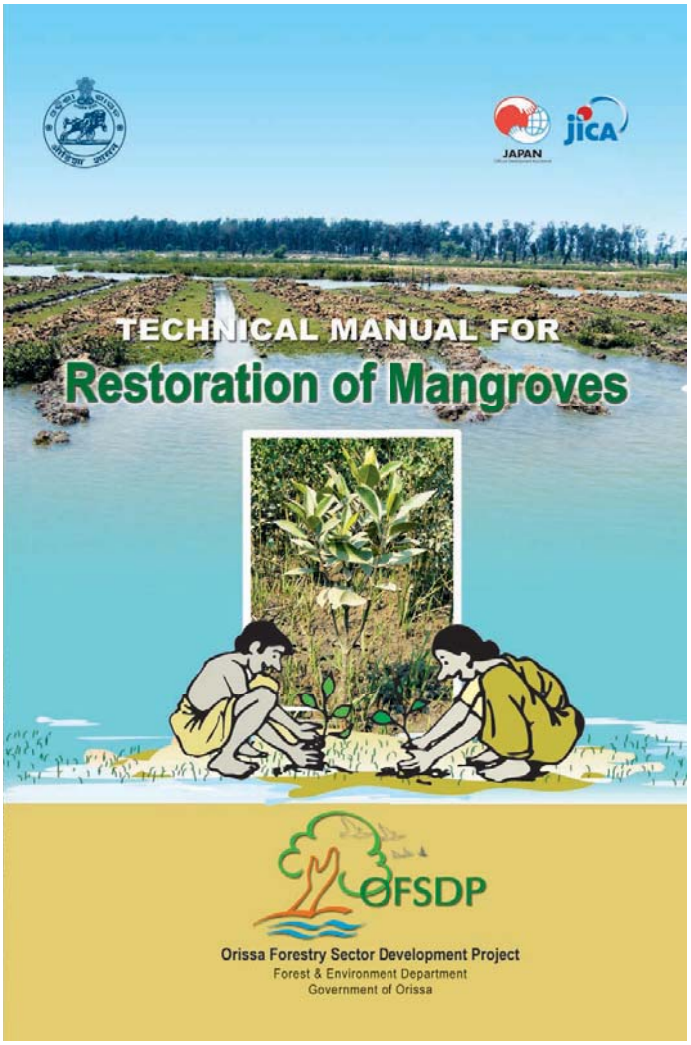

Technical Manual for

Restoration of Mangroves

OFSDP

Orissa Forestry Sector Development Project

Forest & Environment Department
Government of Orissa

www.ofsdp.org

Prepared by

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ORISSA STATE

Naveen Patnaik
Chief Minister, Orissa

MESSAGE

Impact of global warming are predicted to be more intense in coastal regions. With a long coast line of 480 kilometer, people in these areas are more vulnerable to the impacts of rise in earth's temperature. Mangroves are known to be effective bio-shield against natural disasters including cyclones and tsunamis.

I am glad to know that Orissa Forestry Sector Development Project has prepared a "Technical Manual on Restoration of Mangroves" based on the experience gained while raising plantations in degraded mangrove areas along the coast of Balasore and Bhadrak (WL) Divisions with active participation of the local community.

I hope this manual will be of great help to all the grassroot stakeholders.

(**Naveen Patnaik**)

Tarun Kanti Mishra, IAS
Chief Secretary &
Chief Development Commissioner
Orissa

FOREWORD

I am happy to note that Orissa Forestry Sector Development Society (OFSDS) is taking up coastal plantation under JICA funding. This plantation would emphasize on regeneration and plantation of mangrove forests along the coastline of the State. Such activity of OFSDS would not only address the livelihood issues of the coastal communities and rejuvenation of mangrove species, but, as an effective green shield, would also protect the State from natural disasters like cyclone, tsunami, flood and storm surge etc. I hope that the Technical Manual which is being prepared on reforestation of mangrove areas would serve the purpose by improving the mangrove forests and by paving a path to coastal prosperity.

Orissa Forestry Sector Development Society with competent and dedicated staff and its vast experience would successfully meet the challenge and in coming years be able to achieve its mission.

(**Tarun Kanti Mishra**)
23/7

Technical Manual for Restoration of Mangroves

Contents

PREFACE

Mangroves have tremendous socio-economic importance and provide protection to the hinterland from damages of cyclones/tsunami. Inspite of this, mangroves have been degraded due to human interventions such as illicit felling of trees, unregulated grazing, brackish water aquaculture. With a long term goal of restoring the degraded mangrove areas, OFSDP included afforestation of mangroves as an important component to be implemented in two coastal districts, Bhadrak and Balasore.

In Orissa, successful plantations of Mangroves have been raised, but while planning for activities in the degraded mud flats in the target areas, need of a Technical Manual covering various aspects of Afforestation of Mangroves was felt. Hence, a draft manual was prepared after studying the past efforts and field visits to the target areas by Mr. Dexter M. Cabahug Jr., Expert with Project Consultants. Draft manual was sent to field officers and refined in the light of experience gained in the course of raising mangrove plantations during 2008-09 and first half of 2009-10 under the project.

This "Technical Manual for Restoration of Mangroves" covers definition and functions of mangroves; selection of restoration areas; planting techniques - direct hypocotyle planting, fishbone channel system; nurseries, protection/ management and Monitoring & Evaluation aspects.

It is hoped that the manual will serve the long felt need fo "step-by-step guidance" for successful restoration of degraded mangrove areas.

Arun K. Bansal, IFS
PCCF & Project Director

INTRODUCTION

This "Technical Manual for Restoration of Mangroves" comprises Eight chapters namely **(1) Mangroves and their Importance**; **(2) Selection of Mangrove Areas for Restoration**; **(3) Plantation of Mangroves**; **(4) Direct Hypocotyle Planting; (5) Fishbone Channels; (6) Planting Stock Production; (7) Plantation-Maintenance and Protection; and (8) Monitoring & Evaluation**.

This manual is the result of experience gained in the course of implementing the "Coastal Plantation - Mangrove" component in Bhadrak & Balasore districts under the Orissa Forestry Sector Development Project (OFSDP) launched in 2006-07 by the Government of Orissa with the assistance from Japan International Cooperation Agency.

Objectives

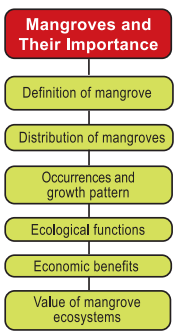
- To evolve an easy to follow technical manual for overall mangove management, insight for growth potential of mangroves as an effective green shield to counter coastal erosion from natural calamities and consequent enhancement in the biodiversity of coastal regions.
- To generate awareness on importance of mangrove conservation & consequent benefits to the surrounding communities through bio-resources available in mangrove forests.
- To provide an optimal approach for active involvement of neighbouring communities, organized in Eco Development Committees in the changed participatory regime.
- To document appropriate approaches in restoration & management of mangrove forests for upcoming efforts in the State of Orissa & the eastern coast of the country.

Scope & Application

- Better understanding & methodologies for beneficial utility of mangrove ecosystem & biometrics for scoping studies.
- Appropriate rehabilitation activities right from site selection to silvicultural tending activities.
- Creating scope for specific structural support system for intensive community involvement & eco-development perspective in the coastal belt.
- Since most of the content is based on the experience gained so far in the "Coastal Plantation" activities in the OFSDP, there is need of modification and improvement on the basis of experiences gained during further implementation process, and
- Standardization of these techniques for future interventional approaches is also required.

CHAPTER- 1

MANGROVES AND THEIR IMPORTANCE

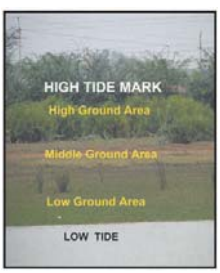


1.1 Definition of Mangrove

What is Mangrove?

Mangrove is a type of forestland growing along the tidal mudflats & along the shallow water in coastal areas extending inland along rivers, streams & their tributaries.

Operationally, target mangrove area for rehabilitation lies between the low



tide and the high tide mark which is defined in the Coastal Regulation Zone as CRZ-1 and can be classified as –

- Low Ground Area
- Middle Ground Area
- High Ground Area

1.2 Distribution of Mangroves

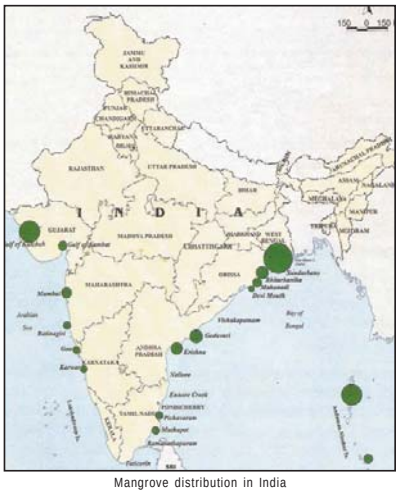
Mangroves are found in the tropics between the latitudes 30°N and 30°S in about 112 countries.

In India, Mangrove wetland are classified in three types based on their spatial and temporal variation of environmental features.

i. **Tide-dominated** - Sundarbans and Mahanadi mangroves

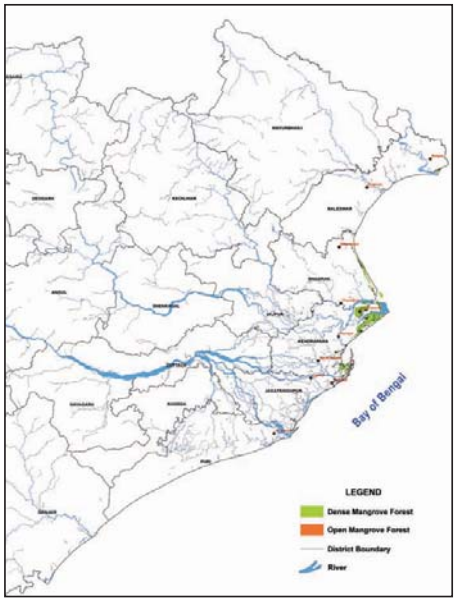
ii. **River-dominated** - in Godavari, Krishna, Pichavaram and Muthupet mangroves

iii. **Drowned - river type** - Gujarat mangroves



Mangrove distribution in India

Mangrove distribution in Orissa



1.3 Occurances and Growth Pattern

Coverage of mangroves are controlled by the environmental factors - particularly geomorphology of the coast, climatic conditions, tidal range, duration and quantity of fresh water flow.

Mangrove forests are found in inter tidal region of tropical and sub-tropical coastlines. Trees and shrubs in mangroves can grow well in saline water and water logged conditions.

Mangroves have two components - forests and associated water bodies- tidal channels and canals, collectively know as mangrove wetlands.

These wetlands have regular inundation by low saline waters, and sometimes by fresh water during monsoon, and brackish water or sea water during other periods.

The soils in the mangrove wetlands are generally anoxic - very low or no soil oxygen- due to water logged conditions. Mangrove species adapt to survive such harsh conditions through various form of aerial roots to overcome the problem of anoxic soil. Some of the main rooting pattern adapted are -

1. **Stilt root -** In Rhizophora species root diverge from the tree for about 2mt. above the ground and penetrate the soil some distance away from the main stem. Such aerial root of neighbourng trees form an impenetrable mesh of stilt roots.

2. **Pneumatophores -** In Avicennia species, shallow horizontal roots radiate outward often for a distance of many meters. At interval of 15 to 30 cm., vertical structures, called pneumatophores emerge as lateral branches that stand erect up to 30 cm. above the soil.

Rhizophora apiculata (RAI) with stilt root

Pure Avicennia marina forest with pneumatophore
(Banipahi forest,Chandabali,Bhadrak DMU)

A single Avicennia tree of 2 to 3 m height may have upto 10000 pneumatophores. In Sonneratia, the height of the pneumatophores may reach more than 3m.

3. **Knee root -** Bruguiera and Ceriops roots reorient upwards through the soil and grow away from the parent tree. The tip of the upward extension forms a pronounced loop where secondary thickening occurs, mainly on the upper side.

   A blunt, knoblike structure is raised above the soil surface and these root are called knee roots. A single horizontal root develops a series of "knee roots" at regular intervals. The size, shape and frequency of knee roots are characteristic for each species but vary according to soil conditions.

Reproduction:

Most of the mangrove plants are hermaphrodite- they have both self pollinating and cross-pollinating mechanisms.

Most of the Mangroves are pollinated by animals mainly insects, birds, bats, bees, wasps and flies except Rhizophora, which is wind pollinated.

Vivipary is an important/ unique reproductive mechanism in mangroves. In this process a parent tree do not leave a seed or fruit but a seedling- called propagule. After pollination the growing embryo remains attached to the parent tree and grows into a propagule.

Mangrove plants usually produce a large number of propagules. It has been estimated that Avicennia can produce about 20 lakhs propagules

Kandelia candel (Sindhuka) with hypocotyles(a vivipary Character)

Bruguiera cylindrica (KALIACHUA) with hypocotyle & flower

per hectare. It is probable that vivipary and the production of large number of propagules is an adaptation to the local habitat. On leaving the parental tree, a mangrove propagule must be physically able to withstand a certain amount of rattling around in the tide and currents.

Bruguiera gymnorrhiza (Bandari) with hypocotyle & bud

1.4 Ecological functions

- Mangroves produce leaf litter and detritus matter, which are valuable sources of food for animals in estuaries & coastal waters;
- Mangroves produce organic biomass (carbon) and reduce organic pollution in near-shore areas by trapping or absorption;

- Mangroves protect the environment by protecting coastal areas and communities from storm surges, waves, tidal currents and cyclones;
- Mangroves reduce saline water intrusions into the water table and to agricultural and paddy areas;


It serve as educational & recreational grounds for nature lovers

- Mangroves prevent and/or reduce soil surface erosion and river bank erosion;
- Mangroves trap sediments and silts which build up land.

1.5 Economic benefits

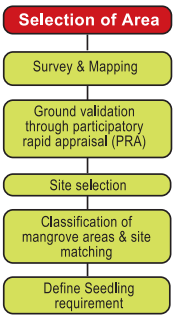
- Mangroves are a good source of wood timber and nipa shingles for housing materials, firewood, charcoal and poles for fish traps and also for handicrafts.
- Juvenile and mature fish species from mangroves support aquaculture and commercial fisheries.
- Mangrove seeds and propagules can be harvested and sold.
- Fish, crustaceans, and molluscs can also be harvested from mangroves.
- Mangroves are sources of tannins and medicines.

1.6 Value of mangrove ecosystems

- Dixon (1989) estimated value of complete mangrove ecosystems to be in the range of US$ 500 to 1,550/ha/annum (Dixon, J.A., 1989: "*The Value of Mangrove Ecosystems*", from Tropical Coastal Area Management Newsletter-4).
- White and Cruz (1988) computed economic equivalent of loss of Mangroves to be about US$ 600/ha/annum (White, A.T. and A. Cruz-Trinidad, 1998: *Coastal Resource Management Project;* Philippine, p:96).

CHAPTER- 2

SELECTION OF MANGROVE AREAS FOR RESTORATION



Restoration process can be started after proper selection of site along with understanding of the requirement of appropriate planting stock. For this purpose clearcut selection and classification methodology needs to be adopted. This chapter includes the following components for planning plantation and restoration process -

- Survey & Mapping
- Ground Validation - PRA
- Site Selection - Qualitative Assessment of sites
- Classification of Mangroves & Site Matching

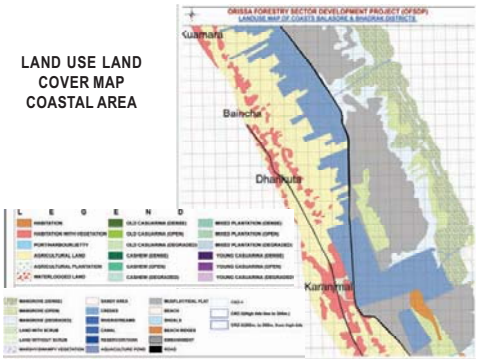
2.1 Survey & Mapping

Need for topographic and satellite maps

- High resolution satellite imageries or land use-cover map (1:5,000 scale) is necessary to get reliable information on biological and physical condition of the sites selected and potential-suitable sites for coastal-mangrove afforestation.
- Ground truthing (Field visit) is necessary to validate the extent of vegetation, vegetation type, structure and land use of mangrove area including water bodies (rivers, creeks, streams, canals, estuaries) and vegetation plant indicators in different ground levels of mudflats

and tidal-flats. Other information such as marsh/swamp land, built up areas, homestead/home garden orchard, coastal vegetation/plantation and villages development inside the CRZ can be delineated using the satellite map or land use and cover map, as shown in the following map.

LAND USE LAND COVER MAP COASTAL AREA



Survey	Mapping	Planning
Natural Forest and Drainage Network	Drainage Network and Location Map	Area Delineation and Calculation
Ground Level and Tidal Inundation	Ground Level and Tidal Inundation Map	Nursery and Plantation Site Selections
Water-Soil Salinity and Soil Type	Soil Type and Salinity Map	Nursery and Plantation Techniques
Land Use and Plant Indicators	Land Use and Vegetation Map	Species-Site Matching and Selection
Base Line Socio-Economic Survey and Livelihood Opportunity Assessment Survey	Social, Resource Use, Conflicting Uses and Village Development Maps	Mangrove Development Plan, Village Development Plan and Livelihood Development Plan

2.2 Ground validation through participatory rapid appraisal (PRA)

- It is ideally useful to secure the latest land use/cover map and/or satellite imageries with high resolution scale before conducting PRA.
- The FD officials and villagers can use the information and data on land uses, development and vegetation type and cover inside the CRZ-1 and CRZ-2 in selection of potential coastal-mangrove restoration and regeneration sites.
- The FD officials and villagers can use the maps and data during PRA for Transact Walk and/or Rapid Mangrove Resource Assessment.
- The interpretations of satellite data can be validated also during PRA.

2.2.1 Validate bio-physical and socio- economic information during PRA

During PRA, rapid mangrove bio-physical assessment in CRZ-1 will gather the following field data which shall be reflected in a sketch map:

- Extent (ha) of CRZ-1 in different ground level,
- Dominant vegetation type in each ground level,
- Frequency of tidal inundation & extent through Key Informant Interview (KII),
- Dominant substrate-soil type in each ground level,
- Extent and water level of flooding during monsoon period through KII,
- Land uses of the CRZ-1 including fishing, grazing, fuel-wood and firewood cutting,
- Fishing gears used in crab, shell and fishing describing its method of fishing,
- Effective Area and Extent of natural mangrove afforestation

Ground level Data			
Data Needed	Low Ground	Middle Ground	High Ground
Length (m)			
Area (ha)			
Vegetation Type			
Soil Type			
Tidal Inundation			
Land Use			
Freshwater Source (Distance)			
Vulnerability to Wave Action			

2.3 Site selection

To ensure the suitability of the sites for mangrove restoration, consider the following biological & physical factors:

Ground Level Class	Tide Water Level (m)	Tidal Inundation Frequency	Water-Soil Salinity (ppt)	Substrate-Soil Type
Low Ground Zone	0.71 to 2.0	10 to 20 Days/Month	40-30 % 0 (Euhaline Zone)	Sandy-Fine Alluvial Silt
Middle Ground Zone	> 2.0 to 2.6	2 to 9 Days/Month	30-18 % 0 (Polyhaline Zone)	Sandy Clay
High Ground Zone	> 2.6 to 2.8	4 Times in dry season by every spring tides	18 -5 % 0 (Mesohaline Zone)	Silty Clay
Extremely High Ground Zone	> 2.8 to 3.3	Flooded with rain water during monsoon period only.	5-0.5 % 0 (Oligohaline Zone)	Silty

2.3.1 Qualitative assessment of the bio-physical characteristics of the sites

Observe and interview key informants during transact walk.

The ground level may be determined using contour map or topographic survey. However, if no survey or map is available, observe on the ground plant indicators and validate the observations during Transact Walk either through Focus Group Discussion (FGD) and Key Informant Interview (KII).

Inquire the frequency and level of tidal inundation from the reliable key informant fishermen through either KII or FGD during PRA.

During Transact Walk, determine up to which portion the tide water reach and recede during full moon in different seasons.

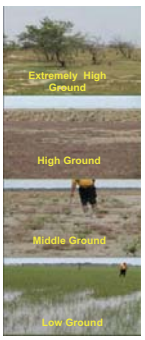
Take the average and mark on the ground the portion which is tidally inundated:

1. At least 15 days /month;
2. Six days per month;
3. Four times in dry season by every spring tide only;
4. Flooded only with rain waters

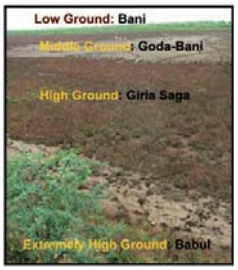
Measurement of Water Level in different Ground Level

2.3.2 Existing vegetation as indicator of soil salinity, ground level and frequency of tidal inundation

Different Ground Levels



Existing Vegetation as Indicator of Ground Level and/or Salinity



Plant-Vegetation Indicator

Low Ground : Bani, Dhani Dhana,Nalia grass;

Mid Ground : Goda Bani;

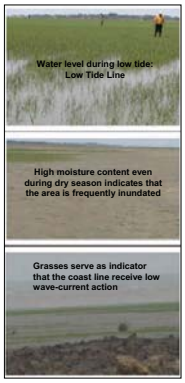
High Ground : Giria Saga, Harakancha ;

Extremely High Ground : Babul, Prosopis

2.3.3 Bio-physical considerations in site selection

- Select sites nearby and/or adjacent to rivers, creeks, streams, canals & channels to ensure mixing of freshwater with the sea water for diluting salinity and form brackish-water;
- Select sites adjacent to existing patches of natural mangrove stand where the existing vegetation serve as buffer against strong waves & water current particularly during monsoon period;

Rivers, Creeks, Streams and Canals



- **Select Sites Closer to the Low Tide Line**
  - ❖ Regular inundation is assured;
  - ❖ Soil contains high moisture, soil particles frequently saturated with brackish-water even during dry period;
  - ❖ The coastline with natural vegetation such as grasses & Bani, indicates that the site receives low to moderate wave action and water current

2.3.4 Socio-economic considerations in site selection

- **Extent of dependence on mangroves** as source of firewood, fodder and grazing;
- Landless and/or casual laborers which are **potential source of work force** for nursery, land preparation, planting, maintenance & protection;
- Near-shore and **marginal fishermen** such as crab catching, and fishing along the estuary, river, creek and fishing along the coast using non-motorized boat;
- **Ease/accessibility** of the proposed mangrove restoration site/area from the village.

Basic socio-economic data for site selection

- Total Population
- Total Household (HH)
- Fisherman HH
- Farmers HH
- Wage Earner HH
- Fisherman HH with Non-Motorized Boat
- Fisherman HH Catching Crabs
- Fisherman HH Catching Fishes in Mangroves, Rivers, Canals
- Landless HH
- HH w/ Agricultural Land
- Max. Agricultural Land/HH
- Min. Agricultural Land/HH
- No. of HH w/Homestead
- Ave. Homestead-Garden Area
- No. of HH w/Cattle
- Ave. Cattle HH
- No. of HH w/Buffalo
- Ave. Buffalo/HH
- No. of HH w/Goat-Sheep
- Ave. Goat-Sheep No./HH
- Ave. Kg. Firewood Needed/Mo/HH
- No. of HH w/Cooking Gas Stove
- Presence of NGO

2.3.5 Scoring and rating for site

Scoring

- **Ranges of Scoring : 1-10**
  - High Score = 8-10
  - Moderate = 4-7
  - Low = 1-3
- **Total Scores of Bio-Physical =** Score 1 + 2 + 3 +...9
- **Total Scores of Socio-Economic =** Score 1+2+....10
- **Plus Factor (Environmental)** Score1, 2 and 3.

Rating

- **A- Bio-Physical**
  Total Scores of Bio-Physical **x .6**
- **B - Socio-Economic**
  Total Scores of Socio-Economic **x .4**
- **C- Environmental Plus**
  Total Scores of Environmental **x .15**

Overall Rating of the Village = A + B + C

2.3.6 Ranking and prioritization

Rank the sites-villages as 1st, 2nd, 3rd etc. from highest and lowest total rating, as illustrated below for areas in Bhadrak district.

The top ranking site-village shall be prioritized for implementation

Site-Village	Overall Rating	Ranking
Nuagan	**85 %**	2nd
Mohanpur	90	1st
Kantipur	82	3rd
Karanpali	67	7th
Karanjamal	74	6th
K. Prasad	75	5th
Kuamara	80	4th
Balimunda	63	8th
Dipora	58	9th

Priority	Area (Ha.)	Seedling Required	% Direct Planting
Mohanpur	150	487,500	35 %
Nuagaon	125	406,250	45%
Kantipur	100	325,000	40 %
Kuamara	75	243,750	30 %

2.4 Classification of mangrove areas & Site Matching

2.4.1 Classification from low tide line to the high tide line-

Ground Gradient /Level	Low Ground	Middle Ground	High Ground	Extremely High Ground
Substrate-Soil Type	Sandy-fine Alluvial silt	Sandy Clay Substratum	Silty Clay Bottom	Silty Substratum
Wave –Current Action	Maximum	Moderate to Low Wave	Feeble Wave	Minimal only during monsoon
Salinity Ranges	40-30 ppt	30-18 ppt	18-5 ppt	5- 0.5 ppt
Salinity Zonation	Euhaline Zone	Polyhaline Zone	Mesohaline Zone	Oligohaline Zone
Frequency of Tidal Inundation	Most Frequent: At Least 10-20 days per month	Moderately Frequent: At Least 2-9 days per month	Least Frequent: 4 Times in every spring tides in dry season	Flooded with Rain water during monsoon period

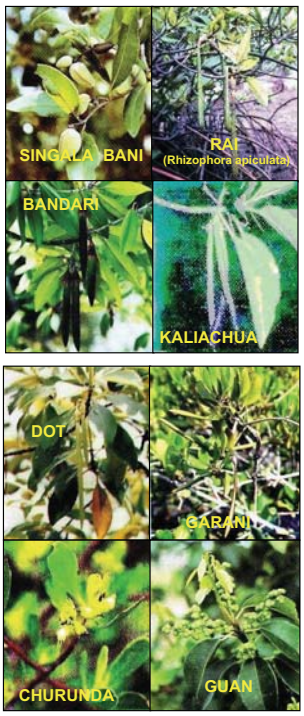
2.4.2 Species-site matching

Species	Ground level	Soil Type	Tidal Inundation	Salinity Range
RAI (*Rhizophora stylosa*)	Low Ground	Sandy-Rocky to Coralline	Every High Tide at least 20 days/M	18-35 ppt
RAI (*Rhizophora mucronata*)	Low Ground-Along River	Sandy-Clay Soft Depth Mud	Every High Tide at least 20 days/M	10-30 ppt
RAI (*Rhizophora apiculata*)	Low –Middle Ground	Sandy-Clay Soft Shallow Mud	At least 10 days/M	10-25 ppt
SINGALA BANI) (*Avicennia marina*)	Low –Middle Ground	Sandy-Rocky To Coralline	At least 10 days/M	20-40 ppt
KALA BANI (*Avicennia alba*)	Low Ground – Along River	Silty-Clay	Every High Tide	18-30 ppt
BANDARI (*Bruguiera gymnorhiza*)	Middle – Along River	Sandy Clay	At least 10 days/M	10-25 ppt
KALIACHUA (*Bruguiera cylindrica*)	Middle-High Ground	Newly Established Sandy-Silt	At least 6 days/M	18-30 ppt
DOT (*Bruguiera parviflora*)	Low to Middle Ground	Sandy Clay	At least 6 days/M	18-30 ppt
ORUA (*Sonneratia alba*)	Low Ground	Sandy- Clay Soft Shallow Mud	At least 20 days/M	18- 30 ppt
GARANI (*Ceriops decandra*)	Middle-High Ground	Sity Clay	At least 6 days/M	18-30 ppt
GARANI (*Ceriops tagal*)	Middle-High Ground	Silty-Clay	At Least 6 days/M	18-30 ppt
KHARSI (*Aegiceras floridum*)	Middle – Along River	Silty Clay	At least 10 days/M	5-25 ppt

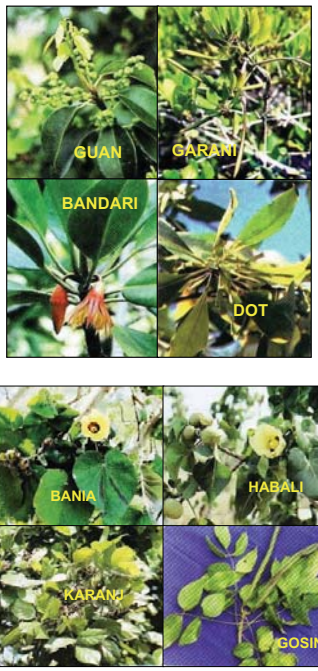
Species	Ground level	Soil Type	Tidal Inundation	Salinity Range
GUAN (*Excoecaria agallocha*)	Middle-High Ground	Silty-Clay	At least every spring tide	5-18 ppt
CHURUNDA (*Lumnitzera racemosa*)	Middle-High Ground	Silty-Clay	At least every spring tide	5-18 ppt
DHALA BANI (*Avicennia officinalis*)	Middle-High Along River	Silty-Clay	At least 6 days/M	5-18 ppt
BANDARI (*Bruguiera gymnorrhiza*)	Middle-High Ground	Sity Clay	At least every spring tide	5-18 ppt
ORUA (*Sonneratia caseolaris*)	Middle-High Along River	Silty-Clay	At Least 6 days/M	5-18 ppt
SINDUKA (*Kandelia candel*)	Low-Middle Along River	Silty Clay	At least 10 days/M	5-18 ppt
KERUAN (*Sonneratia apetala*)	Middle-High Ground	Silty-Clay	At least 6 days/M	5-18 ppt
BANDA SUNDARI (*Heritiera fomes*)	Middle-High Ground	Silty-Clay	At least 6 Days/M	5-18 ppt
DHALA SUNDARI (*Heritiera littoralis*)	High Ground	Silty-Clay	At least every spring tide	0.5-18 ppt
SISUMAR (*Xylocarpus granatum*)	Middle-High Along River	Sity Clay	At least 6 days/ M	5-18 ppt
BANIA (*Hibiscus tiliaceous*)	High-Extreme High	Silty	At Least every spring tide	0.5-5 ppt
HABALI (*Thespesia populnae*)	High-Extreme High	Silty	At least every spring tide	0.5-5 ppt

2.4.3 Species in low ground areas

2.4.4 Species in medium ground areas



2.4.5 Species in high ground areas



2.5 Seedling Requirement

> **Low ground species -**

RAI (*Rhizophora apiculata, Rhizophora mucronata and Rhizophora stylosa*), spacing 1.5m x 1.5m, Seedling requirement per hectare - 4,444.

SINDUKA (*Kandelia candle*) - Spacing - 1.0m x 1.0m, Per hectare requirement-10,000.

SINGALA BANI (*Avicennia marina*), KALA BANI (*Avicennia alba*) and ORUA (*Sonneratia alba*) species - Spacing - 2.0m x 2.0m, Per hectare requirement - 2,500.

> **Medium ground species -**

SINGALA BANI (*Avicennia marina*), KALIACHUA (*Bruguiera cylindrica*), DOT (*Bruguiera parviflora*), GARANI (Ceriops decandra), CHURUNDA (*Lumnitzera racemosa*) in the spacing of 2.0m x 2.0m, Seedling per hectare required - 2,500.

RAI (*Rhizophora Apiculata*), Bandari (*Bruguiera gymnorhizha*) in the spacing of 1.5m x 1.5m, seedling requirement per hectare - 4,444.

> **High ground species -**

GUAN (*Excoecaria agallocha*), GARANI (*Ceriops decandra*), DOT (*Bruguiera parviflora*), BANIA (*Hibiscus tiliaceous*), HABALI (*Thespesia populnea*) and PONAGAM / KARANJ (*Pongamia pinnata*) in the spacing of 2.0m x 2.0m, seedling requirement per ha. - 2,500.

BANDARI (*Bruguiera gymnorhizha*) in the spacing of 1.5m x 1.5m, seedling requirement per ha. - 4,444 (total for 5 ha. 22,220).

> **Extermely high ground, embankment, village woodlot, homestead, roadsite, paddy field boundary species -**

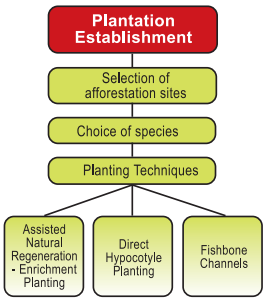
BABUL (*Acacia nilotica*), PROSOPIS (*Prosopis juliflora*), Acacia auriculiformis, Eucaltus camaldulensis, Acacia mangium, Melaleuca leucodendron, Sesbania grandiflora, Sesbania bispinosa.

In the spacing of 2.0x2.0 meter, per ha. seddling requirement - 2,500.

Note: 30% allowance shall be added to the requirement of seedlings as computed above while planning for nursery.

CHAPTER- 3

PLANTATION of MANGROVES



Objectives

- A well defined management objective is important because the choice of species, spacing & specific silvicultural practices depend on the objectives of the plantation.
- The objective of mangrove plantations under the project is primarily to establish a protective green shield/layer against natural calamity, to enhance bio-diversity and for augmenting livelihood support potential of mangrove forests.
- The selection of sites, choice of species, plantation planning and design will be reckoned on the above objectives.

3.1 Plantation Establishment

- Consider the management objectives, socio-cultural and biophysical attributes in planning and designing restoration of mangrove areas.
- The following general plantation activities are discussed in the chapter. Specific planting technique and production of planting stock are discussed in subsequent chapters.

Site Identification & Selection

Choice of Species

Species-Site Matching

Plantation Establishment Techniques

Planting

Care and Maintenance of Plantations

Silvicultural Treatments

Planted & Natural Mangrove

3.2 Selection of afforestation sites

Site Identification & Selection

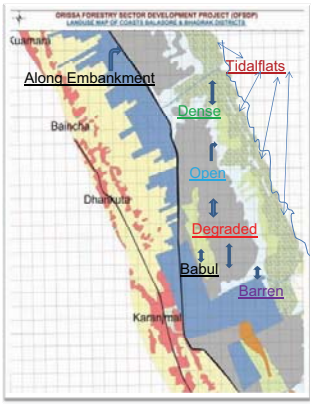
Following factors are important for selection of suitable site for restoration / plantation of mangroves:

1. Water-Soil Salinity
2. Ground Level and Frequency & Height of Tidal Inundation
3. Type of Substrate
4. Current species present & vegetation as indicator of species suitability
5. Extent of Wave Action
6. Presence or Absence of Pests
7. Historical Users of the Area

Following table gives a sample data of a site -

Ground level Data-BAINCHA					
Site/ Vegetation Status	**Tidal-flat**	**Dense Mangroves**	**Open Mangroves**	**Degraded Mangroves**	**Barren**
Vegetation	Regeneration-BANI	Bani	Bani	Gliria Saga	Goda Bani
Soil	Muddy-Murky	Muddy	Muddy	Sandy	Sandy
Inundation	At least 20 days/mo	12-20 days/mo.	12 days /mo	During rainy days only	5 days/mo
Wave Action	strong	moderate	low	low	low
Land Use-1:Grazing	no	yes	yes	yes	no
Land Use-2:Firewood	no	yes	yes	no	no
Land Use-3: Fishing	yes	yes	yes	yes	yes
Land Use-4:Fuelwood	no	yes	yes	yes	no
Freshwater Source	creek	creek	creek	canal	canal

- **Select sites nearby and/or adjacent to rivers,** creeks, streams, canals & channels to ensure mixing of freshwater with sea water to dilute saline into brackish-water;
- **Select sites adjacent to existing patches of natural mangrove** where the existing vegetation serves as buffer against strong waves and tidal water current particularly during monsoon season;
- **Select sites closer to low tide mark where** tidal inundation is assured, soil contains high moisture, coastline has natural vegetation.



Substrate has an important role in final selection of site and choice of species:

Following are some common substrate in mangrove areas in Orissa:

a. **Mud** - This is best characterized as a soft sediment composed of a combination of organic and inorganic material. It may be as shallow as 2-3 cm or as deep as a few meters. In general mud is a good substrate to:

- ❖ Rhizophora species (Rai)
- ❖ Bruguiera species (Bandari)
- ❖ Ceriops species (Garani)

Avoid planting in areas that have foul smell similar to rotten eggs because the soil may be acidic and the likelihood of plant dieback will be high.

Avoid very narrow strip where mud is up to the knee because the survival of plant will not be high while the amount of work to plant and manage a plantation will be quite high.

b. Rocky or coralline – This substrate may best be described as hard shelves where small or thin pockets of softer sediment are found. These areas are not recommended for production forest because of relatively low soil fertility. But for protective and other ecological purposes the following species are recommended:

Rhizophora stylosa (Rai),

Sonneratia alba (Orua),

Avicennia marina (Singala Bani)

c. Sandy Substrate- Sand may be as shallow as 2-3 cm or as deep as several meters. It is not advisable to plant in shallow sandy substrate for wood production purpose. But for protection purpose the following species do well in sandy substrate:

- Rhizophora stylosa (Rai)
- Rhizophora apiculata (Rai)
- Avicennia marina (Singala Bani)
- Sonneratia caseolaris (Orua)

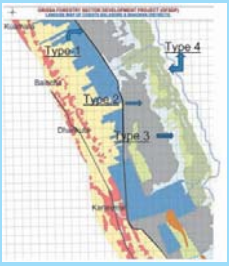
d. Muck – Similar to mud, except that it contains a large amount of plant debris. Its organic content is higher than mud. Like mud, muck may have the same foul, rotten egg smell; if so, planting should not be attempted. In general muck is a good substrate to plant:

- Rhizophora mucronata (Rai)
- Bruguiera gymnorhiza (Bandari),
- Ceriops decandra (Garani)

Annual target and allocation of plantation area should be based on the availability and suitability of areas for different method/modules of mangrove afforestation.

The target area shall be shown on the land use map including the vegetation cover and planting module, and demarcated on the ground.

- Along Embankment - Type 1
- Mud Flat (suitable for Fishbone Channels) - Type 2
- Degraded mangrove - Type 3
- Tidal flats - Type 4



While deciding mangrove species for plantation, following further considerations are of great help :

(i) Common Species Present

- Species or vegetation currently existing in the area may indicate which species may grow well in the area.
- If the area once supported a mangrove forest, people living near the area know which species were there.
- Think carefully and twice before deciding to plant species that are not found in and around the area. It is likely that nature has already tried to establish those species and failed.

(ii) Tidal Height

- Tidal height affects growth and survival of mangrove plants. Seedlings planted at a low tide depth, less than 30 cm, generally have a much higher survival than those planted at tide depth exceeding 40 cm.
- Avoid planting in area where tide water does not always recede or not drain out daily during low tide. This area is susceptible to barnacle or shell and crab infestation.
- Areas constantly battered by waves are critical for planting. As much as possible, avoid these areas to reduce the frequency of uprooting or breakage of newly planted seedlings/plants unless they support grass cover.

(iii) Presence or Absence of Pests

- The absence of pest species such as barnacles and crabs may be an indicator of the suitability of the area for plantation. These pest species can cause problems to young plants.
- Crabs girdle the cambium of young seedlings/ propagules.
- Barnacles cling to the stem of young plants that block the exchange of Oxygen for photosynthesis and ultimately suffocate and break the stem
- Filamentous algae can pile up against the young plants and knock them over by their sheer weight.

(iv) Traditional Users of the Area

- All traditional users of the area should be identified & allowed an opportunity to join the EDC or Mangrove Eco-Restoration Committee & share the Benefits.
- The villager's support shall be easily secured if they feel they are part of the project & given opportunity to participate in the implementation.
- It is important to plan & design the plantation with them so their needs and interest regarding boat traffic, access to fishing ground, shell gathering, crab catching, collecting forage & other issues are included and considered in the plan.

3.3 Choice of species

Recommended species for different ground level.

- 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)
  - Bio-physical characteristics of the selected area
  - Socio-economic & cultural aspect of the villagers/village

  In the long run, it is the biophysical characteristics that will determine the success of the plantation.

3.4 Plantation establishment techniques

- Determining what needs to be done to prepare the site and work schedule to complete in time;
- Planting organization, areas & spacing;
- Seedling density or spacing;
- Sketch map;
- Plan implementation;

Several Organizational ideas can be used in planting:

- An inverted V shape spacing with the point of the V facing the sea to deflect wave impact. Spacing should be less than 0.5 m
- Planting in triangular formation with one the corners of the triangle pointing seaward. Spacing is less than 1 m.
- Cluster planting is done to act as wave break. Spacing is much closer (25 x 25 cm). After 3-5 years, when the clusters are fully established, the gap in back of the clusters can be planted at a wider spacing, as the area will be more or less protected by the clusters.
- Strip planting- the same principle applied in cluster planting. Strips (10 or 20 x 100 or 150 m) are established 100-200 m from the shore at very close spacing to withstand strong waves. Once established, the open areas between the planted strips & shoreline may now be planted at a wider spacing

Seedling density or spacing

- The closer the spacing, the greater the ability of the seedlings or propagules to withstand wave impact.
- Generally, wider spacing is employed when bigger trees are needed. The wider spacing reduces competition for sunlight and nutrients.

Sketch map

This map forms the backbone of the plan. The map should be clear enough to provide guidance on the location of passages, blocks, seedling density, species and other peculiar features.

Bush Cutting/Clearing

- **Total bush cutting-** Removes all oft the undergrowth from the area
- **Strip cutting-** Removes undergrowth along the pre-determined strips, generally 1 m width.
- **Spot cutting-** Removes undergrowth in a 1-m radius around the point where plant will be placed.
- A stake of at least 1-m height is necessary to be able to locate the seedlings until they become larger.
- Spot brushing is the easiest of the three approaches.

3.5 Planting Technique

The following table summarize the steps in raising plantation depending upon the type of planting material/stock:

Sl.	Type of seedling	Step-1	Step-2	Step-3	Step-4
1	Potted seedling	Pre-planting treatment	Direct planting & sticking	Cleaning & weeding	Patrolling & regular inspections
2	Vegetative propagated seedlings	Pre-planting treatment	Direct planting & sticking	Cleaning & weeding	Patrolling & regular inspections
3	Propagule Hypocotyle direct planting	Pre-planting treatment	Direct planting & sticking	Cleaning & weeding	Patrolling & regular inspections

Direct Planting

- Propagules of Rai, Sinduka, Bandari, Garani, Dot & Kaliachua are planted directly on the ground.
- Digging holes deep enough to hold the seedlings/propagules firmly which can be made by using a long, heavy, pointed pole.
- Propagules are inserted directly into the mud deep enough into the substrate to prevent it from toppling over
- Buried or insert into the ground 1/3 of the total length of the propagules.
- Remove the brownish cap at the end of the propagule & be careful not to break the tip or the plumule.

Potted Seedlings

- Used for the trees with tiny seeds that are difficult to sow directly in the field.
- Potted seedlings involve considerable cost and should only be done when it is the only option.
- Seedlings from the RAI group also can be raised in the nursery and planted as potted seedlings for specific sites such as open areas with unstable substrates where there is concern about the early survival of the seedlings.
- If seedlings or wildlings 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 root ball. Begin planting at the seaward side at low tide.

Wildlings

- Where enough seeds or propagules are not available, wildlings may be potted after hardening in the nursery for a month.
- In up-rooting/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 is intact.
- Planting wildlings requires extra care to protect against damage to the roots, one of the natural adaptive structures of mangrove to tolerate a saline environment.

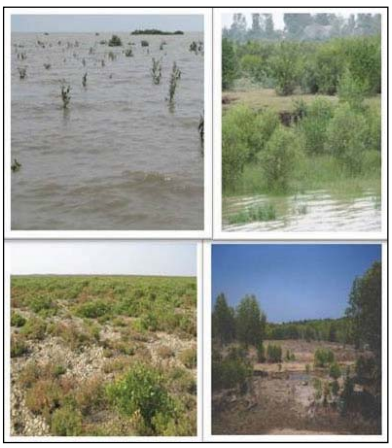
3.6 Assisted Natural Regeneration - Enrichment Planting

Assisted natural regeneration or enrichment planting should be considered in sparse mangrove forest to introduce mangrove species other than Bani to increase the species diversity in shorter period rather than solely relying longer recruitment through natural regeneration.

These are type-III areas between embankment and tidal flats which support sparse mangrove plants and can be recouped through plantation of suitable species in blank patches alongwith digging channels for enhancing tidal flow as per requirement and feasibility.

Enrichment Planting - is the process of rehabilitation by increasing the number of seedlings of desirable species. This is generally undertaken in low density mangrove stands to increase land productivity and conserve/increase biodiversity. This can be considered in inter channel spaces in type-II plantation after 1-2 year of plantation.

- **Planting of Rhizophora spp. and other desirable / suitable species** in gaps of dense natural stands, or planting immediately under the canopy of less desirable species after pruning the lower horizontal branches to let in more sunlight. Cut branches may be used for posts and firewood while the leaves can be used for fodder.



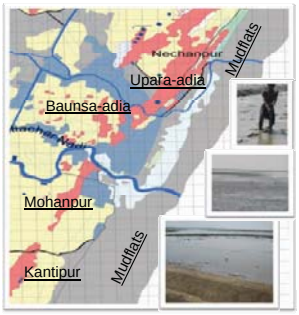
- **Planting of other desirable / suitable species in the space between side channel in fishbone method of planting.**

CHAPTER - 4

DIRECT HYPOCOTYLE PLANTING

- **Direct Hypocotyle Planting**
- Collection of hypocotyles
- Grading of hypocotyles
- Transporting hypocotyles
- Hardening the hypocotyles
- Planting with stakes
- Maintenance and protection
- Fencing along the shorelines

Direct planting of hypocotyles should be the first priority method for planting due to low plantation cost. However, direct hypocotyle planting should be limited to areas on the sea face with existing grasses and/or natural regeneration up to areas which are frequently inundated at least 12 days every month. In the project divisions, such area are found from Mohanpur to Eram in Bhadrak and Baunsa-adia up to villages with tidalflats similar to Upara-adia of Balasore.



4.1 Selection of Site for Direct Hypocotyle planting

Select tidal flats covered with Dhani dhana grasses along the Bani forest with natural regeneration.

These areas are usually the traditional fishing grounds of the fishermen, so sensitize the fishermen group to exclude the plantation areas from fishing.

Cattle and buffalo prefer Bani for forage, and spare other mangrove species such as Rai, Sinduka, Kaliachua, Bandari, Garani, Guan, Orua, Keruan, etc To the extent feasible, plant species other than Bani to reduce grazing pressure.

4.2 Involve the EDC in selection of site and species

The villagers are familiar with the history and present conditions of the mangrove.

Thus, the EDC should be involved in the planning especially in site-species Matching, to ensure the suitability of species to different substrate and of course in protection of planted areas from grazing and fishing.

4.3 Collection of Hypocotyles

Select only matured hypocotyles which have ring like swollen portion below the seed cap and have yellowish colour.

Seed cap can be easily detached in matured hypocotyle.

Ensure that the seed cap remains intact while transporting to protect the plumules from damage.

4.4 Grading of Hypocotyles

Discard hypocotyles which are damaged, broken and not yet matured

Segregate the hypocotyles according to sizes and maturity.

A number of hypocotyles of similar size be bundled in such a manner that bundles are easy to carry and transport.

4.5 Transporting and handling of Hypocotyles

Place the bundled hypocotyles into the jute bags with seed cap in vertical upright position.

Water the jute bags with brackish water to moisten the hypocotyle for long distance transport, particularly during hot-summer season

Extra care should be taken during long distance transportation of hypocotyles

Arrange the jute bags in the boat, vehicle or carrier in parallel position alternately.

Take extra care to avoid the breakage of hypocotyle during transportation.

4.6 Hardening the Hypocotyles by air drying under shed

Take out the hypocotyles from the jute bags.

Put the hypocotyles in the elevated flat-form under shade for 5-10 days before planting.

Hardening of the hypocotyles make them un palatable to crabs and crustaceans and hence higher chances of their survival after planting.

4.7 Priority planting sites in the tidal flats (Type IV areas)

Suitable-ideal planting sites in the tidal flats are:

1. Sites covered or vegetated with Dhani dhana grass
2. Sites along the existing natural mangrove forest/ stand
3. Sites with natural regeneration

Areas that receive moderate to low waves and current.

4.8 Staking is necessary to provide support to the newly planted hypocotyles

Put stick in designated planting spot with prescribed spacing.

Closer spacing planting is recommended in open tidal flat sites

Orient the wider portion of the sticks parallel to the shore to cover the hypocotyle against the direction of wave and current.

4.9 Plant 1/3rd of the length of the Hypocotyle into the ground supported with the stick

Take out the seed cap.

Plant 1/3 of the length of hypocotyle into the ground supported by stick that is driven into hard substrate.

Tie the hypocotyle loosely to the stick at the base with biodegradable materials

4.10 Proper timing of planting

Hypocotyles of Rai (R.mucronata, R.apiculata and R. stylosa) and Sinduka are abundantly available from mid March to May and again from mid Sept. to November twice in a year.

The best time to plant in the tidal flats using Rai and Sinduka is after monsoon between September and November.

SPP	FRUITING PERIOD											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
RAI R. apiculata		■	■	■	■	■	■		■	■	■	
RAI R. mucronata		■	■	■	■	■	■		■	■	■	
RAI R. stylosa		■	■	■	■	■	■		■	■	■	
SINDUKA		■	■	■	■	■	■	■	■	■	■	■
	RED COLORED (FRUITING)	■										

4.11 Maintenance and protection is necessary to attain desirable growth

Casualty replacement is necessary after monsoon when hypocotyles are abundantly available.

Replanting and protection should be undertaken for at least three years to attain a required survival rate of 85 and average height growth of 2.5 m.

4.12 Fencing along the shorelines is necessary to serve as barrier against drifting sea debris

Fencing is necessary to serve as barrier against sea debris, sea weeds and grasses drifting during high tides, especially during monsoon periods.

The height of the stick be such that it is seen or noticed during high tide by the fishermen.

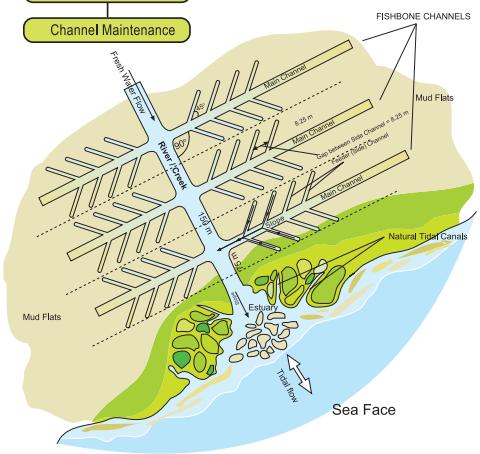
If shorter sticks (1m length) are used, perimeter fence is necessary in the outer portion of the plantation along the shorelines.

CHAPTER - 5

FISHBONE CHANNELS

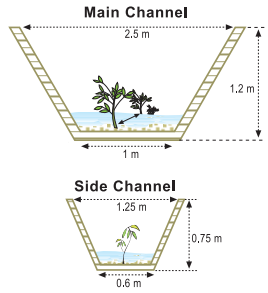
- Fishbone Channels
- Selection of Natural Creek/Channel
- Layout and design of Fishbone Channel
- Planting Suitable Species
- Channel Maintenance

In this method Plantation is resorted to in mud flats where infrequent tidal inundation is augmented through Fishbone Channels.



5.1 Design of Fishbone Channels

CHANNELS	MAIN	SIDE
Top Width	2.5 m	1.25 m
Bottom Width	1.0 m	0.60 m
Depth	1.25 m	0.75 m
Angle with the Sea/River/Creek/ Canal	Right Angle	-
Angle with the Main Channel	-	Right Angle
Distance between Main Channels	75	-
Distance between Side Channels	-	8.75



5.2 Recommended Species

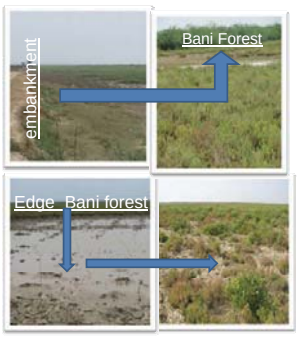
Following table gives species recommended in the channels- main and side as well as inter-channel spaces, spatial location with respect to embankment.

Location with respect to embankment	Main Channel	Side Channel	Between Channel
Towards embankment	Garani, Guan, Bandari, Dot	Singla Bani, RAI, Bandari, Kaliachua	Karanj, Gosinga Hentala, Bania
Middle	Singla, Bani, RAI, Bandari, Kaliachua	Sinduka, RAI, Bani, Keruan, Kala Bani	Churunda, Guan Garani
Towards Shoreline	Sinduka, RAI, Bani, Keruan, Kala Bani	Sinduka, RAI, Bani, Keruan, Kala Bani	Sinduka, Bani, Keruan

5.3 Priority of Sites

Fishbone channels should be started along the embankment towards the existing Bani forest;

- Planting of potted seedlings outside/without fishbone channels should be started from the edge of existing Bani forest towards the embankment or area intended for fishbone.



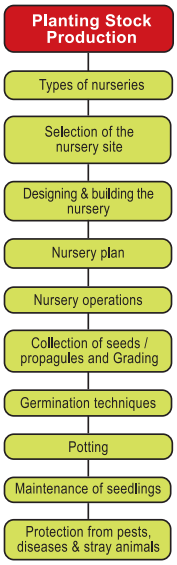
5.4 Species-Site Suitability

- Plant Bhana Bani, Keruan, Bani,Bandari and Garani in between fishbone channels along near natural Bani forest to promote species diversity;

- Plant Karanj, Hentala, Guan, Cynometra and Hisbiscus spp in between the fishbone channels along the embankment towards the natural Bani forest to maximize the area and species diversity.

CHAPTER- 6

PLANTING STOCK PRODUCTION



6.1 What is Mangrove Nursery

- It is a place for raising and tending mangrove seedlings until they are ready for planting.
- The development of nursery technologies ensures a reliable source of planting materials
- Planting healthy seedlings decreases mortality of plantation at the early stages
- **Major Activities** in Nursery Establishment & Management
  - ❖ Nursery Site Selection
  - ❖ Designing and Building the Nursery
  - ❖ Operating and Managing the Nursery

6.2 Types of Nurseries

- **Permanent nurseries** are for mangrove planting over an extended period of time usually to supply planting materials in large numbers. They tend to have a more developed working areas / infrastructure.
- **Subsidiary nurseries** are designed for areas located at a distance from the permanent nursery that makes it difficult/risky to transport seedlings to planting site.

- **Temporary nurseries** are generally set up near the area (typically 5 -10 ha.) to be planted during one planting season.

6.3 Selection of the Nursery Site

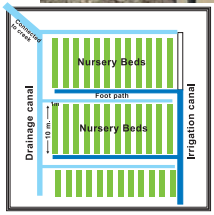
1. **Water Supply**
   close to the river, but avoid area that get flooded during rains or high tides.
2. **Central Location & Accessibility**
   close to the planting sites and near to the Villager s dwellings or site where from seedlings and potting soils can be easily transported
3. **Drainage**
   Select site that is relatively flat and drains well. The ground surface should not be moist and soft. Proper drainage is essential, so that water does not remain stranded for more than one hour after watering.
4. **Size of the Area**
   325 m^2/hectare of plantation, plus 100 to 200 m^2 for work area. (10,000 seedlings/ha with 20 allowance)

For production of poly pot planting stock of 10000 seedlings/ha., nursery area required is 500 m^2 for one ha. of plantation including work ..... for drainage etc.

6.4 Designing & building the nursery

Important steps in planning/ designing a nursery:

- Identify who will work on the nursery project
- Determine location and area of the nursery
- Develop a plan for the nursery along with connection with tidal water, with proper drainage to drain out water.
- Establish the nursery



6.5 Steps in post selection designing of nursery

1. In a JFM mode, the EDC must decide who will responsible for all the phases of the project.
   The EDC General body will discuss and decide as to who will be responsible for different tasks.
2. Develop a sketch map showing the boundary of the nursery area
   - ❖ Lay out the nursery in square or rectangular dimension
   - ❖ Check if the area is large enough for all nursery management activities.

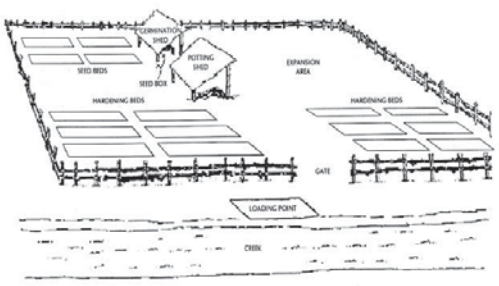
6.6 Is the nursery area big enough?

- First, determine area of plantation (how many hectares) in a year.
- Multiply that number by 500 and add 100 or 200.
- This is the area in sq. meter required for the nursery.
- A larger area is better than a smaller one. If the nursery site is too small, then:
  An alternate area of sufficient size will have to be found.
  Additional area need to be identified and establish two nurseries.

6.7 Developing the nursery plan

- First, determine transportation point of the seedlings for field planting
- The location of the transportation point determines where to place the hardening beds
- In planning, basic nursery components must be considered such as:
  Seed Germination Beds, Seed Box, Germinating Shed
  Potting Shed, Bagging and Storage Shed, Potting Soil and Sawdust Stockpiles, Compost Beds and Seedling
  Hardening Beds

6.8 Basic nursery components



6.9 Building the nursery

Site Preparation

- ❖ If possible, the nursery site should be an open area to avoid the cutting of trees
- ❖ Be sure to remove all stumps and pull out all grasses to prevent re- growth
- ❖ After being cleared, the site should be leveled
- ❖ After leveling, the nursery should be laid out.

Seed Germination Beds

- These 1 x 10 m beds are raised slightly (5 to 10 cm) above the level of the surrounding area by adding potting soil to each bed or by digging out the soil from the 40 cm wide area adjoining the beds
- Keep the soil from spreading by lining each bed with a wood or bamboo curb.

Seed Boxes

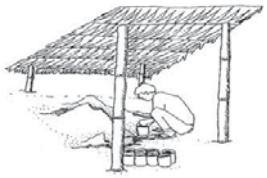
- The fine size seeds of Sonneratia group of spp. need to be sown in the seed boxes with a suggested dimension of 30 x 35 cm.
- Drill a series of small holes between 0.3 and 0.7 cm every 5 cm to allow water to drain
- Fill the boxes with three different layers of sand and stones: fill the bottom 5 cm with small stones, the next 3 cm with coarse sand and the top 2 cm with fine sand mixed with compost and/or potting soil.

Germinating Shed

- It is more like a simple roof with no walls than a shed. Roughly 3 x 5 m in area under 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

Typically about 3 x 4 m in area, they are built with three walls and instead of a door, the fourth wall is kept open. Potting is typically done on the floor although a bamboo table for potting can be built to facilitate works. Polythene bags should be freshly filled at the time of seed dibbling in the nursery.



Bagging and Storage Sheds

These sheltering and storage sheds are similarly constructed. Since they can be used to store tools, these sheds could be enclosed and locked.

Potting Soil and River Sand

- The potting soil pile should be at least 5 cum in volume and the river sand pile at least 1 cum.
- Both piles should be under roof to protect the materials from rain and should be piled close to the bagging shed.

Compost Piles

- Compost piles should also placed under a roof.
- Be sure that they are of sufficient size to provide enough mulch.

Seedling Hardening Beds

- Hardening beds need not be raised
- Hardening beds require a temporary roof with multiple layers of covering, typically mesh nets (gauge 14) to control the amount of light reaching the seedlings. These beds are 20 to 30 m long and 1 m wide.
- The roof should be at least 1.5 m above the ground. Remove each layer of roof to allow more light to reach the plants over time.

6.10 Operating & managing the nursery

What are the Daily Activities at a Nursery

- it is to be ensured that water drains out completely from the nursery after about an hour or so, standing water will increase salinity.
- in the first week after dibbling of seeds in poly bags, beds may be covered with rice straw and tidal water is sprinkled twice daily.
- water twice a day at the early stage synchronizing with tides. Later,

once daily towards the out planting season (4 to 6 months old) to acclimatize seedlings.

- a nursery with 50,000 seedlings requires one person watering 2 to 3 hours per day.
- At least five hundred 10 x 15 cm poly bags can be filled with potting soil by one worker everyday (assuming all the potting materials are ready).
- Depending on the size of seedlings, a worker can prick or pot 600 - 1,000 seedlings in a day.

6.11 Nursery operations

Collection & transporting seeds and propagules

- Timing of Collection
- Identifying mature seeds & propagules
- Methods of Sorting & Transporting seeds & propagules

Propagation Practices

- Preparation of Potting Soil
- Germination Techniques
- Potting
- Hardening

Maintenance of Seedlings

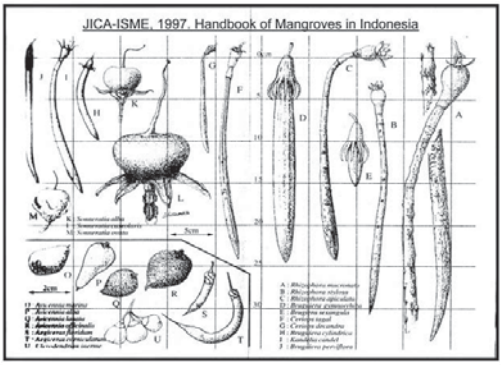
- Watering
- Shading
- Weeding
- Protection from pests, diseases and stray animals
- Records Management
- Grading, Sorting, Packaging & Transport of Seedlings
- Post Nursery Operations

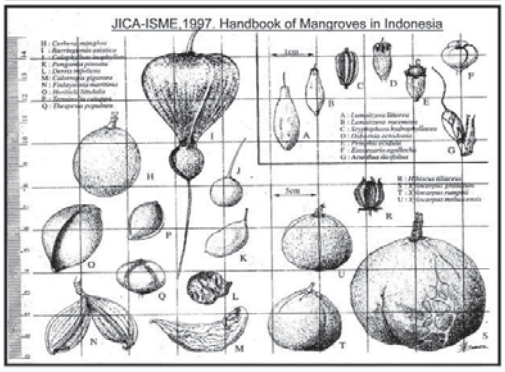
6.12 Seed Collection period for selected Mangrove Species

(Refer to Seed Calendar of Mangrove Species)

Species	Season 1	Season 2	Remarks
R. apiculata (RAI)	Feb-July	Sept- Nov	Twice a ear
R. mucronata (RAI)	Feb-July	Sept- Nov	Twice a ear
B. gymnorhiza (BANDARI)	April-May		
B. parviflora (DOT)	April-May		
C. decandra (GARANI)	May-July		Throughout the ear
K. candel (SINDUKA)	July		Throughout the ear
A.marina (SINGALA BANI)	July-Dec		
A. alba (KALA BANI)	July-Nov		
S. alba (ORUA)	July-Nov		Throughout the ear

6.13 Mangrove species fruits form characteristics





6.14 Timing of collection of seeds/propagules

Collecting propagules/ seeds at a right time is critical

- Peak seasons vary by area and date
- Knowing when to collect makes the operation quicker and more efficient
- The seed calendar may not be exactly the same in each area but it provide a good idea of the general time to expect to find mature seeds & propagules
- Seeds and propagules are not always available, hence wildlings may be used

Wildlings less than 30 cm tall are collected by balling with a spade.

For 10, 20 and 30 cm tall wildlings, the diameter of excavation should be approximately 10, 20 and 30 cm respectively. Wildlings are to be put in folded banana leaf for immediate potting.

Main Characteristics of Good Quality Seeds/Propagules:

- Fully Mature
- Good Size
- Free from Defects & Insects
- Fresh and Without Developed Roots

Seeds/propagules collection

What to Collect?	Where to Collect?	What Species?
All through out the year but abundant in mid May to June and mid September to October	Bhitarkanika, Confluence of Subarnrekha and Budha Balanga, Naya Tapu and Burhiya Chara islets in Mahanadi delta	RAI (Rhizophora apiculata)
		RAI (Rhizophora mucronata)
		RAI (Rhizophora stylosa)
		SINDUKA

What to Collect?	Where to Collect?	What Species?
Abundant in July to August	Bhitarkanika Mahanadi	BANDARI
		KALIACHUA
		DOT
Abundant July to August in Bhitarkanika; September in the Natural Stand along the Coastline of Bhadrak	Along coastline nearby the plantation	SINGALA BANI
		KALA BANI

Mangrove species seeds / propagules collection

What to Collect?	Where to Collect?	What Species?
August to September	BHITARKANIKA	Orua
June to July		Garani
June to July		Churunda
July to August		Guan
December to January		Bania
December to January		Habali
June to July		Pongam / Karanj
July to August		Kharsi

6.15 Identifying mature seeds and propagules

- **All trees from Rai and Sinduka groups** exhibit a whitish to yellowish ring-like mark on the propagules located 1 to 3 cm from the top of the pericarp.
- The ring is absent or very thin in propagules that are not yet ripe

- The Bandari, Dot and Kaliachua groups do not exhibit the ring noted in Rai group but immature green propagules turn brownish or bronze as they mature.
- Mature propagules drop together with the fruit unlike the Rai whose propagules drop without pericarp.

- Another indicator of maturity is color. The propagules turn from green to brown as they mature.
- **In the Sonneratia group**, the fruit will turn shiny yellowish to light green and soft when ripe.

- **In the Avicennia group** seed coat changes from green to light yellow and becomes wrinkly and often opens.

6.16 Sorting and transporting seeds/propagules

Sorting of propagules is the first stage in the transport process. Classify according to Maturity, Health and Insect infestation, and physical injury.

- **Packing** of propagules in bundles of 50 to 100 wrap in a moist banana leaves or gunny sacks. Small seeds should be transported in bags with a moist cloth and do not expose to direct sunlight.
- After returning to nursery, the seeds/propagules must be prepared for planting or storage

- Allow small seeds to air-dry prior to storing.
- Place the air dried seeds in polyethylene bags
- Seal the bags and store them at room temperature
- Propagules may be kept under shade for period up to 2 weeks
- Avoid placing them on the ground or any moist surface.

6.17 Propagation practices

Propagation practices include the following activities needed to germinate seeds/ propagules & produce seedlings:

- Preparation of Potting Soil
- Germination Techniques
- Potting
- Hardening

Preparation of Potting Soil

- Fast root development is enhanced when the potting soil is porous.
- Use sandy-loam soil that is high in organic matter or compost mixed with cured sawdust or rice stalks.
- Pulverize and then screen these materials & thoroughly mix the soil & organic matter (a 50:50 ratio is best)

6.18 Germination techniques

Avicennia group is considered semi-viviparous and easiest to germinate either in seed beds or directly in polythene bags. Seeds are sown in an upright position half buried with the emerging leaf or the cracked portion of the seeds at the ground level.

Rai, Garani, Sinduka and Bandari groups have viviparous seeds or propagules that are sown or planted directly in the field and have high survival rate in areas not exposed to strong waves

Sonneratia group seeds are sown in a seed box with sandy soil. Seeds are then covered with a thin layer of soil and watered daily with brackish water. Soak the fruit in fresh water for 7 days and sow the macerated seeds in depressed seed beds

6.19 Potting

Potting means transfer of **germinants** /seedlings from the seed box/bed to the plastic bag or pot where it is hardened before planting in the field.

- Potting is done by pricking the **germinants** using a flattened stake to minimize root damage.
- The seedling is 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 hypocotyles deep in an appropriately sized bag.

Illustration of germination

6.20 Seed germination & nursery technique

Sl.	Species	Step-1	Step-2	Step-3	Step-4
1	*Avicennia Spp*	Pre-treatment	Sowing	Pricking/ transplanting	Hardening
2	*Sonneratia Spp*	Pre-treatment	Sowing	Pricking/ transplanting	Hardening
3	*Bruguiera Spp*	Pre-treatment	Sowing	Pricking/ transplanting	Hardening
4	*Ceriops Spp*	Pre-treatment	Sowing	Pricking/ transplanting	Hardening
5	*Exocaecaria Spp*	Pre-treatment	Sowing	Pricking/ transplanting	Hardening
6	*Lumnitzera Spp*	Pre-treatment	Sowing	Pricking/ transplanting	Hardening
7	*Hibiscus/ Thespesia/ Pongamia*	Pre-treatment	Sowing	Pricking/ transplanting	Hardening

Seedling of selected mangrove species

6.21 Maintenance of seedlings

- **Watering**- Seeds & seedlings must be watered daily as early as possible every morning since failure to water even for one day can adversely affect the growth rate and survival of the plants. Well may be dug, if river is far or when no river.

- **Shading-**The newly potted seedling should be shaded from intense sunlight. Shading material usually consists of coconut leaves and wire mesh to gradually expose the seedling in the hardening process

- **Weeding** should be conducted regularly to keep the seedlings free from competition. At least once a week check all seed boxes, seed beds and hardening beds for weeds that might have sprouted

- **Hardening** is the process of pre conditioning seedlings in a nursery to the harsh field environment by gradually exposing the plants to increasing amounts of sunlight. Seedlings are fully exposed to sunlight and watering is reduced.

6.22 Typical hardening treatment

1st Week
- Remove first layer of shading (allowing 25 sunlight)
- Water once a day

2nd Week
- Remove second layer of shading (allowing 50 sunlight)
- Water once every 2 days

3rd Week
- Remove third layer of shading (allowing 75 sunlight)
- Water once every 3 days

4th Week
- No more shading
- No more watering

6.23 Protection from pests, diseases & stray animals

Pest/Disease	Damage	Control Measures
Tussock Moth (All Spp)	Larvae or hairy caterpillar feeds on leaves of young seedlings	Manual removal of larvae
Seed Borer (All Spp)	Bores propagules and breeds on seedling/hypocotyl	Exclusion of propagules with evidence of insects or holes
Aphids (All Spp)	Sucks nutrient of Rhizophora seedlings	Spraying with chemicals at Company s specification
Scale Insect (All Spp)	Sucks nutrients causing curling of leaves	Spraying with chemicals at Company s specification
Slug Caterpillar (All Spp)	Defoliation	Manual Removal of larvae
Bag worm (All spp)	Defoliation	Manual Removal of bagworm
Leaf Spot Rhizophora spp	Brown spot interferes with photosynthesis; defoliation if severe	Removal of infected leaves and burning
Rhizophora mosaic	Defoliator; Interferes with photosynthesis	Removal of infected seedlings and burning

6.24 Record management

Species	Provenance	Date of collection of propagule /seed	Date Sown	% Germination	Date Planted	% Survival	Remarks
Rai	Bhitarkanika	July 15, 2008	July 20, 2008	98	Oct. 15, 2008	90	As of April 15,2009
Dot	Subarkanika	Aug 26, 2008	Aug 30, 2008	95	Dec 10, 2008	85	As of June 15, 2009
Bani	Eramadia	Sept 15, 2008	Sept 20, 2008	90	Feb 15, 2009	88	As of Aug. 15, 2008

6.25 Grading, sorting, packaging & transport of seedlings

- After hardening, the seedlings should be graded using pre decided criteria.
- Normally, the criterion is height to at least 30 cm 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.
- The seedlings that do not meet the grading criterion should be reared further in the nursery until the desired size is met
- The seedling shall be subjected again to the hardening process before out planting.

Grading, Sorting and Packing

6.26 Post nursery operations

- When all the seedlings are already taken out for planting in the field, the nursery should be prepared for the next batch of seedlings.
- Some repair of the infrastructure & retooling of equipment may be necessary.
- Likewise, cleaning and sanitation of the nursery should be done to prevent infestation of the incoming seedlings.

Raising Avicennia Nursery

Poly bags filled with silt soils collected from Natural creeks.

Avicennia seed grading before dibbling in polypots.

Seed dibbling in the poly pots by experienced women

Straw covered on the seed bed to keep favorable temp. & moisture

Regular monitoring of the seed germination by Nursery caretakers

Germination of Avicennia seeds with two leaves & attached cotyledons.

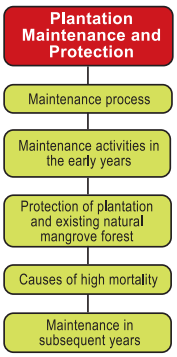
Mangrove seedlings with Four leaves and attached cotyledons

Mangroves seedlings with Six to Eight leaves in the nursery

Part of the nursery view after inundation by tide

CHAPTER-7

PLANTATION
MAINTENANCE and PROTECTION



Organize Social Fencing

Mobilize and Organize the members of EDC to reverse the trend of mangrove degradation and serve as social fence in order to develop their sense of ownership thus embedded in their regular daily routine the responsibility to protect , manage and sustain the initiatives and interventions of OFSDP;

Current Situation, OFSDP Interventions and Shared Visions-Goals-Objectives of FD and EDC

Forge a formal arrangement and provide security of tenure and incentives to sustain and institutionalize the responsibility and commitment of the EDC as stewards of the coastal-mangrove resources.

7.1 Maintenance Process

- The first two years after their establishment are probably the most intense phase of care for plantation
- Generally, from 3rd through 4th years the level of care is somewhat less.
- The 5th year sees an increase in care because this is the time for first thinning if growth has been normal and the economic size of desired products is attained
- The 6th through 14th years see a period of relatively low maintenance in longer maturing species.
- In most other longer maturing species, the 15th year see a round of thinning.
- ears 16th through 19th are typically ones of low maintenance.

7.2 Maintenance activities in the early years

- Regular visits
  - Develop a routine so that the entire plantation is inspected at least every other day. It is best conducted at low tide since it will be easier to walk around the plantation;
- Removal of debris
  - Removal of floating green algae before it can carried & dump into the seedlings and can do much damage;
  - Removal of debris that might adversely affect the seedlings including driftwood, fishing nets and other heavy materials that can knock over the seedlings or damage them by tearing their back;
- Installation or fence repair
- Removal of barnacles and other pests
- Up-rooting and replacement of sick or dead plants.
  - Replanting (20 Allowance for Mortality every year for 3 years
  - Regular Removal of Debris, Sea Grasses and Barnacles

  - Maintenance of Main Channels for supply and distribution of brackish-water and if permissible use the main channels for crab culture by the EDC as income generating activity which provide additional source of income hence incentive to them to effectively protect mangrove plantation and existing forest
- Gap planting or replacement of dead planted seedlings is necessary since the average overall survival rate of each village –plantation ranges from 40-60 only. Set the standard passing rate of survival to 85 . The project prescribes a 3 and 2 years maintenance for Mangrove and Casuarina plantations respectively;
- *Tending and Silvicultural Treatment*
  - Pruning (Root and Branches)
  - Thinning (20 after 5 years)
  - Sanitation/Salvage Cutting of those defected trees/stand maybe utilized for firewood and fodder
  - Pruned parts/ leaves will be utilized as fodder and firewood
  - Thinned Trees including leaves will be utilized for firewood and fodder
- *Establishment of Seed Production Areas in the Plantation of ifferent Species*
  - Selection of Seed/Plus Trees
  - Marking/Tagging
  - Growth and Physical Form Measurement
  - Monitoring of uantity and uality of Seeds/Hypocotyle

7.3 Protection of Plantation and Existing Natural Mangrove Forest

- Boundary Fence: Fencing is necessary to keep the livestock such as cattle and buffalo away from the plantation.
  - Planting of at least 5 layers of thorny trees such as Babul along the embankment which will effectively serve as live fence after 2-3 years;
  - Live fencing or planting of thorny plants & non-palatable plants such as Caesalpinia bonducella (Gilo), C. crista (Nentei), Prosopis aphylla, Acacia nilotica (Babul) & Excoecaria agallocha (Guan) are suitable

local species thriving in the High to Extremely High Ground areas which are potential for live/green fencing;

- Trenches/Canals
  - If necessary, cattle-bufallo proof trenches should be excavated along the embankment at the side of paddy or prawn-pond areas. These trenches-canals maybe used also as site for pisciculture (crab and prawn culture). The design and construction of trenches should consider the soil instability and erosion rate of silt and sandy soil;
- Combination of Live Fences and Trenches
- Regular/Daily Patrolling by Full time Watchman
- Regular/Daily Patrolling by EDC in Rotation Basis

7.4 Causes of high mortality

Common causes and practices responsible for high mortality rates in mangrove planting are:

- Sites selected are not suitable for mangrove planting such as the area infested by pests such as shells, barnacles, filamentous algae;
- Sites are not drained daily as tides receded during low tides and battered with strong current and wave;
- Species selected are not suited to actual bio-physical characteristics of the area such as low ground species are planted in high ground areas and vice versa;
- Sowing or planting of propagules more than half of their length in the soil. Other seeds (such as ylocarpus, Aegiceras spp) should be sown just below the substrate.

7.5 Maintenance in subsequent years

Thinning is felling of some trees to reduce competition from sunlight, nutrients & soil moisture in order to improve the quality of the stand.

- It is performed only two or three times during the life of the stand.
- The timing and number of thinning depend on the expected age at harvest for the trees.
- After each thinning/stage count how many have been felled. If the target has been reached, thinning must stop.

- First, fell only those trees that are obviously malformed, stunted or sickly. Next, fell those trees that appear to be significantly shorter than the surrounding trees. Finally fell the trees that are not as tall as the average trees.

Pruning- is cutting of unnecessary branches and stems. Pruning is done to:

- Enhance height and trunk diameter growth rate;
- Improve the tree form and wood quality.
- The following are some pruning rules to avoid adverse effect on trees:
  - Do not cut more than 30 of the live crown over a 1-2 year period;
  - Paint stub preferably with tar to prevent fungal attack;
  - Cut smaller branches close to the trunk to increase merchantable height;
  - Use pruning saw attached to a long pole to reach branches up to 5 m in height.

7.6 Harvesting & Regeneration

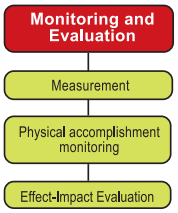
Since the intention of regeneration is for sustainable forestry systems, it is important that the plantations are harvested & regenerated in that manner so that the future generation can make use of the economic and ecological benefits.

- **Harvesting –** The appropriate harvesting techniques for four major products:
  - **Firewood or Charcoal** harvesting can begin at the time of the first thinning for plantations & all other planting strategies. Thinning and pruning can be used as a method of firewood harvesting. If the Rhizophora & Bruguiera plantation has been established solely for firewood, the tip of the seedlings can be split to encourage branching. Initial spacing for such plantation should be at least 1 x 1 m (10,000 seedlings/ha). This is done to encourage crown development & maximize the yield of branches for firewood. The plantation should be matured enough, with usual thinning & pruning, to support sustained harvesting between the 7th & 12th years after planting. At that time, firewood can be harvested exclusively from the top branches of individual trees allowing the lower branches to regenerate.

- **Piles, Poles, Posts and Timber** In the plantation developed for producing these products, it is possible and indeed desirable to harvest firewood. By aggressively pruning side branches after the first thinning (while leaving the crown alone), energy will be directed into producing more trunk wood and therefore bigger and taller poles more quickly. As thinning and pruning are used to produce firewood it also is possible to shift to selective cutting and remove poles on an as needed basis. This would help to move the plantation towards a seed tree form of forestry where the largest seed or mother trees are kept for seedling production and the middle story is harvested for poles or posts.
- Traditionally, **fodder** harvesting has been done for cattle, buffalo and goats. Fodder (the leaves and shoots from the cut branches) is taken from pruning and thinning activities and given to these animals. Fodder can be obtained as part of thinning and pruning activities. It is important to make certain that there is enough fodder to support the number of animals you want to grow.. Overgrazing by cattle and buffalo has caused significant loss to mangrove forests.
- **Regeneration Systems-** This refers to cutting methodologies used to make certain that a forest remains as felling continues. When properly pursued, regeneration systems allow for a virtually continuous harvest..
- **Selective felling -** The more the trees are felled in selective harvesting, the faster the remaining trees grow since much more sunlight reaches the ground. The new openings created by the harvest also hasten regeneration. This method can lead to a more or less naturally regeneration method called the Seed Tree and Plant method.
- **Strip Cleaning / felling -** is typically done in larger plantation (greater than 10 ha). A strip 10-20 m wide by 50-100 m long is cut at a 45 degree angle from the sea to lessen the impact of waves and to enhance regeneration by recruitment of wildlings or new planting. Alternating strips of forest are harvested. The harvested areas are allowed to re-seed naturally or are replanted. The seed tree and plant method also can be used in strip cutting. A total of 40 mature trees can be left in place to act as seed trees. Over time, the forest naturally regenerates.

CHAPTER- 8

MONITORING and EVALUATION



8.1 Measurement

- The net planted area should be measured on the ground and mapped to determine the actual area planted,
- Average survival rate should be determined by 20 systematic sampling every six months for 2 years,
- Average height and diameter should be measured by at least 10 systematic sampling once every year for at least 5 years,
- The environmental effect and impact of coastal- mangrove plantations should be measured once a year for at least 5 years.

8.2 Physical accomplishment monitoring

- Villagers-EDC Proposed Environmental and Socio-Economic Monitoring and Impact Indicators (ointly Conducted by PMU-DMU's-FMU's and EDC)
- Physical Accomplishment
  - Actual Area Planted
  - Total Potted Seedlings Planted by Species and Spacing with and without fishbone
  - Total Hypocotyle Directly Planted by Species and Spacing with and without fishbone
  - Total Seeds Dibble Directly Sown by Species and Spacing with and without fishbone
- Survival / Mortality (10 sampling)
  - Survival of Potted Seedlings Planted by Species and Spacing with and without fishbone every 6 months for 2 years.
  - Survival of Hypocotyle Directly Planted by Species and Spacing with and without fishbone every 6 months for 2 years.

  - Survival of Seeds Dibble Directly Sown by Species and Spacing with and without fishbone every 6 months for 2 years.

8.3 Effect-Impact evaluation

- Measurement of Growth-Height (5-10 sampling)
  - Growth-Height of Potted Seedlings Planted by Species and Spacing with and without fishbone every year for 5-10 years.
  - Growth-Height of Hypocotyle Directly Planted by Species and Spacing with and without fishbone every year for 5-10 years.
  - Growth-Height of Seeds Dibble Directly Sown by Species and Spacing with and without fishbone every year for 5-10 years.
- Measurement of Growth-Diameter (5-10 sampling)
  - Growth-Diameter of Potted Seedlings Planted By Species and Spacing with and without fishbone every year for 5-10 years.
  - Growth-Diameter of Hypocotyle Directly Planted by Species and Spacing with and without fishbone every year for 5-10 years.
  - Growth-Diameter of Seeds Dibble Directly Sown by Species and Spacing with and without fishbone every year for 5-10 years.
- Monitoring of Diversity and Density of Fauna at least 10 sites in every ground level plantation with and without fishbone and control in site without plantation every end of dry (May) and rainy season (Nov) on the 3rd year onward
  - Macro-benthic fauna 30 cm below ground.
  - Macro-benthic fauna on the surface and above ground.