Green Coast

For **nature** and **people**
after the tsunami

Best Practice Guidelines on Restoration of Mangroves in Tsunami Affected Areas

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Contents

1. Glossary

Afforestation	Cultivating plants (mangroves) in an area where no plants (mangroves) grew previously
Air layering	A form of vegetative propagation where a branch is stimulated to form roots while still on the parent plant by removing part of the bark and keeping the area moist
Cotyledon	Leaf forming part of embryo or newly emerged seedling
Ecosystem	Part of the environment that can be recognized with geographical margins due to the characteristic plants and animals that live in them and perform functions as a result of the interactions among its components, both biotic and abiotic
Habitat	Physical space in which an animal or a plant lives
Hypocotyl	The prominent green or greenish brown part of the germinating seed (viviparous) that will give rise to roots at its pointed end.
Inter-tidal zone	Area between land and sea that is flooded during high tide and exposes during low tide
Mangrove associates	Plant species that are found to occur in mangrove as well as in other wetlands, particularly in freshwater marshes
Propagules	Partially germinated seeds with characteristic presence of the hypocotyls, any seed, fruit or other portion of a plant which is able to produce a new plant
Pneumatophores	Roots that grow out of the soil and maintain air passage with the underground root during high tide or breathing roots
Reforestation	Cultivation of mangroves in a deforested mangrove area
Sapling	A young tree
Seedling	A very young plant grown from a seed
Stem cutting	A cut branch of a tree, 12 – 15 cm long with 3 -5 or more nodes, used for vegetative propagation
Stomata	Pores on a plant leaf surface through which water is lost through transpiration
Supra-tidal	Areas that lie immediately above the highest tidal flood level
Transpiration	Water loss through stomata in a plant
True mangrove species	Mangrove species that occur exclusively in the inter-tidal areas or typical mangrove areas
Viviparity	Germination of seeds while it is attached on to the parent tree
Wildlings	A transplanted seedling/ sapling

2. Mangroves

What are mangroves?	Mangroves are a salt-tolerant group of tropical plants that occupy the inter-tidal zones of the sheltered coasts such as estuaries and lagoons. They are variously adapted to cope with the unfavourable environmental conditions for growth and reproduction resultant by inundation with salt water, unstable soils due to tidal flow and lack of freshwater
Why are they unique?	
Breathing roots	Most mangroves have unusual structures to provide them with air during the high tide that they get flooded with salt water. Roots are usually developed towards earth but some mangroves have roots coming out of soil and grow into air to remain above the tide levels so that the connection between the submerged part of the root system and the atmosphere is maintained and a continuous supply of air is received by them even when flooded. These abnormal breathing roots are **adaptations** characteristic to mangroves.
Salt glands	Some other mangroves have devices to exclude salt from their leaves so that salt will not affect their health. Some can exclude salt in water from their roots while some others store them in their leaves (vacuoles) and shed them periodically
Storage of water	Freshwater is precious in a saline environment and it is stored in mangrove leaves and hence they are fleshy. Freshwater in the plant is lost through pores (stomata) in the leaves and some have relatively a few pores and some others have them covers with hairs so that less water is lost through them. Most leaves have shiny, waxy surfaces to reflect sun rays so that the leaf temperature is kept low and the water loss is reduced. This layer also protects water in the leaf through reducing transpiration
Viviparity	Inter-tidal areas are not at all favourable for seed germination as there is no freshwater and a suitable place to anchor themselves. This problem is evaded by having an unusual method of seed germination called **viviparity,** where seeds start germinating while they are still attached to the parent plant, a condition that allows the seeds to obtain freshwater from the parent plant and evade saline environment that is unsuitable for seed germination.
Prop/ stilt roots	The problem of unstable soils in the mangrove areas that makes standing the plants upright is difficult is overcome by having prop and stilt roots that give extra support to the trees to be erect.

3. Why should mangroves be restored?

Ecological functions/ Environmental services	Mangroves as an ecosystem are capable of performing certain functions or environmental services. Mangrove plants produce organic matter through photosynthesis and this produces the food for most of the fish and shellfish in the coastal waters. Fish and shrimp catches increase with the increasing presence of mangroves in the inter-tidal zone. They also provide habitats and serve as nursery grounds for the juveniles of aquatic organisms on which important fisheries are based on.
Erosion barriers	Mangroves with their characteristic root system are capable of reducing erosive forces of waves, tidal currents and consolidating sediment, thus check erosion. Superiority of mangroves against engineering structures in withstanding high wave energies and protecting coastal areas was evident during the Indian Ocean tsunami in 2004.
Wind barriers	Mangroves serve the function of wind breakers in the coastal areas that frequently subjected to monsoon winds.
Forest products	Mangroves are primarily used for light timber requirements and firewood. Non-wood products , bark (for tannin), leaves (fodder and vegetables), fruits (to make beverages), honey, wax and thatching material as well as finfish and shellfish are also collected from mangrove ecosystems.
Reduces salt water intrusion towards land	While reducing the energy in waves, mangroves absorb salt along with water and store them inside plant tissues.
Extent of mangrove destruction	With all the tangible and intangible benefits of mangroves, they are being destroyed and areas reclaimed for other land uses such human settlements, urban development, industries, shrimp farms, highways and dumping grounds of solid waste.
Impact of tsunami on mangroves	Observations in the aftermath of the Indian Ocean tsunami in December 2004 revealed that mangroves (and other coastal vegetation) are capable of effectively dissipating energy in waves and thus perform a coastal defense function. Inferiority of exorbitantly expensive engineering structures in coastal protection has been manifested in many an occasion and therefore a protection strategy based on natural defensive capacity of coastal vegetation, particularly of mangroves, has come into limelight as an alternative strategy.

4. Objective of the Guideline

Mangrove restoration	Re-introduction and re-establishment of assemblages of native mangrove species to sites that can support them to be developed into mangrove ecosystems which perform similar functions as those that were there originally.
Objective of restoration	Re-establishment of habitats (structure) and functions such as coastal protection, contribution to fishery production, enhancement of aesthetic quality of the landscape that have been lost.
Objectives of the guidelines	To provide the reader with appropriate knowledge and understanding over the following aspects of mangrove silviculture (planting) for coastal protection 1. Uniqueness of mangroves and the potential benefits of their cultivation 2. Identification of appropriate land for mangrove cultivation 3. Selection of mangrove species and combinations for planting 4. Methods of mangrove cultivation 5. Technical knowledge on establishment and maintenance of mangrove nurseries 6. Factors that affect success of mangrove plantations 7. Techniques of after-care 8. Strategies to mobilize communities for mangrove silviculture

5. Factors to be considered for successful mangrove restoration

Factors affecting mangrove restoration success	▪ Soil stability and flooding pattern ▪ Elevation of the site ▪ Soil/ water salinity and freshwater input to the site ▪ Tidal and wave energy associated with the site ▪ Availability of propagules/ seed material ▪ Spacing and thinning of plants ▪ Presence of weeds ▪ Success of nursery techniques ▪ Monitoring the progress ▪ Incidence of propagule predation ▪ Cost of restoration ▪ Cooperation of the local inhabitants
Aspects to be paid attention to	▪ Identification of appropriate sites for mangrove cultivation (soil stability, flooding regime, elevation, extent of pollution) ▪ Selection of species/ species assemblages suitable for the soil and hydrological conditions of the site ▪ Quality of the planting material ▪ Adoption of an appropriate planting technique ▪ Reduction of predator pressure ▪ After-care practices ▪ Mechanisms to obtain local community participation and support for restoration

6. Identification of sites for mangrove cultivation

Areas where mangroves occur	All mangroves occur in inter-tidal areas that are sheltered from high energy waves such as those in estuaries and lagoons. They cannot be found naturally and therefore grown in beaches exposed to waves.
Soil conditions of inter-tidal zones	Although the inter-tidal zone is a strip of land between land and sea, its' soil conditions vary from the water-front areas towards inland. In areas where the difference between the high and the low tides is large (2 m or more) the inter-tidal area is flushed well everyday. In such areas soil salinity (salt content) is observed to decrease towards land. On contrary, areas where the tidal difference is low, like that in Sri Lanka where the maximum high tide recorded is less than 1 m, except for rains, the inter-tidal areas are not flushed well, thus salt tends to accumulate in the landward margin of the inter-tidal areas. In arid coastal areas such as on the north western, northern and south eastern, the salinity builds up to such an extent, that tall inter-tidal vegetation such as mangroves is not possible to establish, instead short, salt-tolerant, herbaceous salt marsh plants tend occupy the highly saline areas. Under extreme salty conditions salt flats are formed where no vegetation occurs. Therefore salt marshes and salt flats should be avoided for mangrove cultivation
Hydrological conditions of inter-tidal zones	Besides, the input of freshwater from rivers/ streams as well as from surface runoff during rainy periods too affects soil salinity periodically. In an estuary, salinity of surface water that floods the potential mangrove areas (inter-tidal areas) and therefore the soil salinity itself decreases towards upstream. Salinity of the waters and the inter-tidal soils of estuaries of perennial rivers with large discharge volumes such as those in the wet zone of Sri Lanka are comparatively lower than that of the estuaries in the dry zone where the discharge volumes are low and hence the extent of salt water movement upstream, particularly during low rainfall period is high, causing the water and the soil salinities to increase.
Availability of nutrients for plant growth	The major source of inorganic nutrients for inter-tidal plant growth is the land-derived nutrients brought in by the rivers and streams. As such, mangroves in estuarine inter-tidal areas receive the highest amount of nutrients and thus show maximum growth. Since localities away from rivers and streams receive relatively little amounts of plant nutrients, mangroves planted in such areas will take considerably a long time to grow in to mature pants. Mangrove plantations in the estuaries will grow faster than those in other areas.

7. Mangrove plant species for cultivation

Twenty true mangrove and eighteen mangrove associated species have been recorded from south western coast of Sri Lanka alone and records from other parts of the island extends the true mangrove list up to 29. According to their abundance and extent of distribution they can be categorized as very common (widely distributed and abundant) common (widely distributed in low numbers) and rare (restricted distribution in low numbers), as presented in Table 1. The very common species appear to grow under a wide range of soil and hydrological conditions, indicating that they are the most appropriate species for mangrove reforestation/ afforestation.

Table 1: Common and rare true mangrove plant species of Sri Lanka.

Vernacular name (Sinhala – S; Tamil – T)	Scientific name	Distribution
Very common true mangrove plant species		
Manda (S); Kanna (T)	*Avicennia marina*	In all mangrove areas
Mal Kadol (S)	*Bruguiera gymnorrhiza*	Wet coastal areas
Thela (S); Thilla (T)	*Excoecaria agallocha*	In all mangrove areas
Beriya (S); Tipparethai (T)	*Lumnitzera racemosa*	In all mangrove areas
Maha Kadol (S); Kandal (T)	*Rhizophora mucronata*	Western, southern, SW and SE coasts
Maha Kadol (S); Kandal (T)	*Rhizophora apiculata*	Western & southern coasts
Kirala (S); Kinna (T)	*Sonneratia caseolaris*	Wet zone coastal areas
Common mangrove plant species		
Katu ikiliya (S); Mulli (T)	*Acanthus ilicifolius*	Disturbed inter-tidal areas
Heen kadol (S); Vethilikanna (T)	*Aegiceras corniculatum*	All mangrove areas in low abundance
Manda (S); Kanna (T)	*Avicennia officinalis*	Sporadically on western coastal areas
Mal Kadol (S)	*Bruguiera cylindrical*	Abundant in Kala oya estuary
	Bruguiera sexangula	Sporadically in the wet zone
Rathu kadol (S); Chirukandal (T)	*Ceriops tagal*	All mangrove areas in low abundance
Ethuna (S)	*Heritiera littoralis*	Estuaries on the west coast
	Pemphis acidula	Arid inter-tidal areas
Kirala (S)	*Sonneratia alba*	Puttalam lagoon
Gin Pol (S)	*Nypa fruticans*	Estuaries of wet zone
Rare mangrove species		
Beriya	*Lumnitzera littorea*	Madu ganga estuary
	Scyphiphora hydrophyllaceae	Puttalam lagoon
Mutti Kadol (S); Somuntheri, Kadal manga (T)	*Xylocarpus granatum*	Puttalam and Negombo lagoons

8. Identification of common mangrove plants

Leaf shapes, presence of breathing roots and their shapes as well as the shape and size of propagules (with hypocotyls) are useful characters for mangrove plant species identification. Figures 1, 2 and Plates 1, 2, 3 and 4 present these features of the major mangrove plant species that are used for restoration/ afforestation.

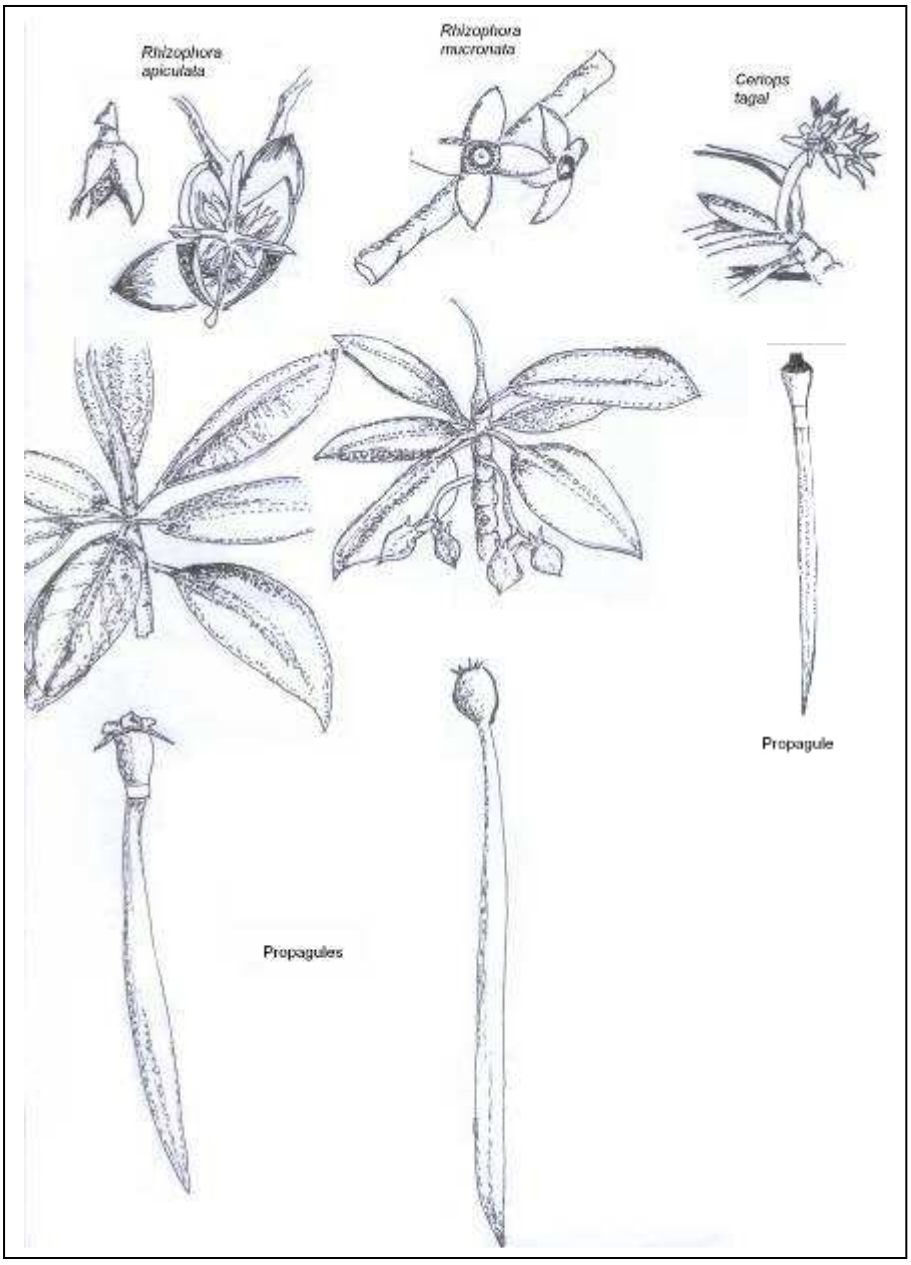

Fig.1 : Leaf and propagule characteristics of *Rhizophora apiculata, R. mucronata* and *Ceriops tagal.*

Photograph By Manoj Prasanna

Plate 1: *Lumnitzera racemosa* (Beriya)

Photograph By Manoj Prasanna

Plate 2: *Avicennia marina* (Manda)

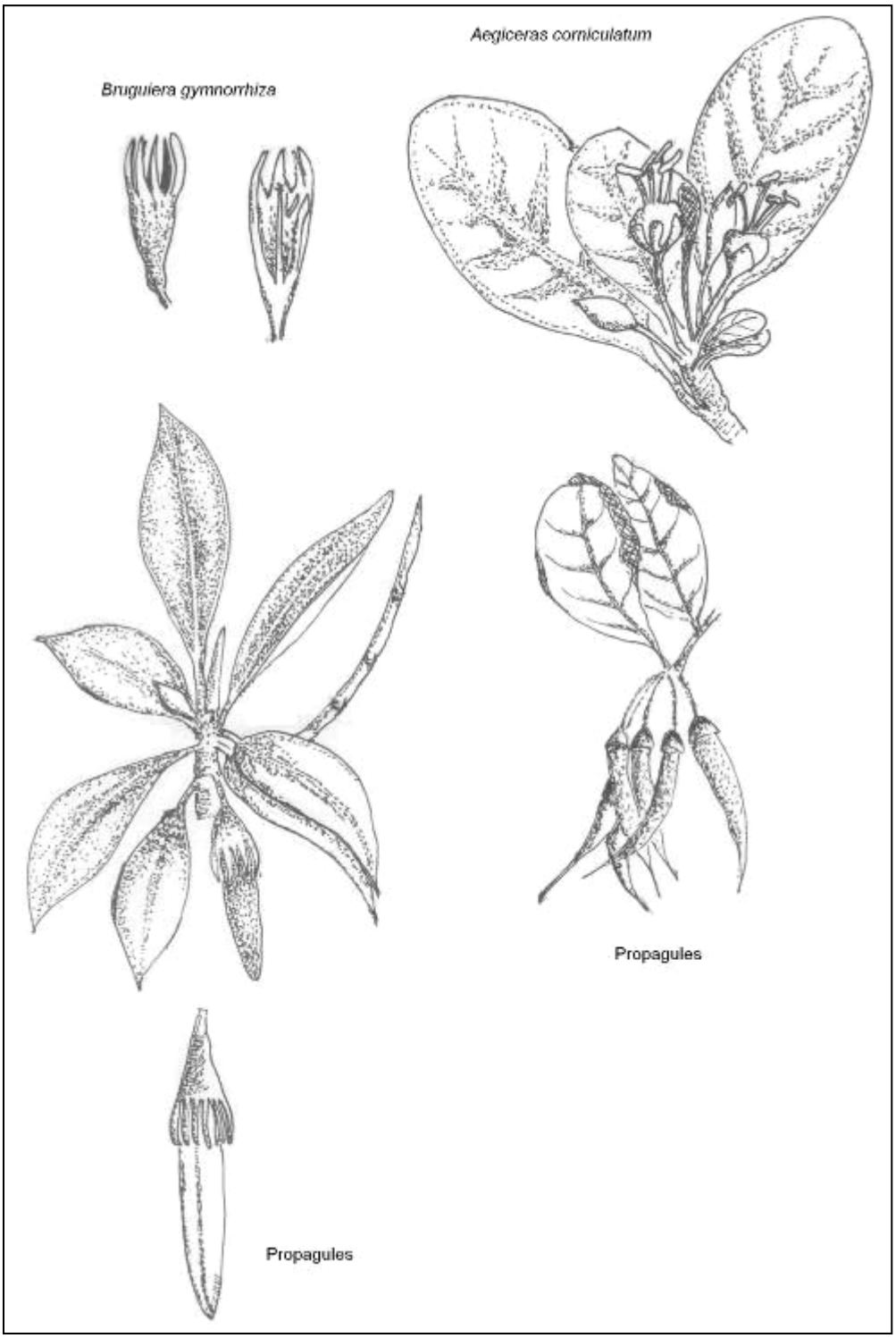

Fig. 2 : Leaf and propagule characteristics of *Bruguiera gymnorrhiza* and *Aegiceras corniculatum*

Photograph By Manoj Prasanna

Plate 3: *Excoecaria agallocha* (Thela, Thelakeeriya)

Photograph By Manoj Prasanna

Plate 4: *Nypa fruticans* (Gin pol)

9. Knowledge useful for mangrove cultivation

Natural zonation of mangrove plants in an inter-tidal area

All mangrove plant species do not have the same ability to tolerate soil salinity , nutrient, wave energy and flooding (anaerobic) conditions that vary within as well as among mangrove areas. Depending on the soil, hydrological, extent to which the area is protected from waves with high energy and nutrient conditions of the inter-tidal area, mangrove species occupy different localities in an inter-tidal area, forming zones of vegetation. Each zone is composed of either one or a few species of mangroves that can tolerate its environmental conditions. Knowledge on mangrove zonation therefore is essential to determine suitable candidate species for planting. Although natural zonation depends also on dispersal of propagules from water towards land which is determined in turn on the size and weight of the propagule and the strength of the tidal current, it is not a critical factor in that affect success of cultivation of mangroves as propagules are transported to the site of cultivation. Figure 3 presents a typical mangrove vegetation profile of an inter-tidal area, where zonation of mangrove plant species from water to land is depicted.

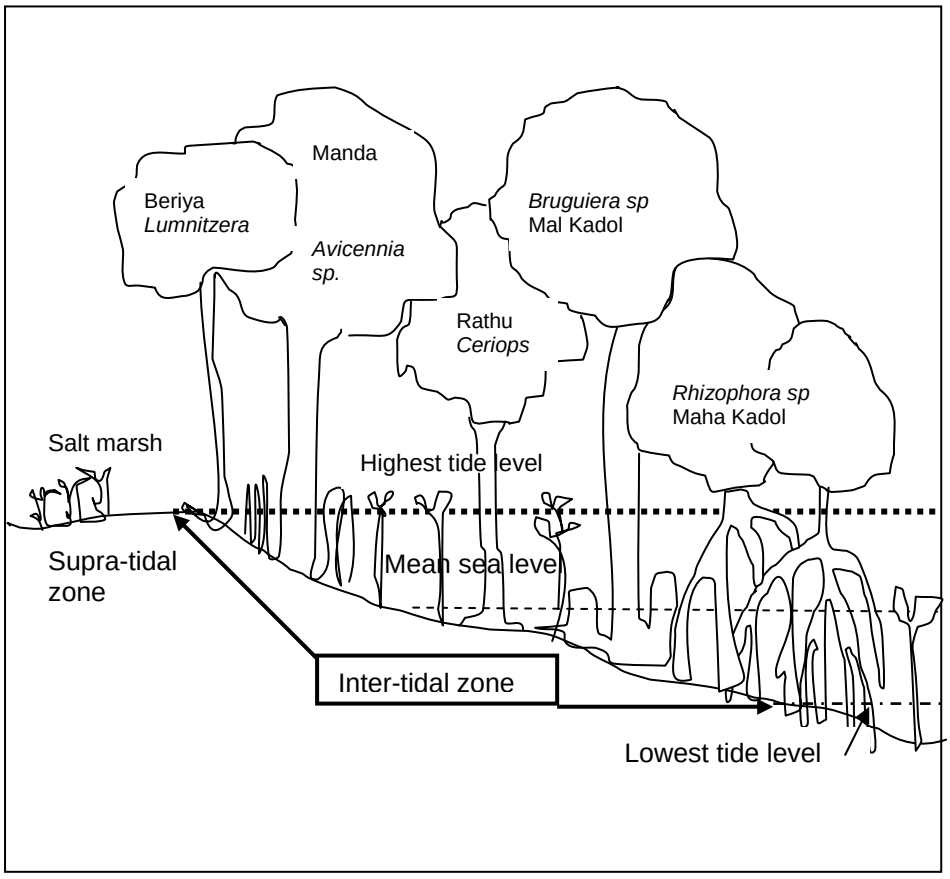

Fig. 3: Vegetation profile of an inter-tidal area occupied by mangrove plants, showing typical zones from water to land.

10. Selection of mangrove plants for cultivation

Simple method	Consulting the inhabitants of the area who knew about the species that were present previously in the locality. If hydrological conditions of the inter-tidal zone have not been changed drastically, those species will be the ideal to reforest such an area. Identification of the tree stumps (of the destroyed mangrove area) will also give an idea as to the species that were present before destruction.
Mangrove plant species of high salt tolerance (> 25 ppt)	*Avicennia marina, Avicennia officinalis, Aegiceras corniculatum, Lumnitzera racemosa* , *Rhizophora mucronata, Pemphis acidula* They are suitable to be cultivated in ▪ the seaward end of estuaries where the freshwater discharge is low (in the dry climatic zones) ▪ inter-tidal zone of lagoons in the dry climatic zone ▪ landward margin of mangrove stands in lagoons and estuaries of the dry zone
Mangrove plant species of moderate salinity tolerance **(15- 25 ppt)**	*Rhizophora apiculata, Ceriops tagal, Bruguiera gymnorrhiza, Bruguiera cylindrica , Xylocarpus granatum, Acanthus ilicifolius* These species are appropriate to be planted in ▪ seaward areas of estuaries and lagoons in the wet zone
Mangrove plant species of low salinity tolerance **(< 15 ppt)**	*Sonneratia caseolaris, Acrostichum aureum,Cerbera manghas,* *Excoecaria agallocha, Anona glabra , Heritiera littoralis, Nypa fruticans* These plants are suitable to be planted in; ▪ the upper reaches of estuaries ▪ supra-tidal areas that can be irrigated with freshwater ▪ estuaries with high freshwater input (wet zone)

11. Mangrove seeds and planting material

Mangrove propagation	Mangroves are propagated with seeds (partially germinated), nursery grown seedlings/ saplings, with wildlings, stem and propagule cuttings and air layers. They can also be propagated by transplanting nursery grown seedlings and saplings
Collection of seeds/ propagules	
Rhizophora sp	Mature propagules can be collected year-round from parent trees. Propagules fallen on ground and casted ashore also can be used.
Avicennia marina	From parent trees with the seed coat intact, and then stored in shade
Other species	Seeds/ propagules of other species also can be collected from parent trees or from the ground (fallen) and those that have been cast ashore.
Propagation through propagules	
Maturity characteristics of propagules	▪ Development of a yellow or pale green collar at the base of the hypocotyls – *Rhizophora, Ceriops* ▪ Bulging fruits that detach from the parent tree with slightest touch by hand – *Avicennia* ▪ Colour change in the fruit (from green to brown) – *Heritiera, Xylocarpus, Lumnitzera, Cerbera.* Fruit changes from green to pink – *Aegiceras*
Transportation	Propagules are packed in plastic bags and transported to the planting site. Care should be taken not to damage the growing parts during transportation
Storage of seeds/ propagules	
Avicennia marina	> 4 – 6 days under moist conditions in plastic bags
Aegiceras corniculatum	15 days
Lumnitzera racemosa	
Sonneratia sp, Heritiera	4 weeks
Xylocarpus sp.	2 months
Rhizophora propagules	In plastic bags for 40 - 45 days under moist and shady conditions
Pretreatment of seeds (to facilitate germination)	▪ No pretreatment is required for *Rhizophora, Bruguiera* and *Ceriops* propagules
Reduction of palatability of predators (seasoning)	▪ Storage in containers with high moisture for more than 3 days, under natural shade, *Sonneratia, Lumnitzera*
Weakening seed coat to facilitate germination	▪ Soaking seeds in water – *Xylocarpus* (stagnant or flowing water for 1 week) ▪ Manual removal of the seed coat – *Aegiceras*
Time taken for seed germination	▪ One week - *Avicennia* ▪ Two weeks - *Sonneratia, Rhizophora* ▪ Four weeks - *Aegiceras, Lumnitzera, Heritiera* ▪ Eight weeks- *Xylocapus* Best time to dibble
Propagation through stem cutting	▪ Healthy branches of 12 – 15 cm long should be cut from the parent tree and

	use the plant hormones, Indole Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) to promote root development and plant in polythene bags prior to planting
Propagation through propagule cutting	▪ Can be used for Rhizophora, Bruguiera and Ceriops species ▪ Cut mature propagules in to pieces of 2 – 5 cm long using a clean sharp knife and place the basal part of the pieces in a solution of sodium carbonate (20 g)and sodium tungstate (20 g)solution (80 ml of distilled water, later diluted to 100 ml) for 5 – 10 mins and wash in water and subject to hormone treatment and plant them in polythene bags prior to planting
Propagation through air layers	▪ Remove the bark of the selected branch at 2-5 cm below the node leaving 2 – 4 mm strip of bark intact. Apply the root promoting hormone around the de-barked area using a fine brush and a mixture of sand and clay (3:7) or coir dust must be held around the debarked area using polythene and tie it tight as to prevent water seeping into the rooting medium. Moistening these branches will produce roots within 40 – 60 days and then these branches are cult and planted in polythene bags, watered with saline water (20 ppt) and later planted in the restoration site

12. Mangrove plant nerseries - site preparation

Advantages of a mangrove nursery	Provides seedlings (potted) for plantation even during the times that seedlings are unavailable in natural mangrove areas Able to produce large numbers of seedlings required to plant larger area, even if they are found distant to the sources of seeds/ seedlings
Sites for nursery establishment	An upper or middle inter-tidal area, with gentle gradient and protected from waves and currents The sites should be of silty-clayey mud (substratum) Areas should be flooded by tides daily and should lie close to a freshwater source
Nursery beds	All debris, grass etc. should be removed and level the land where the nursery beds are going to be done. In areas where the tidal range is low and thus the flooding is insufficient to maintain the seedlings, a drain should be dug to allow free flow of tidal water to and from the beds. The bed may be surrounded with a bamboo frame to demarcate the area. If no tree canopy is present, a shelter to avoid the seedlings being directly exposed to sunlight, should be erected above the beds. They should be located parallel to the tidal flow. Distance between two beds may be a minimum of 1m. Size of the bed may depend on the area available for the purpose. Board walks to move around nursery beds is convenient to work in the nursery. Edges of the beds may be supported with bamboo splits to avoid polythene bags being washed away with tides.
Preparation for raised nursery beds	Growing plants on raised beds of sand is ideal to be established in the supra-tidal areas that could be irrigated with sea water to flush out the accumulated salts in the root zone.
Medium used in polythene bags	Mud/ Soil collected from the mangrove areas A few holes should be made around and at the bottom of the bags

13. Nersery preparation

Propagule planting methods	Propagules with evidence of diseases, deformities or damages, small, non-uniformly colored, broken or bruised propagules as well as those showing signs of attack by borer insects should be avoided. Propagules may be planted in a vertical position in 7" by10" plastic bags filled with mangrove soil, partially embedded in the bed to prevent being washed away with the tides. The tapering end of the mature propagules should be gently pushed in the polybags upto 1/3rd or 1/4th of the hypocotyls' length
Seed planting methods	*Avicennia* - Sowing or placing the seed in a hole, at least one inch deep in the mud, in polythene bags or clay pots which can be transferred to planting site *Sonneratia,*– Broadcasting, transplanting young seedlings from the wild, in polythene bags *Xylocarpus* – Growing seeds in polythene bags
Wildlings	*Lumnitzera* and *Sonneratia* seedlings can successfully be uprooted and placed in polybags for further growth under nursery condition, before it is being transplanted in the restoration site. Young seedlings (wildlings) of other mangrove species too could be used for restoration.
Nursery care	In areas where the tides flush the nursery everyday, no irrigation is required. In areas where the tidal amplitude is low (such as in Sri Lanka) nursery seedlings may have to be irrigated with salt water. If the soil salinities build up, irrigation with freshwater twice a week may be appropriate Segrasses, seaweeds and other debris that reach the nursery plants at high tide should be removed manually to prevent the plants being covered with them, which can result their death. Seedlings should be nursery raised nearly for 6 months until they are 30 – 40 cm long.

14. Mangrove planting / Transplanting techniques

Where to plant the propagules and seeds? Figure 1	Follow the natural zonation. Rules of thumb, ▪ *Rhizophora* that can tolerate high inundation and deep mud, should be planted close to water ▪ *Sonneratia* and *Excoecaria* be planted close to water in the upper reaches of estuaries where the salinity is low ▪ *Avicennia* and *Lumnitzera* should be planted in the areas close to hinterland ▪ *Ceriops and Bruguiera* be planted in areas between waterfront and landward
Planting method *Rhizophora* - propagules nursery grown seedlings and wildlings	▪ Embed nearly 15 cm of the propagule in a hole made in the mud using a wooden stick. To avoid crab predation paint hypocotyls in yellow or place them inside a piece of bamboo (to cover the part hypocotyls easily eaten by crabs. ▪ Planting distance – 1.5m x 1.5m
Sonneratia alba, *Xylocarpus granatum*, *Heritiera littoralis* and *Avicennia marina*	▪ Holes should be made using an auger/spade/ during low tide and place the seedling after cutting the polythene bag open ▪ Planting distance - 2m x 2m (need 2500 seedlings/ha) ▪ Wildlings should be uprooted with a root-ball with a diameter half the height of the sapling and transported to the site of restoration by wrapping the root-ball with a gunny bag or a polythene bag
Transplanting wildlings	Holes appropriate for the size of the root ball should be dug in the mud during low tide and carefully place the root-balled wildling in it and later covered the roots with mud. Younger wildlings could be transplanted in polythene bags and raised in a nursery before being planted in the restoration site or older saplings could be root-balled and transplanted directly at the restoration site.
Use of fertilizer	Five hundred grams of diammonium phosphate (DAP) and a few grams of iron oxide in a plastic bag. Seal it and punch two holes on one side of the bag with a small nail. The bag should then be buried next to the tree with the holes facing the tree

15. After-care operations

Intensive care should be given to the young seedlings in a plantation for the first 2 – 3 yrs. Following aspects are appropriate to be taken care of to establish a successful mangrove plantation.

Algal growth	All algae (seaweeds) that are entangled with the transplanted seedlings/ propagules should be removed by hand during low tide to reduce seedling mortality Effect of algae can also be prevented by using seedlings that are 1-2 yrs old, so that their leaves would be held above water level.
Siltation	Silt may get deposited on leaves of the seedlings (if they get flooded with tide) and subsequently gastropods (molluscs) may damage the leaves. This damage can be avoided by using 1 – 2 yr old seedlings.
Predation	Plants predated by crabs or cattle should be replaced. Planting propagules in the hollow of a piece of bamboo or PVC pipe will keep the crabs out of reach of the delicate parts of the seedling that are eaten by crabs
Cattle grazing	Planted area should be surrounded with a mesh/ barbed wire/ bamboo fence to keep the cattle and goats away. Regular patrolling the area for presence of cattle
Erosion	Mud flats that can experience erosion with tidal water movement can be stabilized first with an appropriate species of grass (such as *Porteresia sp)* that can consolidate the mud before planting the seedlings.
Human intervention	Community should be educated of the importance of restoration efforts and should be made part of the team of monitors/ protectors

16. Community based strategies for mangrove restoration

Community education on ecological/ economic importance of mangroves	Fishing communities are generally aware of the importance of the presence of mangroves for aquatic life. Members from local community who have no connection to fishing should be made aware of the importance of mangroves
Mobilization of local communities for mangrove restoration	Members , particularly of the fishing community can be organized to take part in seed/ seedling collection, setting up mangrove nurseries and their maintenance, transportation of seed material, ground preparation, planting and after-care operations. Selection of appropriate persons can be done with the help of the village-level local government officials Female members are more appropriate to be employed for tasks in the nursery Participants from the community may be paid a daily wage that is slightly higher than that of labourers engaged in land-based activities. This is to attract people to work in the mud.
Use of local community groups	Members of local community groups, especially those that are concerned about the environment can be assigned the task of restoration, under the supervision of an expert on the subject.
Mangrove restoration through schools	Children in schools close to mangrove restoration sites and their environmental societies can be educated on the importance of mangroves and their restoration and motivated to perform restoration work under the supervision of an expert on the subject. Such schools can be rewarded by contributing to improvements in their common facilities/ utilities.