roots to prevent regrowth.

After clearing and leveling have been done, the nursery should be laid out using the prepared map. With twine and a measuring tape or rope, determine the lengths and widths of the various parts of the nursery, stake out each of the nursery component areas and begin construction.

Seed boxes – The number of seed boxes requirements depends normally on the species to be raised. One needs more boxes if you choose to grow trees from the *pagatpat* group. Materials include: Boards 1 centimeter thick, 10 centimeters wide and at least 2 meters long. Plywood (at least 1centimeter thick) for the box base and nails.

Fill the boxes with three different layers of sand and stones: fill the bottom 5 centimeters with small stones (less than 1.5 centimeters), the next 3 centimeters with coarse sand and the top 2 centimeters with fine sand mixed with compost and/or potting soil.

Seed *beds for germination*– The beds are raised slightly by about 5 to 10 centimeters above the level of the surrounding area by adding potting soil to each bed or by digging out the soil from the 40-centimeter wide area immediately next to the beds. Keep the soil from spreading by lining each bed with a wood or bamboo curb. If boards are used, dig a 2- to 3-centimeter groove around the bed and slot the board in. If bamboo is used, a similar (though wider) depression should be dug. A line of concrete blocks (only one block high) makes an excellent curb, but tends to be expensive.

Germination shed - The germinating shed needs only simple roofing materials like banana or coconut fronds with no walls. Roughly 3 x 5 meters in area, it is constructed by simply putting in four pieces of bamboo with a woven *cogon* grass roof. Under this roof is a simple bamboo table for the seed boxes. Place the legs of the table in cans filled with water to prevent ants and other crawling insects from reaching the seedlings.

Potting sheds – Potting sheds can be made out of *nipa* fronds or shingles. Typically not smaller than 3 x 4 meters in area, they are built with three walls; and instead of a door, a fourth will is kept open.

Potting media – This can be a combination of sand and ordinary garden soil. In order to protect the material from rain, stage both piles under a roof similar to that built for the germinating shed. These materials may be brought in by truck and should be staged close to the bagging shed.

Hardening beds – Hardening beds need not be raised from the ground as long as it is horizontally level. Hardening beds require a temporary roof with

several layers of covering (coconut leaves or *nipa* shingles) but typically mesh nets gauge 14 to control the amount of light reaching the seedlings. These beds are 20 to 30 meters long and 1 meter wide; bamboo poles can be used to support the roof. The roof should be at least 1.5 meters above the ground to allow easy access to the seedlings.

2.5 Nursery Management and Operation

After construction of nursery is completed shifts to operate and manage the nursery on a daily basis should be put in place. This requires caretakers to assume responsibility for managing the nursery. Typically it takes 4 to 6 months for *Rhizophora* species. For *Avicennia* species, it takes more than a year to grow out seedlings to the point where they can be transplanted. Putting up a nursery is not commonly thought of as typical livelihood, it can be a moneymaking proposition for those involved. As described in detail below, the typical activities that make up nursery operations are: (1) Collecting and transporting seeds and propagules, (2) propagation practices and maintenance of the seedlings and (3) preparation for outplanting.

Collecting and Transporting Seeds and Propagules- Supply of mangrove seeds and propagules is one of the most important considerations in massive reforestations, especially for less common species such as pototan and bakauan babae, busain, tangal and tabigi. This may be one of the reasons why the monoculture plantation of bakauan bato is so common. Another problem is the large numbers of seedlings requirements such that a mangrove plantation needs about 10,000 to 40,000 seedlings per hectare (assuming a spacing of 1 x 1 meter to 0.5 x 0.5 meter respectively.

Timing of collection – Collecting propagules and seeds at the right time is critical. While collection is possible from some mangrove species almost every month of the year, peak seasons vary by area and date. Knowing the right time to collect the seed or propagule also makes the operation quicker and more efficient. Table 2.0 shows the approximate time of the fruiting season for the major mangrove species on a province-wide level. The information will not be exactly be the same in each area, but this should provide a good idea of the general time to expect to find mature seeds and propagules. Seeds or propagules are not always available. In those cases, wildlings (young saplings less than 30 centimeters tall) may be used as planting materials.

Table 2.0. Best collection times for selected mangrove species (adapted from Palis et al. 1988).

SPECIES	Climatic Type*1	Climatic Type 2	Climatic Type 3	Climatic Type 4
Bakauan bato	Jan. & May	Feb.-July	Feb.-April	Jan. & Feb.
Bakauan babae	Oct.-Dec.	Jan-Aug.	April-June	Jan.-Feb.
Bakauan lalaki	Aug. & Sept.	Feb. & March; April-June	March & April	Jan. & March; May & June
Tangal	May	Jan. & Feb; May	May; Nov. & Dec.	**
Busain	Jan.; Oct.-Dec.	Jan. & Feb.; May -July	Feb. & May	May-Aug.
Pototan lalaki	Jan.-May; Oct.	May	April-June	**
Api-api	Jan.-Feb.; May & July	Jan. & Feb.; June-Aug.	**	August
Bungalon	April-July; Nov. & Dec.	Jan.; May-Oct.	Jan. & March	Jan.– Oct.
Pagatpat	Aug.-Nov.	Jan.	Feb.-March	Jan.-March
Tabigi	Aug.-Nov.	Jan.-Aug.	Jan.-April	March

*****Climate type refers to rainfall pattern. Type 1 – Two pronounced seasons; dry from November to April, wet all other times. Type 2 – No dry season. Very pronounced rainfall in November. Type 3 – No pronounced wet or dry season, but relatively dry from November to April. Type 4 – Rainfall distributed more or less evenly throughout the year.
******Species not identified in this climatic type

Procedure of wildling collection—Wildlings are collected by balling with a spade. Insert the blade of the spade into the soil at the appropriate distance form the wildling, lift up the chunk of soil containing the wildling and gently wrap mud around the toot ball (this is known as mud paddling) Place the wildlings in folded banana leaf sheets for transportation to the nursery and immediate potting.

One of the main characteristics of good quality seeds and propagules is superiority of size and that it is free from defects and insect infestation and fully mature. Seeds and propagules with all of these characteristics ensure a high rate of survival in the field.

Mature seeds and propagules identification – Normally, many seeds and propagules are wasted because they are collected while still immature. This wastes the time of the collectors and nursery operators and can reduce the overall success rate of the plantation. It is important, therefore, to select seeds and propagules that are ready to grow. Table 3 provides a guide to identifying mature seeds for collection.

Signs and indicators of mature fruits/propagules area as follows: All trees from the bakauan and tangal groups exhibit a whitish to yellowish ring-like earmark on the propagule located 1 to 3 centimeters from the top of the pericarp (where it attached to the mother tree). Another indicator of maturity is color. The propagules turn from green to brown as they mature.

The busain and potatan groups do not exhibit the ring noted above, but immature green propagules turn brownish or bronze as they mature. Mature propagules drop together with the pericarp or fruit, unlike the bakauan and tangal groups whose propagules drop without the pericarp. In the pagatpat group, the fruit will turn shiny yellowish to light green and soft when ripe. In the *tabigi* group, the light green globular fruit turns light brown with the lines on the fruit becoming prominent. *Dungon* seeds turn from green to dark brown.

Table 3. Indicators of maturity for some species of mangrove fruit (adapted from Field, 1996)

Mangrove Species	Seeds (S)/ Propagules (P)	Maturity Indicator
Saging-saging	P	Fruits become lightly yellowish to reddish brown
Api-api, piapi, bungalon	P	Seed coat changes from green to light yellow. Seed and bungalon puti coat becomes wrinkly and oftentimes opens
Busain, pototan and pototan lalaki	P	Tip of the hypocotyls changes from green to brown
Tangal	P	Ring - like mark immediately below the cap of the propagule and yellow line approximately 1 to 2 centemeters from top of propagule
Nipa	S	Seeds change from light brown to dark brown upon maturity and turns lustrous to dull
Tabigi	S	Fruit changes from light brown to dark brown upon maturity.
Bakauan and tangal group	P	Presence of ring-like mark (abscission layer) below the pericarp or cap (up to 1 centimeter wide)
Busain group	P	No ring-like mark; green propagule turns brownish/ bronze and drops without the pericarp or cap
Pagatpat	S	Dark green or yellowish fruits sometimes with cracks
Pagatpat baye and pedada	S	Fruits turn shiny or yellowish and soft
Tabigi group	S	Green fruits turn to brown with compartment

Sorting and transporting seeds and propagules

Transport of collected seeds and propagules can be very difficult when handling big volumes over long distances. Sorting of propagules is the first stage in the transport process. Carefully inspect your material to see whether it is mature, healthy, free of insect infestation and physical injury.

The next stage is the packing of the seeds or propagules. Larger materials (e.g., the tongki or bakauan propagules), can be packed in bundles of 50 or 100. Bundles made out of palm or banana leaves should be kept moist.

Small seeds should be transported in bags with a moist cloth placed on top of each bag. Be sure to keep the cloth moist throughout the trip and no not expose the materials to direct sunlight, as this will cause damage. Wildlings, like the propagules, should also be packed in groups of 50 or 100 in a folded banana leaf, palm sheet, or gunny sack to protect plants from the sun while in transit.

To transport the materials by motorized banca, it is easy to keep them moist. Pour sea water over them two or three times a day (more if they are in direct sunlight). If the boat is open, protect the shipment with a tarp or some coconut fronds. Avoid placing the propagules or seeds in direct sunlight. Allow small seeds to air-dry prior to storage. Place the seeds in polyethylene plastic bags, seal the bags and store them at room temperature. Propagules may be kept under shade for as long as 2 weeks without adversely affecting their viability. Avoid placing them on the ground or any moist surface to inhibit root development.

2.6 Propagation Techniques

Propagation practices include the following activities such as preparation of potting soil, germination techniques, potting and hardening:

Potting media preparation – Root development is enhanced when the potting soil is porous. Utilize sandy-loam soil that is high in organic matter or compost mixed with cured sawdust or rice stalks. Pulverize, screen and thoroughly mix the soil and organic matter. A 50:50 ratio is best. Potting soil should always be prepared in advance to avoid unnecessary delays in potting which can result in high seedling mortality, especially for wildlings. Thus, it is a good idea to prepare potting soil of several cubic meters.

Germination techniques – Mangrove plantations in the country are more often established in monoculture. This stems from the fact that species like bakauan species can provide all year round propagules in great quantity.

Below are group of mangrove species and their manner of germination techniques:

Bakauan, tangal and busain groups - These species have viviparous seeds or propagules that are sown or planted directly in the field and have a high survival rate in areas which are generally not exposed to strong waves.

In cases where there is a need for nursery raised seedling, the species may be germinated in a plastic bag. Table 4 provides the appropriate

size for bagging each species.

Pagatpat group *(pagatpat* and *pedada)* – *Pagatpat* has a big potential for reforestation due to its wide range of habitat form the seaward side and high salinity to the landward portion. The boomerang-shape seeds of the *pagatpat* are planted or sown in a seed box with sandy soil. Seeds are then covered with a thin layer of soil and watered daily with brackish water. For early and uniform germination, soak the fruit in fresh water for 7 days and sow the macerated seeds in seed beds.

Api-api group *(api-api, piapi, bungalon* and *bungalon puti)* – These species are considered semi-viviparous because of its emerging radicle and split seed coat while still attached to the mother tree. It is the easiest to germinate, either in seeds beds or directly in bags. Seeds are sown in an upright position half-buried with the emerging leaf or the cracked portion of the seed at ground level. For higher germination rates, use seed beds made of sawdust. Once the seedlings develop a pair of leaves they can be handpicked for potting.

Tabigi group –Its big angular seeds are germinated in seed beds or potted directly. As in the *api-api* and *saging-saging* groups, the seeds are sown halfway with the embryo eye just at the soil surface.

Potting – Table 4 shows the different sizes of plastic bags for the different species. Potting is done by pricking the germinants using a flattened stake to minimize root damage. The seedlings are then planted in the bag with the root collar level with the surface of the soil in the bag. Propagules are sown about 1/3 of the length of the hypocotyls deep in an appropriately sized bag. In the absence of seeds, wildlings may be used and hardened following the same potting and seedling procedure. During potting of wildlings, take extra care not to damage the root system.

Table 4. Bag sizes for various species (Sinohin *et al.* 1996)

SPECIES	BAG SIZE (inches)
Bakauan babae	8 x 12
Bakauan lalaki and bangkau	6 x 10
Talisay	6 x 10
Dungon-lati	6 x 10
Api-api family	6 x 10
Tangal	6 x 10
Malatangal	4 x 6
Saging-saging	4 x 6
Pototan lalaki	4 x 6
Kulasi	4 x 6
Nilad	4 x 6

2.7 Maintenance of the Seedlings

Seedling quality in the nursery always depends on care and maintenance. This includes: watering, shading, weeding, protection from pest, diseases and stray animals.

Watering - Seeds and seedlings must be watered daily. Prior to placing in hardening beds, use tap water or brackish water. For hardened seedlings, brackish water must be used in order to acclimatize them to the field environment. The plants should be watered as early as possible every morning. It is important that this be done every day since failure to water even for one day can adversely affect the growth rate and survival of the plants.

Shading – The newly potted seedling should be shaded from direct and intense sunlight. Shading material usually consists of coconut leaves and used fish nets to gradually expose the seedling in the hardening process.

Hardening – Hardening is the process of preconditioning seedlings in a nursery to the harsh field environment by gradually exposing the plants to increasing amounts of sunlight. This should be continued until the seedlings are fully exposed to sunlight before planting. Plant watering should likewise be reduced. Select only the larger hardy seedlings for planting. Smaller seedlings may either be sorted for special care to salvage them or simply discarded. After sorting, the seedling must be properly packaged in baskets or seedling boxes/

trays. Arrange the seedlings such that that there will be no unnecessary movement during transport.

Protection from pests, diseases and stray animals - Conduct daily inspections for insect pests in the nursery area. Table 5 shows insects and diseases that may harm the seedlings. Corresponding control measures are likewise presented. In areas with stray animals, fence the nursery with local materials such as bamboo poles.

Table 5. Damage and control measures for common pests and diseases found in mangrove nurseries (Sinohin *et al.* 1996).

Pests/Disease	Damage	Control Measures
1. Tussock moth	Larvae or hairy caterpillar feeds on leaves of young seedlings	Manual removal of larvae (All species)
2. Seed borer	Bores propagules and breeds on seedling/ propagules	Exclusion of propagules with evidence of insects of holes. Air drying of propagules to reduce moisture content before germinating (All species)
3. Aphids	Suck nutrients of bakauan seedlings	Spraying with chemical at company's specification (All species)
4. Scale insect	Sucks nutrients causing curling of leaves	Spraying with chemical at company's specification (All species)
5. Slug caterpillar	Defoliation	Manual removal of larvae (All species)
6. Bagworm	Defoliation	Manual removal of larvae (All species)
7. Leaf spot	Brown spot interferes with photosynthesis;	Removal of infected leaves (*Nilad, bakauan*) defoliation if severe and burning
8. Bakauan mosaic	Defoliation; interferes with photosynthesis;	Removal of infected seedlings and burning. (All bakauan)

2.8 Seedling Grading, Sorting, Packaging and Transport

After hardening, the seedlings should be graded using certain criteria. Normally, the criterion is height to at least 30 centimeters from the root collar

for seedlings from seeds and from the ring-like marks for propagules. Those that pass the grading criterion should be sorted according to height before packaging and transport to the planting area.

When all plantable seedlings are out on the field, the remaining seedlings that do not meet the grading criteria should be reared further in the nursery until the desired size is met. The seedling shall be subjected again to the hardening process before outplanting.

3. PLANTATION ESTABLISHMENT

Rehabilitation and Restoration Objectives

The most common mangrove and beach area rehabilitation or plantation development objectives include: Firewood/charcoal production, posts and piles, tanbark, thatching materials production, shoreline protection/ productivity of nearby coastal waters and timber production, among others.

3.1 Identification of Site

One of the major reasons of plantation failure is improper location of site. Many people still believe that all open areas, mudflats and seagrass beds are qualified for mangrove forest plantations, especially for bakauan. These areas are considered a separate ecosystem they are not subject to forestation purposes, hence must be protected. Table 6.0 shows examples of the typical zonation patterns with suggested species to be planted. Site selection is based primarily on these important factors: type of substrate, current species present, presence or absence of seagrass, tidal height, extent of wave action, presence or absence of pests, and historical users of the area.

Table 6. Typical zonation pattern of mangrove species and common names (after Agaloos, 1994)

Zone	Tidal regime	Soil types	Species and common names	Good species for planting
Seaward	Daily, including neap tides	Coral rubble, sandy, sandy laom	*Avicennia marina (Bungalon); Sonnaratio alba (pagatpat); Rhizophora stylosa* (Bakauan bato); *R. apiculata* (Bakauan lalaki)	*Rhizophora stylosa* (coral rubble or sand); *Rhizophora apiculata* (sandy loam, silt)
Middle	Daily except during neap tides	Silty to silty clay	*Avicennia alba (bungalon puti; Rhizophora. officinalis (api-api) RRh; R. apiculata (bakauan);* *R. m Mucronata (bakauan babae); Aegiceras floridum (saging-saging; A. corniculatum (busain); Bruguiera cylindrica (cylindrica); Brugiera gymnorrhiza*	
Landward	Inundated only during spring tides	Silty to silty-clay to clay	*B. sexagula (pototan): Ceriops tagal (tangal); C.decandra (malatangal; Exoecaria agallocha (buta-buta); Lumnicera racemosa (kulasi); Nypa* fruticans (nipa)	*Ceriops tagal* (silty to silty clay); *Nypa fruticans* (silty to silty clay, only where there is fresh water intrusion
Riverine: (River mouth and upstream forebank/ backbank)	Variable inundation brackish/ freshwater influence	Sandy to silty-clay to clay	Rivermouth: *Avicennia alba; A. Aigiceras floridum* *(saging-saging: corniculatum; Rhizophora mucronata; R. apiculata; R. stylosa* Upstream : *Avicennia alba; Aegiceras floridum; A. corniculatum; Bruguiera cylindrical;B gymorrhiza; Nypa fruticans; Rhizophora mucronata; R. apiculata*	*Rhizophora stylosa* (sandy) *R. apiculata* (silty to silty clay rivermouth and upstream backbank); *R. mucronata* (silty to silty clay rivermount and upstream forebank) *Nypa fruticans* (silty to silty clay, brackish water)

Substrate type – The substrate is an important controlling factor in selecting an area for plantation development. In evaluating the substrate, it is important to realize some limitations in selecting an area for planting. Categories are listed below, with some as a combination of two or more types. Substrates that support mangroves species include:

Mud – This is best characterized as soft sediment composed of a combination of organic and inorganic material. It may be as shallow as 2-3 centimeters or as deep as a few meters. A very shallow mud substrate is not recommended for wood production plantation. In general, mud is a good substrate to plan either of the following species: Bakauan babae, Bakauan lalake, Busain, and Tangal.

An area with foul smell similar to rotten eggs should be avoided because the soil may be very acidic and the likelihood of plant dieback is high. The consistency of mud can vary from a fairly firm to very thin substrate that easily supports the weight of a walker. Planting in areas with very thin substrate should be avoided because of low plant survival and high labor and management cost in these areas.

Coralline – This is characterized by the presence of hard shelves where small or thin pockets or softer sediment are found. Rocky or coralline areas are not recommended for production forests because of relatively low soil fertility. But for protection and other ecological purposes the following species are recommended: bakauan bato, bakauan lalaki, and pagatpat.

Sandy substrate – Known to most people, sandy substrate consists of very small grains of sediment (often coral) usually less than 2 millimeters in diameter. The substrate has no organic matter although it may overlay mud or muck. Like mud, sand may be as shallow as 2-3 centimeters or as deep as several meters. Very shallow substrate areas are not recommended for wood production. As with rocky or coralline substrate, the following species do well in sandy substrate like bakauan bato, bakauan lalaki, and pagatpat.

Muck – This contains a large amount of plant debris which tends to be deep starting at more than 10 centimeters thick up to as deep as a few meters. Like mud, muck may have the same foul, rotten egg smell. In general, muck is a good substrate to plant bakauan babae, busain, and tangal.

Indicator species – One of the best ways to determine which mangroves will succeed in a particular area is to determine what species are thriving in the area.

Seagrass beds – This group of grass species is also a separate ecosystem which should remain as is. It is not recommend these areas for mangrove plantations because there are many species of coastal animals depends largely in these habitats. Simply replacing one habitat with another does not help to manage and enhance the coastal environment.

Tidal pattern – tidal height is an important biophysical control affecting plantation success. It is important to know if the average daily water depth of the area identified for planting will in fact support growth.

Planting is generally done on bare substrates during the low tide of neap tide, especially for small seedlings and propagules (such as bungalon and pototan- lalaki). Big or long propagules may also be planted in areas when the water depth is as high as 10 centimeters at low tide.

Areas constantly battered by waves especially during stormy days are critical for planting. As much as possible, avoid these areas and endeavor to plant in good sites. Table 7 shows suggested areas with the following media for some mangrove species.

Table 7. Suggested media for selected species of mangroves (Watson,1928).

Name	Common Name	Soil/ Media and location
Acanthus ebractcatus	Diluario	Loam or clay on river banks and clearings
Acanthus ilicifolius	Tingloy	Loam or clay on river banks and clearings
Acrostichum aureum	Lagolo	Almost everywhere if light
Avicennia alba	Bungalon puti	Deep mud within the influence of rivers
Avicennia lanata	Piapi	Sandy mud not far from sea; Singapore and East Coast
Avicennia officinalis	Api-api	Stiff soil on river banks
Bruguiera gymnorrhiza	Busain	Loam or sandy loam. Gregarious in drier areas
Bruguiera parviflora	Langarai	Will grow almost anywhere in mangrove if well drained
Excoecaria agallocha	Buta-buta	Clay
Heritiera littoralis	Dungon-lati	Sandy loam, river banks and inland edge of mangrove
Lumnitzera racemosa	Kulasi	Clay
Nypa fruticans	Nipa	River banks within the influence of fresh water
Rhizophora mucronata	Bakauan babae	Deep mud within the influence of rivers. Not on sea face
Scyphiphora hydrophyllacea	Nilad	Loam or sandy mud on river banks and open spaces
Sonneratia alba (Gedabu)	Pagatpat	Loam, often some distance from river banks

Good planting sites include: Well- protected areas away from strong waves like coves, lagoons, bays and abandoned and reverted fishponds, open areas along rivers, gaps within natural stands, stable mudflats with barrier islands, barnacle free areas and logged-over areas.

3.2 Choice of Species

Plantation success largely depends on the choice of species. Determining which species to plant is a complex decision that is based on the plantation's purpose (whether production or protection) and the biophysical characteristics of the selected area. In the long, it is the biophysical characteristics that will determine the success of the plantation; it is up to the PO to decide which species to plant after considering all factors discussed

above. Table 8 presents the major commercial mangrove species. The information could help determine which species are best suited to your plantable area.

Table 8. Commercial uses of various mangrove species.

SPECIES	USES
Bakauan bato, babae and lalaki	Piles or poles, firewood or charcoal
Busain group	Piles or poles, firewood or charcoal
Tangal	Tanbark (tungog) for tuba industry, poles
Pagatpat	Timber and lumber, firewood or fodder
Bungalon	Firewood, fodder
Api-api and Piapi	Timber, poles, firewood, charcoal
Tabigi	Timber and lumber, firewood or tanbark
Piagau	Timber and lumber
Tabau	Posts and poles
Nipa	Shingles, alcohol, wine

There are a number of factors that contribute to identifying a successful plantation location. One is the choice of species based on pests as consideration. Barnacles and crabs are the most common pests of young plants in coastal areas. If there are large numbers of these pests in the area, find for other sites. If these areas are really in need of rehabilitation, choose *Avicennia* and *Sonneratia* species with at least 2- foot seedling size. Barnacles cannot envelop the whole seedling as they possess smooth bark that prevents barnacles from attaching. Another pest that people often overlook is filamentous algae. This algae can pile up against the young plants and knock them over by their sheer weight. Consider also right timing in outplanting, i.e. when algae production is at the minimum.

Appendix A shows all the various mangrove species used for rehabilitation of coastal areas. It provides a discussion of the detailed description and protocols per individual species for easy reference for the readers.

3.3 Plantation Establishment Techniques

Planting preparation activities - The plantation sites often need some

preparation prior to planting. This may include clearing areas of *Achrosticum* fern or other brush, removing standing dead wood that will shade out the area and removing debris. In this phase, it is important to determine both what needs to be done and when it will be completed. If a completion time is not included, the tasks are not likely to be finished in time for outplanting.

Planting lay-out in the field - To deflect sea wave actions, make an inverted V shape spacing with the point of the V- facing the open sea. Spacing should be less than 0.5 meter. Triangle formation with one of the corners of the triangle pointing seaward can also be employed. Cluster planting to act as a wave break. To maximize survival, spacing is much closer (25 x 25 centimeters). After 3-5 years, when the clusters can be planted at a wider spacing, as the area will be more or less protected by the clusters. Strip planting is a common practice in plantation development. Strips (10 or 20 x 100 or 150 meters) are established 100-200 meters from the shore at very close spacing to withstand strong waves. Once established, the open areas between the bakauan strips and shoreline may now be planted at a wider spacing.

Seedling density or spacing – Spacing can range from 16 individuals per square meter to one individual per 1 square meter. The closer the spacing, the greater the ability of the propagules to withstand wave impact. Wider spacing is employed when bigger trees are needed. The wider spacing reduces competition for sunlight and nutrients. Deciding on the spacing will help to determine the total requirement for your seedlings.

Map – Maps is required whenever forestation is to be made. This helps determine the boundaries, location of passages, blocks and seedling density, among others.

Brushing the area – This is the removal of undergrowth such as mangrove fern (lagolo) and spiny woody vine (diluario) prior to planting. Brushing can be approached in several ways: *Total brushing* – removes all the undergrowth from the area. This is an extremely difficult task in areas of heavy undergrowth and is generally unnecessary.

Strip brushing – removes undergrowth along pre-determined strips, generally 1 meter in width. These strips may be hundreds of meters long depending on the size of the area; they make for easier maintenance of the plantation overtime.

Spot brushing – removes undergrowth in a 1-meter radius around the point where plants will be placed. A stake of a least 1-meter height is necessary to be able to locate the seedlings until they become larger. Spot brushing is easiest of the three approaches.

If the area is invaded by lagolo, use a blunt bolo or spade to uproot the ferns as if it was cogon grass. Cutting off the stems will not eliminate weeds, it is necessary to remove their roots. Because these areas can be so large, spot brushing is recommended to minimize effort and still provide the best environment for the seedlings.

If it is a logged-over area, any remaining logging debris (branches, for example) will need to be taken out. If the area contains brush, vines or low-lying vegetation, it will be necessary to cut it down and remove it. With enrichment planting it may be necessary to prune branches and remove dead trees to provide light and space for the new seedlings. Breaking fishpond dikes and filling in internal canals. Finally, if seedlings are being planted, it will be necessary to dig holes in order to place the seedlings. The holes need not be deeper than the size of the rootball. Begin planting at the seaward side of the plantation at low tide.

3.4 Planting Methods

There are several planting methods. The method used depends on the type of stock and species being planted, *i.e.* seed, seedling, propagule or wildling. Common methods include:

Direct planting – Propagules of *bakauan*, *pototan* and *tangal* are planted directly on the ground. Other species with large seeds like *dungon-late*, the *tabigi* group and to some extent the *bungalon* group, can also be directly seeded.

Potted seedlings – Used for trees with tiny seeds that are difficult to sow directly in the field, the *pagatpat* group, for example. Seedlings from the *bakauan* group also can be raised in the nursery and planted in this manner for specific sites such as open areas with unstable substrates where there is concern about the early survival of the seedlings. Potted seedlings involve considerably more cost and should only be done when it is the only option.

Wildlings – Where there are not enough seeds or propagules, wildlings may be potted and hardened in the nursery for a month. In uprooting/collecting wildlings, extra care must be taken not to damage the root system. For some

species, wildlings can be directly planted provided the soil around the roots us intact. Planting wildlings requires extra care to protect against damage on the roots, one of the natural adaptive structures of mangrove to tolerate a saline environment.

3.5 Care and Maintenance of Area Planted

The first 2 years after their establishment are probably the most intense phase of care for plantations. However, care diminishes on the 3rd through the 4th years.

Early years of m*aintenance* - Maintaining a young plantation involves: regular visits (daily or every other day), removal of debris, installation or fence repair, removal of barnacles and other pests, uprooting and replacement of sick or dead plants. Visit the plantation at least every other day, although daily visits are preferable. Develop a routine so that the entire plantation is inspected. It is best conducted at low tide since it will be easier to walk around the plantation. Because it is impossible to look at each and every seedling, the inspectors should make it a point to look closely at a few plants in each block. Inspectors should check for: encrusting organisms like barnacles, insects and moth larvae eating leaves, dead or dying plants and plants entangled in green algae or other debris.

Barnacle Removal – The shells must be removed by hand (preferably using gloves) before the propagules are totally covered. Do not scrape the propagules with a bolo since that will result in plant damage and eventual death. Once the organism is carefully scraped off, simply throw it in the water.

Application of Engineering and Bioengineering Measures for Coastal Areas -

Two of the three main reasons for restoring coastal forests (mangrove and beach areas): are restoration of a and protection of coastlands against further degradation and filling of wetlands; erosion of coastal dune systems, siltation of estuaries and inshore waters; and factors that interfere with ecological and geo-morphological attributes of the coastal systems both for mangrove and beach forests. Thus, these require rehabilitation measures more than vegetative means.

Shorelines and other hydraulic structures are continually subjected to wave and current action as well as fluctuating water levels. Conventional armor revetments such as concrete slabs, blocks or ripraps are used to protect

hydraulic structures against soil erosion. However, severe erosion can still take place especially when fine- grained subsoil is not protected by additional filters. The use of new inert materials called geosynthetic filters have been used beneath hydraulic structures to replace traditional sand and gravel bedding filters. It allows a direct transition between revetment and subsoil and thus, eliminating thickness of granular filter and hence cost. Similar to other engineering structures, design of geosynthetic filters is important to ensure long term effective performance of geosynthetics and stability of hydraulic structures. Aspects of geosynthetic filter design involved assessing subsoil and water conditions and also construction stresses. Studies have confirmed the constriction theory developed by Giroud (1996) for filtration, in that the filtration behavior is dependent on the porosity, fibre diameter, and optimum thickness of the geotextiles. These studies also showed the importance of installation damage and that high resistance against such damage in the geotextile is necessary. With optimum filtration characteristics and correctly designed mechanical properties, geotextiles particularly nonwovens have proven effective to control and prevent both internal and external soil erosions.

There are other menus of bioengineering and engineering measures that are found appropriate for estuarine, beach, mangrove and other coastlines coastal needing rehabilitation shown in Appendix B.

REFERENCES

Agaloos, B.D. (1994) Reforestation of mangrove forest in the Philippines. *In* Proc. of ITTO : Development and dissemination of reforestation technique of mangrove forest, Japan.

Arboleda, Justiniano. (1999). Cocogreen. Products of Coco technologies Corporation Brochure. 1999.

Chapman, V.J. (1962). Respiration studies of mangrove seedlings. Bulletin of Marine Science Gulf Caribbean 12:137-167, 245-263.

Chiappone, M. and R. Sluka. (1996). Fishes and fisheries: Site characterization for the Florida Keys National Marine Sanctuary and Environs, Volume 6. The Preserver, Zenda, Wisconsin.

Chiappone, M. and K.M. Sullivan. (1996). Functional ecology and ecosystem trophodynamics: Site characterization for the Florida Keys National Marine Sanctuary and Environs, Volume 8, The Preserver, Zenda, Wisconsin.

Cintron, G., A.E. Lugo, D.J. Pool and G. Morris. (1978). Mangroves and Environments in Puerto Rico and adjacent islands. Biotropica 10: 110-121.

Dagar, J.C., A.D. Mongia, and A.K. Bandyopadhyay. (1991). Mangroves of Andaman and Nicobar Islands.

Department of Environmental Protection. (no date). Walking trees: Mangroves. http://www.dep.State.Fl.us/cama/habitats/mangrove.htm

Field, C. (1996). Restoration of mangrove ecosystems. ITTO-ISME.

Florida Fish and Wildlife Conservation Commission-Florida Marine Research Institute. (no date). Ecosystem assessment and restoration-habitat assessment and restoration. http://www.fmri.usf.edu/programs/earthar.htm

Hooi, Loke Kean. (1999). Bio-engineering Measures for Soil Conservation in Bangladesh Hill Ecosystem. In Proceedings of the 1st Asia Pacific Conference on Ground and Water Bioengineering for erosion control and slope stabilization. Manila Philippines. 19-21 April 1999. pp 327-337.

http://www.hort.purdue.edu/newcrop/dukeenergy/sonneratiacaseolaris.html

Kitamura, S., C. Anwar, A. Chaniago, and S. Baba. (1997). Handbook of mangroves in Indonesia: Bali and Lombok. Okinawa: International

Society for Mangrove Ecosystem.

Kuenzler, E.J. (1974). Mangrove swamp systems*. In* H.T. Odum, B.J. Copeland and E.A.

MacMahon (eds.), Coastal ecological systems. Washington D.C.: Conservation Foundation.

Lewis, R.R. (1980). Impact of oil spills on mangrove forests. International Symposium on the Biology and Management of Mangroves in Tropical Shallow Water Communities, 2nd . Papua New Guinea.

Lugo, A.E. and C. Patterson-Zucca. (1977). The impact of low temperature stress On mangrove structure and growth. Journal of Tropical Ecology 18: 149-161.

Melana, D.M., J. Atchue III, C.E. Yao, R. Edwards, E.E. Melana, and H.I. Gonzales**. (2000).** Mangrove management handbook. Manila: DENR.

Melana, E.E., and H.I. Gonzales. (no date). Field guide to the identification of some mangrove plant species in the Philippines. DENR-Region VIII.

Odum, W.E. and R.E. Johannes. (1975). The responses of mangroves to man-induced environmental stress. In E.J.F. Wood and R.E. Johannes (eds), Tropical marine pollution. Armsterdam, Netherlands: Elsevier, pp. 52-62.

Odum, W.E., C.C. McIvor, and T.J. Smith. (1982). The ecology of the mangroves of South Florida: a community profile. United States Fish and Wildlife Service. FWS/OBS 81-24, p. 105.

Odum, W.E., and C.C. McIvor. (1990). Mangroves. *In* R.L. Myers and J.J. Ewel (eds), Ecosystems of Florida. Orlando, Florida: University of Central Florida Press.

Olexa, M.T. and T.E. Freeman. (1975). Occurrence of three unrecorded diseases on mangroves in Florida*. In* G.Walsh, S. Snedaker and H.Teas (eds), Proceedings of the International Symposium on the Biology and Management of Mangroves. Gainesville: University of Florida, pp. 688-692.

Palis, H.G., C.A. Lat, and B.S. Alcantara. (1997). Guidebook on the phenology and identification of Philippine mangrove species. College, Laguna: ERDB.

Primavera, J.H. and J.M.A. Esteban, 2008. A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. Wetlands Ecology and Management. 16:345-358. Springer.

RISE. Vol. 2, No. 5, 1990. Nipa (*Nypa fruticans* Wurmb). College, Laguna: ERDB.

RISE. Vol. 1, No. 8, 1989. Bakauan lalake (*Rhizophora apiculata* Lam); Bakauan babae (*Rhizophora mucronata* Blume); Bakauan bato (Rhizophora stylosa Griff). College, Laguna: ERDB.

RISE. Vol. 3, No. 10, 1991. Kapok: silk cotton tree (*Ceiba pentandra* (L) Gaertn.); Talisai (*Terminalia catappa* L.), Dita (*Alstonia scholaris* (L) R.Br.). College, Laguna: ERDB

RISE. Vol. 3, No. 5, 1991. Api-api (*Avicennia officinalis* L.); Bungalon-puti (*Avicennia marina* (Forsk.) Vierh. var. alba (Blume) Bakh.); Bungalon *(Avicennia marina* (Forsk.) Vierh.); Pagatpat (*Sonneratia alba J.*Sm.). College, Laguna: ERDB.

Shulman, M.J. (1985). Recruitment of coral reefs fishes: effects of distribution of predators and shelter. Ecology 66:1056-1066.

Sinohin, V.O. *et al* (1996) Manual on mangrove nursery establishment and development. ERDB-DENR. 18p. J'. 96.

Snedaker, S.C. and A.E. Lupo. (1973). The role of mangrove ecosystems in the maintenance of environmental quality and a high productivity of desirable fisheries. Final Report Contract 14-16-008-606 United States Bureau of Sport Fisheries and Wildlife, Washington D.C.

Snedaker, S.C. (1989). Overview of ecology of mangroves and information needs for Florida Bay. Bulletin of Marine Science 44:341-347.

Strong, A.M. and G.T. Bancroft. (1994). Patterns of deforestation and fragmentation of mangrove and deciduous seasonal forest in the Upper Florida Keys. Bulletin of Marine Science 54:795-804.

Teas, H. (1977). Ecology and restoration of mangrove shorelines. Environmental Conservation 4:51-57.

Technical Working Group, Philippine Coconut Authority. (2004). Benchmark Information on the Philippine Coir Products for the Development of Standards (in Support of Memorandum Circular No. 25, 2003). A collation brochure, PCA. Jan. 2004.

Watson, J.G. (1928) Mangrove forest of Malay Peninsula. Malayan Forest Record no. 6, Fraser and Naeve, Ltd, Singapore, 276 p.

.

APPENDICES

Appendix A. Recommended Mangrove Species for Rehabilitation

Plate 1. *Rhizophora apiculata* Blume
Common Name: Bakauan lalake
Family: RHIZOPHORACEAE

Rhizophora apiculata is a medium to tall straight tree reaching a height of 30m and a diameter of 50cm with many rambling prop roots. The outside bark is dark, black and smooth and orange red to red beneath when young. At older age, the bark turns grey and more or less striated with vertical grooves. Leaf is elliptic-oblong to sublanceolate, 7-18 cm in length and 3-8 cm in width and smaller than *R. mucronata*, acute to apiculate apex. The midrib on the lower part of the leaf is pink to reddish.

The flowers are sessile, attached in pairs and 3-7 in numbers. Petals are white to cream or yellow in color and measures 8-11 mm in length and 1.5-2mm in width. Mature buds are elliptic, 14mm in length and robust-looking. The matured fruit is 20-40cm long, relatively smooth, dark green buoyant hypocotyl. The viviparous fruit (propagule) and its tip is more blunt compared to other *Rhizophora* species.

The species is typically occupying the middle to upper part of mangrove swamps on mud and sand. It also grows along exposed coral reefs and along or close to water channel. It favors habitat with relatively deeper peat and water levels, higher pH, organic matter content, sand content and lower salinity.

The woods are used as firewood, charcoal, marine timber, railroad ties, fence posts and flooring. The bark is used for tanning and dyeing purposes.

Pest & Diseases: Seed - aphids, caterpillar, termites

Plate 2. *Rhizophora mucronata* Lam.
Common Name: Bakauan babae
Family: RHIZOPHORACEAE

Rhizophora mucronata is a medium-size tree with branched prop roots reaching a height of 25 m and a diameter of 60 cm or more. The bark is gray to black, large scale outside and yellow-orange inside. It is coarsely ridged about 2 cm thick and with many vertical grooves.

Bakauan-babae grows best on water-logged, deep, soft and muddy soil, thrives in soft and deep muddy soil and in relatively low salinity and shallow water areas.

The fruit is large, 5-7 cm in length x 2.5-3.5 cm in width, globular and oblique. It is fine brown in color which later developed into worty, yellow-green pointed hypocotyls. The hypocotyls is cylindrical, strong rugose, 36-64 cm length x 1.75 cm width and one seeded. The fibre-packed propagule is rough with worty surface and yellow-green in color. Despite of its size and weight, it has buoyancy and attendant dispersal property.

Seed Calendar

During the months of May to June, mature seeds of bakauan-babae can be collected. But generally it flowers and bears fertile seeds every year. The time of bearing seeds varies from place to place.

Method of Collection

Collect seeds fruit from fruit bearing bakauan in natural mangrove stand. Germinated seeds attached to the mother tree are best for planting. If these are not sufficient, collect from germinated fallen seeds.

It is best to collect mature seeds while these are still attached to

the mother tree (healthy and superior mother trees) possessing the following characteristics: superior height bid diameter, clear bole height, straight stem, balanced crown, big branches and healthy. This ensures minimal incidence of insect infestation and burn injury to seedlings planted

Type of seeds

The seedling is long (growing to a length of about 75-100 cms), spindle-shaped, and green. It grows downward and out of the fruit before the latter falls from the tree. The seedlings drop into the mud where it takes root.

Method of Extraction

Wildings growing vigorously with at least one pair of leaves are collected by pulling them gently to extract the propagule intact with root system

Seeds Pest and Diseases: Seed borer

Causal Pathogen: *Poecilips fallax* Eggers

Control Measures:

The occurrence of the beetles can be minimized by airdrying the hypocotyls for seven days before planting to harden the seed and to reduce moisture content

Nursery Pest and Diseases: Fidder crabs or Barnacles

Method of Extraction:

Allow the freshly gathered seedlings to wilt first under the shade in the nursery or by raising seedlings in pots for 1-3 months. This method can make the seedling hypocotyls less attractive to barnacles. Barnacles can also be scraped off from the stem of the bakauan trees. However, care should be observed in the process

Plantation Pest and Diseases: Marine Wood Borers

Causal Pathogen: virus, bacteria, fungi, nematode

Control Measures:

Control measures include eradication and prevention. Affected trees as well as debris and stumps should be removed.

Planting

Wildings growing vigorously with at least one pair of leaves are collected by pulling them gently to extract the propagule intact with root system.

The seedling is long (growing to a length of about 75-100 cms), spindle-shaped, and green. It grows downward and out of the fruit before the latter falls from the tree. The seedlings drop into the mud where it takes root.

Planting Procedures:

Establish planting spots with the necessary spacing using planting bars or stakes. Spacing for planting bakauans varies depending on the end uses recommended for plantation. A spacing of 1 x 1 sq. meter is appropriate for poles and piles

Care and Maintenance:

Remove the weeds that interfere with growth of the seedlings to lessen the competition in soil nutrients, space and sunlight.

Pest and Diseases: The disease-causing organisms of *Rhizophora* species are marine wood-boring organisms, snails, barnacles and seed borer.

Plate 3. *Rhizophora stylosa* Griff.
Common Name: Bakauan bato
Family: RHIZOPHORACEAE

Rhizophora stylosa is a small tree; height: up to 10m tall; diameter: up to 20cm; stilt roots distinct; bole erect, cylindrical. Branching not primarily sympodial. Flowers differ in other Rhizophora by having longer styles, up to 0.5cm long, petals 8mm long. Leaves bright yellow green, upper surface smooth and shiny, spots on undersurface, 6.3 - 13.7 cm long and 3.8 – 8 cm wide.

Propagule 25 - 60 cm long, cylindrical, green, smooth with irregular brown lenticels, root tip pointed. It thrives well on sandy to corraline areas.

Seed Technology

Fruit is relatively large, bulbous and very oblique, averaging 27 mm wide and light green in color. The hypocotyl is large averaging 42 cm long, sharply pointed

Calendar

Several fruits are observed throughout the year for Climate types III and IV; August to September for Climate type 1 and February to March for Climate Type II

Seed type: Propagule

Method of Extraction

Indicator of mature propagule is the swollen basal portion of the pericarp and the whitish ring-like mark near the pericarp. It is best to collect mature seeds while these are still attached to the mother tree. Seeds should be collected form the nearest or from places with similar climatic and edaphic conditions as the planting sites

Seed Pest and Diseases

Marine Wood Borer (a), Fiddler Crabs and Barnacles (b), Seed Borer (c) and *Diopatra cuprea*

Control Measures

For *Diopatra cuprea:* catching is an effective control which is done by using chopped rotten coconut meat or rice bran as attractants or baits. The pest would slowly come out of its hole and it can be easily snatched and pulled out

Nursery Control measure

For Seed borer: the occurrence can be minimized by air drying the hypocotyls for seven days before planting to harden the seed and to reduce moisture content.

Plantation-Causal pathogen: virus, bacteria, fungi, nematode

Plantation- Control Measure

For marine wood borers, control measures include eradication and prevention. Affected trees and debris and stumps should be removed

For Fiddler crabs and barnacles: the problem can be checked by allowing the freshly gathered seedlings to wilt first under the shade in the nursery or by raising seedlings in pots for 1 to 3 months. Barnacles can also be scraped off from the stem of the trees.

Site preparation:

Clear site by removing debris; divide the whole plantation area into compartments with sizes manageable by a planter.

Staking

A space of 3 – 5 meters between compartments should be allotted for human passage and 10 meters for boats; and establish a temporary fence or put stakes around the perimeter of the planting site to serve as boundary and ensure protection.

Planting

Establish planting spots with the use of planting bars/stakes

Spacing

A spacing of 1x1 sq. m. is best for poles and piles while 2x2 sq. m. is for fuelwood and charcoal. Outplanting in open mudflats of the seaward fringes is done during low-tide months. Dig holes deep enough to hold the seedlings firmly using long, heavy, pointed pole

Planting Procedure and Maintenance

Wildlings growing vigorously with at least 1 pair of leaves are collected by pulling them gently to extract the propagules intact with root system.

Protect the newly planted seedlings by establishing a temporary fence around the plantation. Set up warning signs to protect against vandals. Replace dead seedlings. Thin to control competition. Visit the area regularly.

Plate 4. *Ceriops tagal (Perr.) C.B. Rob.*
Common Name: Tangal
Family: RHIZOPHORACEAE

Ceriops tagal is a small slender tree and similar in stature with *C. decandra*. It reaches a height of 15 m and a diameter of about 40 cm. The bark is light yellow, light gray or light brown with re-brown lenticels. Some trees have tint of waxy pink that overlap the bark giving an attractive complexion. It is fairly smooth, flaky and produces peeling

The fruit is ovoid, 1.5-2.5 cm long, has a reddish purple tint towards the tip. The calyx is fruit reflexed. It contains one seed. The hypocotyls of *C. tagal* is club-shaped and sharply angular, slender, somewhat worty and typically longer than that of *C. decandra* reaching 15-25 cm. It lacks obvious ribs when mature and unlike *C. decandra* whose hypocotyls hang down.

Seed calendar

Average number of fruits is observed from last week of April to second week of May for all Climate types except Climate type IV.

Plate 5. *Avicennia officinalis* L.
Common Name: Api-api
Family: AVICENNIACEAE


Avicennia officinalis is typically seen as a small to medium-size tree (10-16 m high), moderately stout and usually with crooked trunk. The aerial roots are numerous, small, 8-20 cm high and conical. Slender stilt may sometimes develop. The bark is smooth to grid-cracked in texture and peeling. The vertical fissures have conspicuous rows of medium-sized lenticels. It is gray-brown in color but will vary into different shades.

The seed is heart-shaped; slightly flattened, usually beaked when young; capsule 1 to 2 cm long; contains one single seed which completely fills the lower part of the capsule. Fruits are observed from November to December for Climate type I, May to September for Climate type II, March for Climate type III and July to September for Climate type IV.

Method of extraction

Seeds can be best collected during the months of June to mid-August. The seeds should be collected from large, healthy and mature mother trees processing superior characteristics such as straight bole, superior height, big diameter, clear bole height, straight stem, balanced crown, big branches and good tree health.

Seed treatment

Seeds germinate even without chemical treatments to hasten germination. Oftentimes, the seeds germinate before they fall.

Method of Sowing

Sow the seeds in seedbeds or directly pot them in mangrove soil 1 to 2 cm deep. However, in areas where wave and tidal actions occur, this depth is

not advisable since the seeds might be dislodged. As for the potted seeds, place them under a partially shaded area.

Site preparation / Clearing

Avicennia grows best along sandy substratum, deep mud and along inland unto tidal forest. In the establishment of a plantation site, the site must be clear of undesirable vegetation (e.g., weeds, debris, shrubs and other dead trees).

Planting Spacing

The spacing for planting varies depending on the purpose of the plantation. If the species for fuelwood, a 4m x 4m spacing is recommended. Otherwise, a 2m x 2m spacing is normally practiced.

Planting Procedure

Potted or wildlings are buried into the mud or holes previously prepared at a depth of 6 cm after the plastic has been removed. The holes are thoroughly filled with soil to protect the seedling from toppling down.

Timing

Best results are achieved by planting seedlings in close clumps. Clumping offers the plants at the middle added protection.

Care and Maintenance

The newly planted plantation should be regularly visited to monitor the growth of the seedlings. The cleanliness of the plantation should be maintained by removing weeds that might hamper the growth of the new stands.

Plate 6. *Avicennia marina* (Forsk.) Vierh.
Common Name: Bungalon
Family: AVICENNIACEAE

Avicennia marina is a tree with leaf that is simple, opposite, golden brown beneath, oblong to oblongelliptic with acute or rarely sub-obtuse apex. The leaf is 5 to 7 cm long and 2.5 to 5 cm broad.The midrib is prominent. Flowers are without individual stalks and grow either in small heads or spikes. Inflorescence is elongated and spicate or sub-spicate. The style is usually very short or sub-obsolete and the stigma is sub-sessile. Corolla limb is mostly glabrous on the upper (inner) surface

Fruit description

Heart-shaped; slightly flattened, usually beaked when young; capsule 1 to 2 cm long; contains one single seed which completely fills the lower part of the capsule. The fruit is 2 cm in width, slightly heart-shaped to rounded, slightly flattened and usually posses a beak-like structure at young stage, but becomes obscure at maturity

Calendar

Fruits are observed from November to December for Climate type I, May to September for Climate type II, March for Climate type III and July to September for Climate type IV.

Seeds- Methods of Extraction

Seeds can be best collected during the months of June to mid-August. The seeds should be collected from large, healthy and mature mother trees processing superior characteristics such as straight bole, superior height, big diameter, clear bole height, straight stem, balanced crown, big branches and good tree health.

Methods of Sowing

Sow the seeds in seedbeds or directly pot them in mangrove soil 1 to 2 cm deep. However, in areas where wave and tidal actions occur, this depth is not advisable since the seeds might be dislodged

Site preparation / Clearing

Avicennia grows best along sandy substratum, deep mud and along inland unto tidal forest.

Planting Procedure

Best results are achieved by planting seedlings in close clumps. Clumping offers the plants at the middle added protection.

Care and Maintenance

Additional protection may be provided by establishing temporary fence/stakes or by piling rocks around the seedlings to prevent algae, flotsam and jetsam from entangling with the seedlings by receding tides.

Plate 7. *Avicennia lanata* Ridley
Common Name: Piapi
Family: AVICENNIACEAE

The leaves are nearly always opposite or whorled, mostly simple; stipules are lacking. The flowers are nearly always bisexual and zygomorphic. The calyx is synsepalous and most commonly 5-merous. The corolla is sympetalous, usually unequally 5-lobed, and sometimes strongly 2-lipped.

Soil texture

Middle - silty to silty clay

Riverine – Upstream

Sandy to silty clay

Fruit description

Heart-shaped; slightly flattened, usually beaked when young; capsule 1 to 2 cm long; contains one single seed which completely fills the lower part of the capsule. (RISE)

Fruit Calendar

Fruits are observed from November to December for Climate type I, May to September for Climate type II, March for Climate type III and July to September for Climate type IV

Seeds- type

The seeds of Avicennia are said to be matured when their seedcoats split.

Methods of Extraction

Seeds can be best collected during the months of June to mid-August. The seeds should be collected from large, healthy and mature mother trees processing superior characteristics such as straight bole, superior height, big diameter, clear bole height, straight stem, balanced crown, big branches and good tree health

Seed Treatment

Seeds germinate even without chemical treatments to hasten germination. Oftentimes, the seeds germinate before they fall

Methods of Sowing

Sow the seeds in seedbeds or directly pot them in mangrove soil 1 to 2 cm deep. However, in areas where wave and tidal actions occur, this depth is not advisable since the seeds might be dislodged. As for the potted seeds, place them under a partially shaded area.

Site Preparation

Clearing. *Avicennia* grows best along sandy substratum, deep mud and along inland unto tidal forest.

Planting

After clearing the area, holes of similar size with that of the pot are dug for added compaction

Plate 8. *Ceriops decandra* (Griff.) Ding Hou
Common Name: Malatangal
Family: RHIZOPHORACEAE

Ceriops decandra is considered a small tree, 4-6 m tall but may reach up to 15 m and diameter of 20cm. However, it may flower even at 1m tall. Crown is relatively narrow. The bark is dark gray with white spots and rough. It has prominent corky postutes are different from that of the smoother trunk.

The fruit is ovoid-conical, 1.0-1.7 cm long, being curved above a 5 lobbed calyx and producing a slender clearly ribbed, hypocotyls, 15 cm in length. It is green in color and has red cotyledons, 2-4 mm long protruding from the fruit. Malatangal fruit is present throughout the year however; abundant is observed from February to May for Climate type II, July to August for Climate type III and April to May for Climate type IV.

Plate 9. *Nypa fruticans* Wurmb
Common Name: Nipa
Family: ARECACEAE


A low and shrubby palm found in mangrove area. The trunk occurs underwater; the rootstock about 3.81 cm or bigger in diameter. Petioles very stout, some 1.22 to 1.52mm long from end to rootstock. Leaves are 3 to 9m long, erect and recurved with leaflets from 0.91 to 1.91m long, rigid, shiny bright green and powdery white underneath.

The fruits are actually a closely packed clump of carpels, each about 7.62 to 16cm long. Fruits are spherical, 30.48 cm in diameter. Seeds are hard, white and edible with the size and shape of a small hen's egg.

Seed Technology

Nipa fruits should be collected when the bunch of closely packed clump carpels are already dark brown, still intact and attached to the stalk. Fruits left unharvested start to germinate even when they are still attached to the bunch. Seeds may be stored in a shaded place or in a place where fresh flowing water is present. Mature seeds can be directly planted in the field or can be grown in nurseries until 18-20cm high. In sowing, half of the seed must be buried with the basal portion either in the ground or in individual plastic bags or seed boxes filled with top soil. Mature nuts germinate in 13 days. However, germination could be limited in waterlogged soils.

Plantation Technology

The site should be cleared of debris and unwanted vegetation. Floating debris brought in by tide should also be removed to prevent damage to the seedlings. Holes large enough to accommodate the root system of the wildlings could be dug with the use of long heavy poles. Wildlings about three months old are approximately 20cm long and bears 2-3 leaves. At this stage, they could be

easily collected from natural stands with minimum damage to the root system.

Wildlings and seedlings are planted in to the holes. Marshy area is better worked during low tides. Planting distance: 1) sap production: 1.7 – 2m apart; 2) frond production: 1x1m.

The area must be thinned to maintain a spacing of 1.5 – 1.7m apart.

Plate 10. *Scyphiphora hydrophyllacea* Gaertn. f.
Common Name: Nilad
Family: RUBIACEAE

Scyphiphora hydrophyllacea is a bushy, erect shrub or a small tree reaching a height of 2-5 m with a diameter of 20 cm. The bark is grey to dark brown and slightly flaking. The leaf is simple, obovate-oblong and measures 4-9 cm in length x 2-5 cm in width. Is acute at the base, apex is rounded to bluntly pointed or slightly emarginated and margin entire.

Seed Technology

The fruit is cylindrical, with 8-10 grooves/ribs and usually less a centimeter in length. It is fleshy or green when young, but turns brown when ripe and drying out. A ring-like rim around the top of the fruit is also noticeable. Average number of fruits is observed from August to October for Climate type 1, June for Climate type 11 while few from June to February for Climate type IV. Peak of flowering is from January to May. Seeds are available on January, June and August.

Wildlings with 8 leaves or more are ideal for balling. Treat them with commercially available root promoting hormone like hormex. Pot the earthballed wildlings and continue weekly drenching and nursery acclimatization for three more weeks or until the plant has established its root system. After four weeks, raised wildlings are ready for outplanting.

1996. Procedures include the following: collection of apical shoots and lateral branches cuttings from young saplings early in the morning or late in the afternoon, treating the base of cuttings withs 0.24% NAA for one minute and sowing it in 1:1 sterilized coconut coir dust and sand media under sealed misted white polyethylene bag covered enclosures and hardening the rooted cuttings after 8 to 12 weeks before outplanting.

Plate 11. *Calophyllum inophyllum* L.
Common Name: Bitaog
Family: GUTTIFERAE

Bitaog is a large tree reaching a height up to 20 m and a diameter of 200 cm or more. Bole is short and dense, crown widespreading. Bark is brown, 12 to 20 mm thick, and produces a sticky yellowish sap. Leaves are simple, opposite and glabrous. Flowers pure white with yellow stamens, fragrant. Fruit spherical, smooth, green or yellow, pulpy inside covering a thin shell that protects a hard, oil kernel. Flowering to seed formation March –June.

Seed Technology

Store the seeds with 20% MC and above. Place the seeds in plastic bags and seal them tightly and store the seeds in the refrigerator or in a cool room for 6 months.

Pre-treatment includes Use newly collected seeds, cut or remove the outer seed coat totally; and soak the seeds in 0.2% fungicidal solution overnight .

1. Pre-treatment- break seed coat with hard object and soak the seeds in tap water overnight
2. sowing- sow seeds in plastic trays with fine sand or sow directly in seedbed
3. Storage- store seeds in refrigerator to maintain 20% MC

Planting stock production:

1. Propagules- seeds

2. Potting- transplant seedlings to 4 x 6 inches plastic bags with ordinary garden soil + humus
3. Planting medium:
   - Place the seeds in plastic bags lined with moistened jute sack
   - Incubate the seeds for 1 week
   - Sow the seed in seed boxes or in "4 x 6" plastic bags
4. Shading- keep seedlings in recovery shed for 2 weeks before transferring to hardening beds
5. Watering- water early morning and late afternoon;
6. Weeding- twice a month
7. Hardening- keep seedlings in hardening beds for 4 months with full sunlight and less watering
8. Protection- sterilize media by heating in fire for 4 to 6 hours

Plate 12. *Acacia farnesiana* (L.) Willd.
Common Name: Aroma
Family: FABACEAE

A small tree reaching a height of about 5m. The branches are crooked with sharp stipular spines 1-4 cm long. The leaves are bipinnate,5-8 cm long. The pinnae are usually 10-12. The leaflets are 15 to 40, oblong, 4-7 mm long. The inflorescence are auxiliary, solitary or fascicled, rounded about 1 cm in diameter.

Flowers appear from April to May in leafless condition. Pongamia can be easily grown from seeds and cuttings. It spreads from root suckers as well as seedlings.

Nursery Practices:

1. Sow the seeds in drills 3cm deep 15 cm wide with a distance of 4 cm
2. Transfer the seedling to transplant beds or polyethylene bags to appropriate sizes to produce lateral roots before they reach a height of 15cm. Plants in transplant beds should have a distance of not less than 25 cm.
3. Transfer the seedlings to the field when they reach a height of about 50 cm.

Plate 13. *Terminalia catappa* L.
Common Name: Talisai
Family: COMBRETACEAE

Talisai is a medium-sized tree growing up to 25 m and a diameter of about 80 cm. Its bark is rather scaly, dark brown; inner bark is fleshy to stringy near the cambium, reddish with whitish dots. The leaves are 10 to 25 cm long simple, spirally arranged, smooth, shining, 6 to 18 cm long, lower surface bearing a gland near the base of midrib. Its petiole is short. The greenish-white flower is small, 6 to 8 cm long, with foul smell. Fruits 3-6 cm long, somewhat flattened, ellipsoid in outline. Talisai seeds are pulpy nuts. It usually takes weeks before they fully germinate.

Talisai is a perennial species usually propagated by seeds. It usually flowers and bears fruit in December and January and is available in places such as Sta. Maria, Isabela and Baygabay, Albay.

Methods of Collection

When the fruit turn greenish yellow, they are collected from the tree by using a light pole with a hook attached to its end. As seeds become yellowish, they fall to the ground and may be picked up directly.

Seed type

Talisai seeds should remain fresh (with moisture well maintained) after collection. This can be done by placing/packing the seeds in perforated plastic sacks/bags immediately after collection. Seeds must be sown immediately after transporting.

Pest and Diseases

The larvae of Bugworm is the most destructive stage that infect Talisai. Growers found no serious diseases attacking the trees.

Plate 14. *Pemphis acidula* J.R. & Forst.
Common Name: Bantigi
Family: LYTHRACEAE


Pemphis acidula is a small tree measuring 7-10 m high or usually a diffused low growing shrub, 1-2 m high. It features an Attim's model having shoots that are not articulate, although there may be some periodicity of extension correlated with the frequent by diffuse or irregular branching.

The bark is light gray to brown, becoming deeply fissured with age and shredding into long curling strips.

Fruit description

The fruit is enclosed in enlarged calyx appearing as a spherical capsule (4-5 mm in diameter) with persistent style and dehiscence circimcissile. It is red in color that turns brown later. It contains many (20-30) seeds that are flattened and angular with a corky margin winged and narrowed below

Plate 15. *Pongamia pinnata* (L.) Pierre
Common Name: Bani
Family: FABACEAE

Bani is a tree reaching a height of 6 to 25 m and 45 cm in diameter. Its bark has a dull gray to pinkish-brownish color, smooth but becoming shallowly fissured; the inner bark has a strong smell of crushed bean-pod. The leaves are compound; 20 to 25 cm long, with 5 to 7 leaflets which are smooth, ovate, 6 to 15 cm long, one terminal is longer than the others and pointed at the base. The flowers are numerous, purplish-pink or nearly white, about 1.5 cm long and borne on axillary, hairy racemes 15 to 20 cm long

Calendar

This species usually flowers from April to May. Matured seeds are available from July to September.

Method of Extraction

The fruits and pods are collected from the tree by climbing or by using a light pole with a hook attached to its end.

Seed Type

When the pod is mature and dry, they eventually fall to the ground. Bani fruits are easily defected when matured because of the change in their color

Method of Extraction

To extract fruits or pods, they are dried under the sun to let the pods open. Another method is by using a hard object or knife to open the pods and for the seeds to come out.
Nursery Practices:

1. Sow the seeds in drill 3 cm deep 15 cm wide with a distance of 4 cm

2. Transfer the seedlings to transplant beds or polyethylene bags to appropriate sizes to produce lateral roots before they reach a height of 15 cm. Plants in transplant beds should have a distance of not less than 25 cm
3. Transfer the seedlings to the field when they reach a height of about 50 cm

Site preparation

Clean and remove undesirable vegetation such as weeds, bushes and other plants in the area which will compete with the growth of bani. Prepare the planting holes.

Planting/Spacing

Outplanting bani seedlings should be carried out when they reach the height of about 50 cm at 5x5 m spacing.

Planting Procedure

Seedlings must be planted at the onset of the rainy season. Roots and leaves require trimming before planting.

Sensitivity to Pest/Disease

Disease: Large Bloth Mines

1. Insect- *Acrocecrops anthracuris* Meyrick
2. Symptoms- large bloth mines appear on the surface of the leaflets. The color is red to brown
3. Damage- the larvae of this small moth are leaf miners. The eggs are laid on the surface of the leaves of bani and the larvae burrow in the tissues forming bloth mines.

Control:

Damages are not extensive, such that treatment to control the pest is not that necessary. However, constant inspection of the plantation, especially during rainy seasons, may help remove the eggs on the surface of the leaves.

Plate 16. *Barringtonia asiatica* (L.) Kurz
Common Name: Botong
Family: LECYTHIDACEAE

Barringtonia asiatica is a tree reaching a height of 8-15 m. Leaves are large, often alternating with small ones attached directly to a branch or stem without an intervening bulk, 20-40 cm long, thick and shiny, apex obtuse, base is rounded truncate, petiole is absent. The bark is pinkish to greenish, not scaly ridged; inner bark is thick, white with pale yellowish streaks.

Flowers that have been cut in daytime and set in water will open at dusk. Botong seeds are available in Laguna from September to October.

In the Philippines, it thrives from low to medium altitudes. The tree adapts easily to various soil types. It can tolerate poor soil but prefers sandy soil. Botong is recommended for planting along boulevards or avenues, low islands and along creeks as well as river banks.

No elaborate land preparation is needed other than digging pot size holes. For riverbank rehabilitation, holes are dug a matter from the ridge, depth of holes must accommodate new plant roots. Planting is recommended at the start of the rainy season at a distance of 2 x 4 m. No cultivation is needed except for brushing around the plants for a year. Plants must be protected from wild trees.

Botong is not subjected to attacks by any pests and diseases, unlike other pure plantation of forest trees. No serious attack has been reported.

Plate 17. *Sonneratia alba* (L.) Smith
Common Name: Pagatpat
Family: SONNERATIACEAE

Sonneratia alba is a small to medium size tree that reaches a diameter of 175cm and 26m in height. It has sprawling to erect trunk base but not buttressed. Branches often spread horizontally to form a broad crown.

The bark is flaky, dark gray or reddish brown to pale fleshy colored, smooth or slightly fissured.

The leaf is simple, ovate and measures 6-10cm in length and 2.5-8cm in width. The blade is thick, fleshy and leathery and pale green in color. The young leaf has tiny reddish pointed tip which become brittle when dry and fall-off as it matures.

The flower is white (hence the name alba) usually 2-3 in numbers found together. The fruit is hard, rounded, depressed at the apex, 3-4 cm in diameter and 4-27 cm long. It is green in color, flat on top with coriaceous pericarp without ribs.

The species is generally found in more or less exposed gravely or sandy shores, sometimes mixed with mud and often in exposed reefs and open bays. It grows best in sandy-loam soil as well as in mudflats and coralline substrate.

Plate 18. *Sonneratia caseolaris* (L.) Engl.
Common Name: Pedada
Family: SONNERATIACEAE

Pedada is a tree smaller than its relative Pagatpat. It attains a height of over 15m and diameter of over 70 cm; branches hang down (drooping). In dense stand, bole is straight, cylindrical and tall. Leaf is simple, opposite in arrangement, reddish petiole, elliptic ovate to elliptic oblong and pointed apex, 4cm to 10cm long by 2cm to 4cm wide, leathery, thick and green on both surfaces. Young leaves are lanceolate in shape. Bark is dark gray in color and fissured. Flower is usually solitary but sometimes 2- to 3-flowered, terminal in position, numerous protruding red and white filaments. Fruit is bright green in color, hard, leathery, bowl-shaped, 3-4cm in diameter, depressed at the apex and base, enclosed at base by calyx and surrounded star-shaped red calyx lobes.

It prefers less saline area, along upper reaches of tidal stream at rocky, sandy or muddy substrate. The wood is used as fuelwood while the fruit is used in vinegar making and can be eaten.

Plate 19. *Kandelia candel (*L.) Druce
Common name: none yet
Family: Rhizophoraceae

Kandelia candel is the latest entry to the list of Philippine mangrove species. It is a small tree attaining a diameter of up to 15cm and a height of 5m. Its bark is smooth, brown in color and with lenticels. It has low buttresses. The leaves are simple and opposite, oblong to elliptic in shape with smooth, yellow green to green upper surface and smooth and green color underneath; and 10-16cm long and 3-5cm wide. The flowers are cyme and exillary, with petals white in color, thin and 4 – 5 in number. There are 2 flowers in a cluster. The propagule is smooth, cylindrical and slender and tapering with pointed tip, yellow green to green in color.

The species is considered a back mangrove as it is prefers to occupy muddy substrate along tidal creeks and rivers where they are found in association with Nipa and Pagatpat.

In the Philippines, natural population of the species is so far reported to occur only in selected sites of Aurora and Cagayan provinces in North Luzon.

Appendix B. Bioengineering Measures

Coir Fiber Rolls

Coir fiber rolls are commercially made erosion control products. They consist of tightly bound cylinders of coconut fiber (coir fiber) held together by a coir fiber netting. They are generally available in 10 to 20 foot lengths and are 10 to 12 inches in diameter. They are excellent at providing toe protection where scour is not severe. Once installed, the coir fiber log becomes saturated with water and vegetation can be planted directly in them. Coir fiber rolls provide a natural, unobtrusive appearance and decompose over a three to six-year period leaving the roots of colonizing vegetation to secure the toe of the streambank. They are relatively lightweight (10' length = 75 lbs) and can be installed with a minimum of site disturbance. The only limitations to coir fiber rolls are that in areas of severe scour they are not appropriate and there must be sufficient sunlight available for colonizing plant growth.

Procedure on Installation

Coir fiber rolls are installed by excavating a shallow (3 to 4 inches deep) trench along the toe of the stream bank. The coir fiber log is placed in the trench so that the bottom and back are in tact with the stream substrate and the streambank. Stakes are then driven down along its sides. Coir or nylon twine is woven between and around the stakes and the stakes are driven in firmly, securing the coir fiber log to the streambed. The streambank above the coir fiber log is stabilized using other bank stabilization techniques (Plate 20).

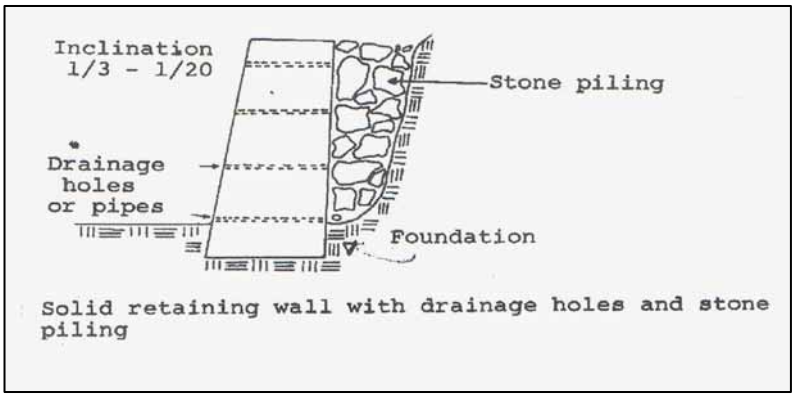
Plate 20. Section View of Coir Fiber Log Installation

BEFORE

AFTER

Plate 21. The potential of cocolog bioengineering means to assist plant propagules survive and establish during the first months.
(Note: The general problem of propagules being easily washed-out (before) can be solved by providing props or anchor material(after) using coir banded as mini-logs).

Appendix C: Retaining Walls



Solid retaining wall with drainage holes and stone piling

Applications and effectiveness

- Provides long-term stability.
- Has structural flexibility. It can be designed to self adjust to eroding foundations.
- Has a long life and seldom needs replacement, low maintenance.
- Is inert so does not depend on specific environmental or climatic conditions for success.
- May be designed for high velocity flow conditions.
- Typically only recommended for toe protection (up to base flow line).
- Shade tolerant design.