MGNREGA
South 24 -Parganas

NEWS
www.naturewildlife.org

MANGROVE
MANUAL

In the context of Indian Sundarban Ecosystem

ALDI SÜD

KFW DEG

Shore

bluesensus
sustainability & seafood consulting

ALDI SÜD

KFW DEG

Shore
SHRIMP ORGANISATION EUROPE

bluesensus
sustainability & seafood consulting


MGNREGA
South 24 -Parganas


www.naturewildlife.org

MANGROVE
MANUAL

In the context of Indian Sundarban Ecosystem

Compiled by:

Nature Environment & Wildlife Society (NEWS)

www.naturewildlife.org

Title:	Mangrove Manual
Compilation	Nature Environment & Wildlife Society
Place:	Kolkata, India
Year:	2021
Edition:	First
Language:	English
Cover & Illustration:	Capital Infoart
Design:	Capital Infoart
Printing:	Capital Infoart
Website:	www.naturewildlife.org
E-mail:	contact@naturewildlife.org
Follow us:	www.facebook.com/NEWSforNature
	www.linkedin.com/company/newsfornature

Copyright @ Nature Environment & Wildlife Society (NEWS)

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, photocopying, recording or otherwise without the prior permission of the copyright holder, nor be otherwise circulated in any form of binding or cover other than that in which it is published.

GOVERNMENT OF WEST BENGAL

Directorate of Forests
Office of The Principal Chief Conservator of Forests,
Wildlife & Chief Wildlife Warden, West Bengal

MESSAGE

I take immense pleasure to state that Nature Environment & Wildlife Society(NEWS) has brought out a "Mangrove Manual", a practical guide book on afforestation and reforestation of mangroves in Indian Sundarban context. The book encompasses a holistic approach of mangrove conservation where theory finds its right path in practical application in a situation specific manner integrating the socio-economic and socio-cultural containers which ultimately guarantee to earn the success of a conservation and restoration programme. In my long association with NEWS, I have witnessed how this organisation devotes itself unswervingly to transform a scientific methodology of conservation into a peoples' technology through dedicated action research for developing a community conservation model. This book is such an outcome of their sincere action research on mangrove eco-system conservation in Indian Sundarban. I firmly believe that this manual would prove very useful to all the stakeholders associated with mangrove eco-system conservation in Indian Sundarban. I congratulate the NEWS team as a whole, for their outstanding collective effort to document their knowledge and experience in black and white. I wish all success of this endeavour.

(VINOD KUMAR YADAV,IFS)
Principal Chief Conservator of Forests, Wildlife &
Chief Wildlife Warden, West Bengal

Bikash Bhawan, North Block, 3rd floor, Salt Lake City, Kolkata - 700 091
Tel. No. 033-2334-6900 / 2358-3208, Fax - 033-2334-5946
Website - www.wildbengal.com E-mail - pccfwl-wb@nic.in & wbwildlife@gmail.com

DR. P. ULAGANATHAN, IAS
DISTRICT MAGISTRATE & COLLECTOR
SOUTH 24 PARGANAS

DO. No. 360 Dated, 23rd July 2021

MESSAGE

I am pleased to learn that Nature Environment & Wildlife Society (NEWS) is publishing a "Mangrove Manual" as a part of celebrating the "World Mangrove Day-2021". NEWS is engaged in mangrove ecosystem conservation of Indian Sundarban over a decade partnering with various stakeholders other Govt. departments. The rich experience of the '5 crore mangrove plantation drive', unleashed in 2020 under MGNREGA cell of South 24 Parganas district has also contributed to the making of this manual. This book is a result of their long journey and experiential learning while they tried to develop several situation-specific models of mangrove afforestation, reforestation and renaturation in Sundarban integrating community as a principal co-actor. I hope this book would act as a guiding literature to all concerned with mangrove conservation in Sundarban. I convey my sincere thanks to the NEWS team for this endeavour and wish its every success.

Government of West Bengal
South 24 Pgs
Office of the District Magistrate

District Magistrate
South 24 Parganas

Office: 12, Biplabi Kanai Bhattacharya Sarani, Alipore, Kolkata - 700 027
Phone: 033-2449 9944 / 2479 1694, Fax: 033-2448 7871
Mobile: 7044112222, Email: dm.south24parganas@gmail.com

FOREWORD

Salute to the 'Green initiative' as a nature based solution for coastal protection in Sundarban, under MGNREGA - South 24 Parganas, West Bengal, India

It was May 2020, Super Cyclone Amphan hit the coasts of Sundarban, wrecking a huge damage in the region. Interestingly, it was observed that mangroves played the role of the sentinels of coast, protecting the life, livelihoods of millions of people. Wherever the mangroves were deforested, lost, destroyed, the embankments breached and saline waters inundated agricultural lands, ponds causing further distress in this fragile terrain.

Hon'ble Chief Minister of West Bengal, Smt Mamata Bandyopadhyay, called for a '5 crore' mangrove plantation to integrate natural solutions in the post-reconstruction/recovery phase. South 24 Parganas District Administration under the able leadership of the District Magistrate, Dr. P Ulaganathan, along with the MGNREGA Cell of the district immediately started a robust planning design to have effective implementation.

The task is multi-sectoral, and hence an effective collaboration system was enacted with Forest Department, Panchayat & Rural Development Department, Block Administrations, Civil Society organisations, Conservation organisations, individuals, journalists in order to roll out a master plan. Block administration was sensitized, Panchayats were trained, local women groups were formed for nurseries, supervision team was formulated involving all the stakeholders. A perfect blend-with scientific principles, integrating local communities and excellent documentation plans for baseline, mid-term and ongoing processes in digital platforms using google earth images, pre-plantation photographs, post-plantation photographs -was masterminded and put into place.

In more than 2500 ha, in 2020 the plantation was effected and monitoring app was also designed for effective survival and growth monitoring. While first year was under the framework of creating outreach; in the second year (2021), based on the evaluation of the first year, where plantation survival ranged from 10% to 82% , the focus was on consolidation- replanting, mitigating the stress factors, and further expansion of another 2500 ha totalling to around 5000 ha.

This is perhaps the largest upscaled mangrove afforestation initiative under any Government Department to have been enacted in the ambience of stakeholder collaboration ecosystem, and NEWS feels privileged to be part of it.

We look forward to the evolution of this programme into generating a vision statement for building coastal resilience in Sundarban.

PREFACE

The book has been inspired by the need to have a documented version of the scientific approach and processes that one should follow while implementing afforestation, reforestation, renaturation of mangroves in Sundarban. While working in this area, time and again, it has been noticed that executing agencies for this purpose are more driven by the passion to do plantation, rather than follow scientific approach in sustaining it. To our knowledge, mangrove plantation is the most difficult of plantation activities, while terrestrial plantation and monitoring is comparatively easier; the reason being that the mangrove habitat restoration or mangrove afforestation, reforestation, renaturation is done in a dynamic landscape, where the habitat is changing every six hours with the high tide and the low tide. Hence, the hydro-geo-morphological assessment along with community mobilization are key to the long term sustenance of such activities.

Livelihoods, Paris has supported NEWS in executing an intense mangrove plantation/afforestation programme, immediately after Aila from 2010 and we fondly remember the association with Mr Narayan Swarup Nigam, who was then the District Magistrate along with Mr Kaushik Saha, Additional District Magistrate in South 24 Parganas. Their support in implementing this massive mandate of planting more than 5000 hectares was possible with participation of all partners from Government Departments, Institutions, civil society organisations, local clubs etc. This programme taught us a lot and the experience is penned through the pages of the manual. With veteran botanical scientists Late Dr L K Banerjee with us, the importance and magnitude of such plantation activities continuously unfurled before us; we learnt and learnt. The learning process has not stopped and I presume will never stop, considering the diversity and challenges of mangrove plantation in Sundarban.

The manual writing was first inspired by Dr P C Saini, when he was the Director, Sundarban Biosphere Reserve. It took an unnecessarily long time for us to complete it, to have a printed version of it. Now, we are happy to have both a printed and e-version of it and also will be having a local vernacular version of it.

I am thankful to Mr Nilanjan Mullick (IFS), Dr P K Pandit (IFS), Mr Santosha (IFS) from the Forest Department, Dr Sourabh Chattopdhyaya from P & RD department and Udo Censkowsky of Blue sensus to have constantly reminding in completing the task and give valuable observation in the matter.

Dr V K Yadav, Chief Wildlife Warden has been very eager to get the publication done and we are grateful to him for his encouragement. I thank Dr Piar Chand, Director-Sundarban Biosphere Reserve, Mr Tapas Das, Field Director-Sundarban Tiger Reserve(STR) and Mr S. Jones. Justin, Deputy Field Director-STR who have been supportive in the endeavour. I sincerely thank for the important contribution of Dr K. Karthigeyan from the Botanical Survey of India.

I thank NEWS team whose rich experience has been captured in the pages of the manual; specially to mention Mr Paritosh Giri, Mr Biswajit Mondal, Mr Chandan Maity, Mr Sourav Bera. I also thank Dr Nimai Bera, Ms Ritwika Ghosh and Ms Oaindrila Chakraborty in doing edits and compilations.

Constant encouraging words from our President Dr J R B Alfred and Secretary Mr Biswajit Roy Chowdhury, fellow colleague Mr Milon Sinha and Dr Chandrima Sinha have given the impetus to

ultimately complete it in the shape of the manual.

We owe our gratitude to the people of Sundarban, especially women who had enriched us with their commitment, dedication and I personally have witnessed larger than life characters in Jhoki di, Mongola di, Ganga di, Renuka di, Zahiruddin and many others who have kept their imprint in our minds in creating mangrove forests in difficult terrain. Lastly, we thank Aldi Sud, KFW-DEG, Shore and blue sensus for giving the financial support to come out with the hardcopy of the manual.

Sincere Regards,

Ajanta Dey

January 2021

Contents

Contents

List of tables

List of figures

List of figures

1.0 INTRODUCTION

Living along the interface between land and sea, the mangrove forest supports genetically diverse groups of aquatic as well as terrestrial organisms. Mangrove forest is a typical type of vegetation community comprising of variety of species having some special adaptations and characteristics for growing in intertidal areas and the estuary mouth between land and sea.

The word mangrove has probably been constituted of a Portuguese word 'mangue' which means trees growing in and around water and an English word 'grove' meaning a group of trees. Mangrove forest constitute a diverse group of habitats such as core forests, water bodies like rivers, criss-crossed creeks and channels, bays and backwater, mudflats, litter forest floors, sea grass ecosystem etc. where each is intricately interwoven to have complex relationships among each other forming the most dynamic and diverse ecosystem, establishing connectivity to each biotic and abiotic niches.

Mangrove species exist in groups and often referred to as 'Mangals' or communities. It can exist and flourish under a wide range of salinity conditions, tidal amplitudes, winds, temperature and in muddy anaerobic conditions. The highly variable conditions make mangrove forests profusely rich from biodiversity point of view and they support huge number of plant as well as animal communities, including many rare, endangered and threatened species. These salt-loving mangrove plants are found throughout the tropical and subtropical regions of the world.

The typical adaptive characteristics of the mangroves in their root system, stems, leaves and canopy formation have made them most important biodiversity component of the coastal areas, as it significantly contributes to building resilience of the coastal region.

The mangrove ecosystem provides various functions –

1) **Protection against storms and cyclones-**Mangroves are time and again found to act as a bio-shield as the wind and wave energy gets dissuaded with the mangrove cover before it strikes the landmass. Many of the studies done during tsunami 2004, in particular, has documented the role of mangroves (Dahdouh-Guebas *et al*, 2005; Kathiresan and Rajendran, 2005).

2) **They retain terrestrial sediments and recycle nutrients,** supporting clear offshore waters, which in turn favors photosynthetic activity of phytoplankton as well as growth and robustness of coral reefs, sea grass beds and reef fish communities (Ghosh *et al*, 2015).

3) **Nursery of fishes, fin-fishes, crabs etc.-**The detritus food chain supports the growth of phytoplankton, zooplankton and periphytons which in turn is consumed by the spawning and juvenile stages of fishes (Hutchinson *et al*, 2014). Also, the muddy waters and branching root systems prevent the big fishes from predating on the small fishes, the ecosystem thus acting as the nursery of the fishes. Thousands of fishermen depend on this productive ecosystem for their livelihoods.

4) It also acts as **carbon sequestering pool**, being one of most carbon-rich biomes, with more carbon below ground, and have higher- below to above- ground carbon mass ratios than terrestrial trees. In the context of Greenhouse gas reduction strategy, the mangroves are a mitigating factor to climate change (Alongi, 2012).

5) Mangrove ecosystem also acts as **absorbent** of toxic pollutants and sediments before they reach the ocean, thus having a natural treatment over the mangrove ecosystem (Suratman, 2008).

6) Non timber forest produces like honey, wax is an important livelihood resources for significant population of the marginalised communities.

7) The aesthetics and recreational facilities are also of immense potential that encourages tourism and related income augmentation for the marginalized communities.

Sundarban:

It is the largest contiguous mangrove stretch in the world covering an area of approx. 10000 sq km, of which 62% lies with Bangladesh and rest 40% is with India (Spalding *et al*, 2010). The Indian part of the Sundarban is located in the western part of the Ganges-Brahmaputra-Meghna delta, where it is flanked by the River Bhagirathi Hooghly on the west and River Raimongol-Kalindi in the east. An area marked with crisscrossed channels, creeks, rivers and swampy lands with mangrove forests, much of it has been reclaimed for habitation over the years.

Sundarban Biosphere Reserve (SBR), as part of Man and Biosphere programme has been constituted in 1989, with 9630 sq km defined by Dampier Hodges line towards North, extending between 21°32′ to 22°40′ N and 88°05′ to 89°51′ E. The protected area consists of 4264 sq km and the human habituated area constitute 5366 sq km (Director, Sundarban biosphere reserve; 2021; Ghosh *et al*, 2015).

Tidal amplitude within the estuaries varies between 3.5-4 m, while seasonal variations range from 1m to 6m (Islam, 2014). The average annual rainfall varies between 1500 mm to 2000 mm.

November to mid-February is the winter dry season, followed by hot and humid summer months between March to May and monsoonal weather pattern dominates the rest of the year.

Average humidity is 82% and is almost the same throughout the year.

The Administrative blocks of Sundarban are spread over 13 blocks of South 24 Parganas district, 6 blocks of North 24 Parganas district and 2 Municipalities.

- **South 24 Parganas**-Sagar, Namkhana, Kakdwip, Patharpratima, Kultali, Mathurapur-I, II, Jaynagar-I, II, Canning-I, II, Basanti, Gosaba
- **North 24 Parganas -** Hingalganj, Hasnabad, Haroa, Sandeskhali - I, II, Minakhan
- **Municipalities** – Joynagar, Taki

Biodiversity:

Flora: Sundarban is one of the most dynamic ecosystems on the earth.

In Sundarban, there are 140 flowering plant species under 101 genera and 59 families comprising true mangroves, mangrove associates, back mangrove trees and shrubs, non-halophytic non mangrove associates but present in mangrove habitats, halophytic herbs, shrubs, weeds, epiphytes and parasitic plants that grow among the '*mangals*' (Naskar *et al*, 2004).

A total of 24 species of true or major mangroves were recorded in the Indian Sundarban. The species list (Table 1.1) comprises of nine species in four genera belonging to the family Rhizophoraceae; three species in one genus under Sonneratiaceae; three species in one genus under Avicenniaceae; three species in two genera under Meliaceae; two species in two genera under Palmae/Arecaceae; and one species in one genus each under Combretaceae, Plumbaginaceae, Sterculiaceae and Myrcinaceae (Barik *et al*, 2014).

Table 1.1 List of true mangrove species from Indian Sundarban Region with their IUCN status.

FAMILY	GENUS	SPECIES	IUCN STATUS (2014)
Rhizophoraceae	*Bruguiera*	*cylindrica* Blume	Least Concern
		gymnorhiza (L.) Lam.	Least Concern
		parviflora (Roxb.) Wight. and Arn.	Least Concern
		sexangula (Lour.) Poir	Least Concern
	Ceriops	*decandra* (Griff.) Ding Hou	Near Threatened
		tagal (Perr.) C.B. Rob.	Least Concern
	Rhizophora	*apiculata* Blume	Least Concern
		mucronata Poir	Least Concern
	Kandelia	*candel* (L.) Druce	Least Concern
Sonneratiaceae	*Sonneratia*	*apetala* Buch.- Ham.	Least Concern
		caseolaris (L.) Engl.	Not Listed
		alba (Sm.)	Least Concern
Combretaceae	*Lumnitzera*	*racemosa* Willd.	Least Concern
Meliaceae	*Xylocarpus*	*granatum* J. Koenig	Least Concern
		moluccensis (Lam.) M. Roem.	Least Concern
	Aglaia	*cucullata* (Roxb.) Pellegr.	Data Deficient
Avicenniaceae	*Avicennia*	*alba* Blume	Least Concern
		marina (Forssk.) Vierh.	Least Concern
		officinalis L.	Least Concern
Plumbaginaceae	*Aegialitis*	*rotundifolia* Roxb.	Near Threatened
Sterculiaceae	*Heritiera*	*fomes* Buch.-Ham.	Endangered
Myrsinaceae	*Aegiceras*	*corniculatum* (L.) Blanco	Least Concern
Palmae/ Arecaceae	*Nypa*	*fruticans* (Thunb.) Wurmb.	Least Concern
	Phoenix	*paludosa* Roxb.	Near Threatened

Of these, *Heritiera fomes* is a signature species of the Sundarban delta, commonly known as 'Sundari'. Many believe that Sundarban may have derived its name from this tree.

Fauna: Forty nine extant species (eight orders: twenty-three families) were recorded out of which four are globally endangered, four vulnerable and two near threatened as per IUCN Red List and, alarmingly, 20 mammal species (40.81%) were found only rarely. Fifteen species are, however, included in Schedules I and II of the Indian Wildlife (Protection) Act, 1972 (Mallick, 2011).

Of them, Royal Bengal tiger (*Panthera tigris tigris*) is the most charismatic species and the only large carnivore. Fishing cat, leopard cat, jungle cat, wild boar, deer etc. are commonly found. *Rhesus macaque* is the only primate species. Otters and dolphins are also inhabitants in this deltaic system.

Among reptiles, the major species is estuarine crocodile and 57 species of snakes have been recorded here (Wild life wing, 2021).

With 400 species of birds recorded (Lepage, 2021), many endangered fishes, crabs, crustaceans, non-vertebrates, Sundarban is bountiful with gifts of nature (Chandra *et al*., 2017).

People:

As per 2011 census report, the population is 4.44 million, and the density of population is 1075 persons per sq km.

The human habitation has been possible in this region due to reclamation of mangrove areas. This had happened in phases since East India Company headquarters was established in 1757 in Calcutta. The headquarters being on the edge of the forest, British Collector General Clod Russell proposed to divide Sundarban into plots for timber extraction and honey collection. The work initiated by Tillman Henkel in late eighteenth century saw marginalized and tribal populations from other states and areas to be engaged as labourers, slowly settling here. Much of the mangrove forest that extended till Kolkata, in late eighteenth century was destroyed by middle of nineteenth century (Ghosh *et al*, 2015).

In between 1951 to 1971, the population increased from 1.15 to 1.94 million, while between1971 to 2011, the population increased by 2.5 million. The trend in the rise of population and settlements in Sundarban is higher because of the porous border with Bangladesh and also it is comparatively easy to get food and a small piece of land to live here than competing in cities. People, here are mostly engaged in agriculture, mainly dependent on monsoon. A good number is engaged in fishing in country boats; also dependent on honey and crab collection from the mangrove ecosystem. With the support of Forest Department through Joint Forest Management Committees, other developmental activities under Sundarban Development Board, Panchayat & Rural Development, West Bengal Accelerated Development of Minor Irrigation Project (WBADMIP) etc alternative livelihood augmentation projects and schemes have been undertaken to reduce the dependence on forest. Thus, bee keeping, fresh water fishery development in ponds and canals, horticulture, tailoring, vegetables as rabi-crop cultivation, crab rearing, brackishwater fisheries etc. have been encouraged.

Embankments:

In this deltaic land, crisscrossed by numerous rivers, rivulets, channels and creeks, habitation in the islands could be possible due to the dykes/embankments built all around the villages which protect the lands inside the villages from saline inundation twice every day, during the high tide. Thus, at high tide, the water level outside the dyke on the riverside is higher than the village level inside. Hence, these embankments are the lifeline for the people of Sundarban. Again, it is also detrimental for the inhabited islands as the embankments are not allowing the free flow of rivers to deposit the accompanying silt on the islands; rather obstructed, the river has no option but to leave it on the river beds thus raising the river beds, and the islands are thus at a much lower height than even the forest land level.

These embankments are earthen, and many a times, efforts have been made to concretize it, but the model has failed to sustain in the complex geo-hydro morphology of the region. Even when very high tidal fluctuation occurs in Spring and Autumn every year, the people of Sundarban count hours if the embankment would be there strong enough to protect them. Either the bricks are destroyed, displaced or the concrete slabs subside into the river being scoured from below. The experiences of cyclone during Aila in May 2009, recent experiences of Amphan in May 2020 have showed how concrete slabs have been scoured. The experience of the Aila, Bulbul (February, 2020), Amphan, Yaas in May, 2021

have also revealed that wherever there were mangroves in front of the dykes, it was intact. It acted as the first line of defense against storm and cyclones, dissuaded wave and wind energy, thus protecting the fragile embankment.

However, wherever mangroves did not exist as first line of defense of the embankments, the embankment has breached and saline inundation has happened; thus, bringing a saline curse to the agricultural fields, destroying the ponds and livelihoods are impacted. Outward migration from Sundarban has thus been significantly noticed in post-Aila situation, where the fields remained uncultivable for at least three years.

Climate Change and sea level rise:

According to the IPCC special report on Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities the trend of annual Global mean sea level (GMSL) rising is3.6 mm yr^{-1}.

The expected impacts of seal level rise on coastal ecosystems over the course of the 21st century include habitat contraction, biodiversity loss, and lateral and in land migration etc. The impacts will be enhanced in cases of land reclamation and where anthropogenic barriers prevent inland migration of marshes and mangroves and limit the availability and relocation of sediment (IPCC, 2019). Besides, due to the tectonic tilt of the Ganges delta towards the east (Ghosh *et al*, 2015), land subsidence has always been a major challenge in this region, which has increased the vulnerability exponentially with respect to sea level rise.

Salinity profile:

There has been a noted change in the salinity profile in the different sectors of Indian Sundarban, namely western, central and eastern sectors. The western Indian Sundarban shows the hyposaline environment which may be due to Farakka barrage discharge of freshwater situated in the upstream region of Ganga- Bhagirathi -Hooghly river system. The central sector represents a hypersaline environment due to complete delinking of the fresh water flow from the upstream region owing to siltation of big rivers like Bidyadhari, Matla connect etc. The eastern sector exhibits a low salinity profile possibly due to interconnection with several creeks and channels of Harinbhanga estuary with the tributaries of Bangladesh Sundarban that arise from Padma Meghna river system. The salinity profile accounted for certain changes in the species composition of mangroves in these three sectors of Sundarban (Trivedi *et al*, 2016). Indian Sundarban thus, is in a typical hydro morphological setting with changing salinity profile and witness various stages of delta formation, being part of a pro-grading delta (Dahdouh-Guebas*et al*., 2005).

Population pressure and reclamation and threats:

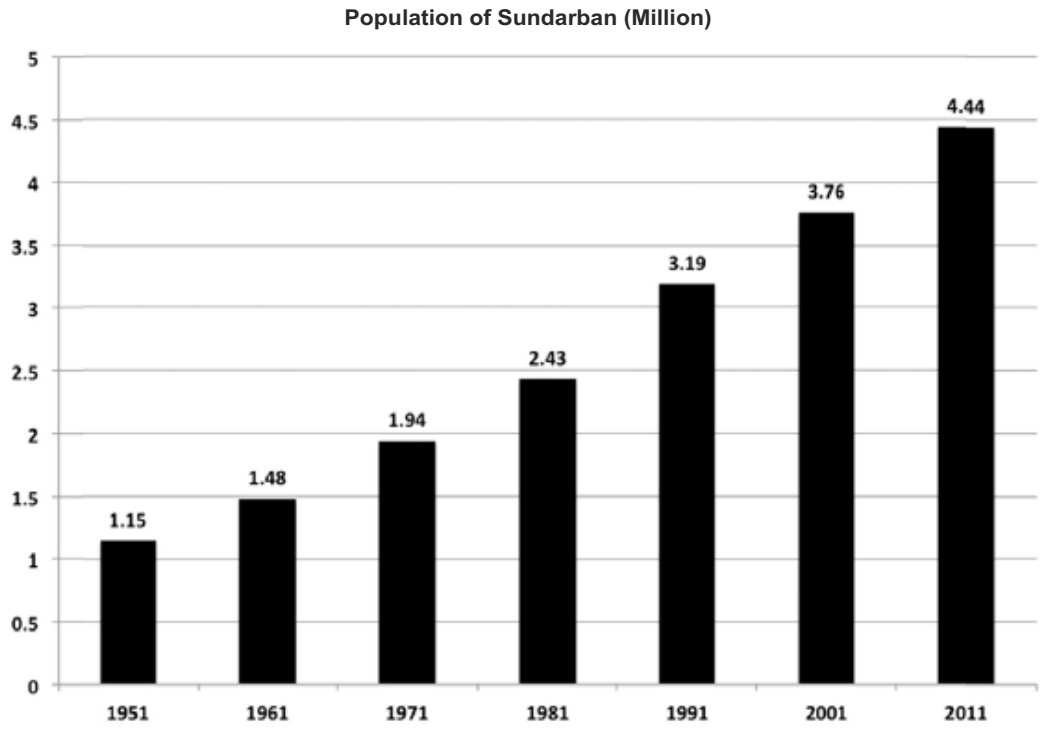


Figure 1.1 Human population growth in the Indian Sundarban between 1951 and 2011 (Ghosh *et al*., 2015)

The figure itself shows, that besides climate change and sea level rise as projected in IPCC report, the anthropogenic pressure is also noticeable, esp illegal shrimp 'bheri'(fishery ponds). Felling for fuelwood, logging, constructing fishing ponds, grabbing land for agriculture, along with house/shops on the silted riverine mudflats are common. Besides, the newly developed mangrove saplings on the mudflats are a favourite food for the goats and cows and they are often let loose in the mudflats to graze on it. During Prawn larva collection the women trample the planted or naturally regenerated saplings, which cause immense loss of biodiversity; as it is estimated that the by catch is 64-99.4% of the total fry caught (Das *et al*, 2016).

2.0 MANGROVE AND ITS ADAPTATIONS

Mangrove forest is a typical vegetative community comprising of species having some special adaptations and characteristics for growing in intertidal areas and estuary mouth between the land and the sea. The mangrove forest of Sundarban is one of the most dynamic ecosystems on the earth.

Mangroves grow and thrive in those areas where the fresh water from the rivers readily mixes with the salt waters of the sea. They manifest themselves in groups often called as 'mangals' and are specially adapted to the estuarine ecology, mostly within the tropical limits in both Northern and Southern hemisphere. It is said that once they were part of the terrestrial plant ecology (Kathiresan & Bingham, 2001), but through the evolutionary process of survival of the fittest they were unable to compete and forced to move towards the sea, and then they beautifully adapted to the hydro morphology in to forming halophytic salt tolerant plants called mangroves.

2.1 Typical adaptations:

1) Roots:

Aerial roots: Aerial roots are developed in many mangrove species which are exposed to the air. As the mangrove mud is anaerobic, aerial roots help the trees to respire. The following four types of aerial roots are common:

- **Pneumatophores:** Specialized aerial roots enable plants to breathe air in habitats that have waterlogged soil. The roots may grow down from the stem and then move upwards to get raised above soil. This type of roots are very common in the genus *Avicennia* and *Sonneratia*.
- **Knee roots:** These are vertically growing, rounded, knob-like structures, extending upwards from the surface. This type of roots are found in the genus *Lumnitzera*, *Bruguiera*, *Ceriops and Kandelia.*
- **Stilt roots:** It is a type of root that emerges from the lower bole of a tree. It supports the plants on unstable soft soil. This type of roots protect the plants from heavy winds as well as the soil from erosion. This type of roots are very common in the genus *Rhizophora*.

Figure 2.1 Pneumatophores of *Avicennia marina*

Figure 2.2 Kneed roots of *Bruguiera cylindrica*

Figure 2.3 Plank roots (buttresses) of *Xylocarpus granatum*

- **Root buttresses:** Buttress roots are large, plank-like extension arising from the base of the trunk and spreading on all direction. These type of roots provides structural support to the plants especially in shallow soils. Plants such as *Xylocarpus granatum*, *Xylocarpus moluccensis* and *Heritiera fomes* has these kind of buttress roots to support them in soft and soggy mud (Ng, Sivasothi, 1999).

2) **Salt glands:** Salt glands present in the bark of trees help them to exclude the excess salt collected by the root system. It is commonly seen in *Aegiceras corniculatum, Acanthus* spp. etc. (Ng, Sivasothi, 1999)

3) Stems: Stems of the mangrove are sometimes covered with perforated barks and salt glands that help the plant to exclude excess salts.

4) Leaves: The thick leaves have waxy coating and sunken stomata to reduce water loss. They also possess special salt-excreting glands on leaves to exude high concentrations of salt. In general, each species has mechanisms to regulate levels of salt in sap (Suriya & Hari, 2018).

5) Germination:

Vivipary: Viviparous plants produce seeds or embryos that begin to develop before they detach from the parent. For true viviparous germination the embryo penetrates through the pericarp of the fruit before dispersal (Elmqvist and Cox, 1996). Seedlings of some species are dispersed by currents if they drop into the water but others develop a heavy, straight taproot that commonly penetrates the mud when the seedling drops, thereby effectively anchoring the seedling. Vivipary is commonly seen in the family Rhizophoraceae

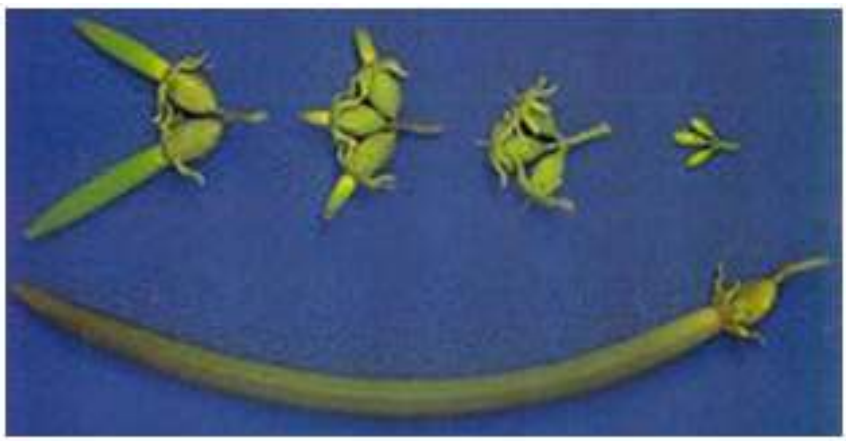


Figure 2.4 Vivipary in *Bruguiera cylindrica* (Source: A Guide to Mangroves of Singapore)

Crypto viviparous: Crypto vivipary is a condition when the embryo significantly develop but do not penetrate the pericarp before dispersal (Elmqvist and Cox, 1996). Crypto- viviparous germination is commonly seen in the genus species such as *Avicennia.*

Non-viviparous germination: Non- viviparous plants produce seeds or embryos that begin to develop after they detach from the parent. Species such as *Xylocarpus* spp*, Heritiera fomes, Phoenix palludosa* exhibit non-viviparous germination.

3.0 RENATURATION, AFFORESTATION, RESTORATION OF MANGROVES AND AFFORESTATION MODELS

Restoration of mangroves involve certain immaculate steps and procedures to be followed in the planning stage:

1) Site selection
2) Species selection
3) Stakeholder's concurrence
4) Understanding scope of governance of local community especially women
5) Risk Mapping

Each of the planning stages involves activities and sub-activities that need to be detailed thoroughly to achieve a successful restoration programme.

The word 'plantation' fails to uphold the underlying thoughts of restoration activities where the responsibility ends soon after plantation; ideally any plantation should not be taken as a one year task, rather a minimum three year project, where planting, replanting and monitoring structures are also established within the project period. Care should be taken to have a plantation/reforestation model with as much assisted natural regeneration, that encourage minimum intervention in the said ecosystems.

In Sundarban, the plantation activities are either taken in islands which really act as the radial point for ecosystem functions and services, locally called 'chars' or in the silted areas adjacent to the embankments which serve typically as bio-shields. Major plantation activities are taken in the Biosphere Reserve beyond the protected area regime of National parks and sanctuaries. It may be noted that life in Sundarban is possible due to the earthen embankment which acts as a lifeline during high tide, when the water level outside is higher than the village level. In this situation, approximately 3600 km long embankment can be protected only by a robust design of the vegetative cover with mangroves as a key species which dissuade wave and wind energy before the water mass strike on the embankments.

3.1 Afforestation/restoration of mangroves:

Case-1:

A landmass is appearing due to siltation and from a typical marshy area the land is gradually becoming stable, the pioneer species *Porteresia coarctata*, locally known as 'Dhani Ghas' is appearing and is growing and spreading. Assisted natural regeneration is the first choice, however depending on the soil character and inundation levels, species can be planted for anchoring effect. It is wise to allow nature to have her say in the first stage of succession after the colonization of *Porteresia coarctata.*

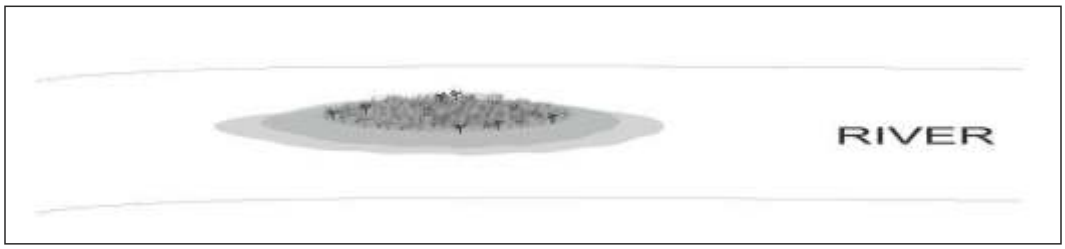


Figure 3.1 Mangrove afforestation model-1

Case-2:

In the higher mudflat area the trees are mostly absent and the landscape is almost flat and dominated by 'giria' (*Suaeda maritima* (L.) Dumort.) herb, though there are layer of trees in the middle level of the mudflat. In these cases mostly the inundation level is less, no inundation in winter and even in the summer and rainy season the inundation varies from 3 to 7 days around the spring tides respectively. For afforestation in that higher mudflat area, the inundation level has to be checked and with channel digging water flow and fresh siltation is to be allowed before going for plantation activities.

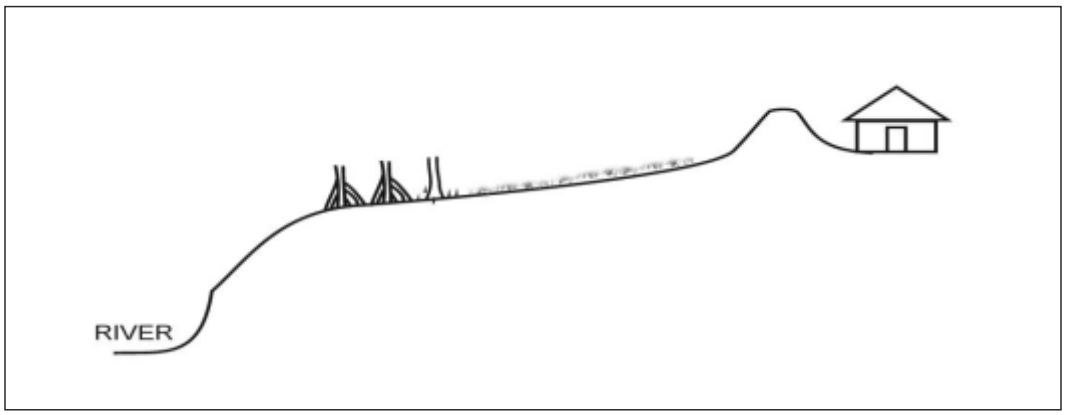


Figure 3.2 Mangrove afforestation model-2

Case-3:

There are patches of open bare spaces in an established mangrove canopy cover. Now, regarding definition of forest cover as per Indian State of Forest Report (ISFR),' all lands more than one hectare in area with a tree canopy of more than10 percent irrespective of land use, ownership and legal status' is under unclassified forests whereas the Recorded forest area covers the protected areas, national parks and institutions. So, in between these mangrove forests, the blank areas may be replanted after suitable analysis of the situation.

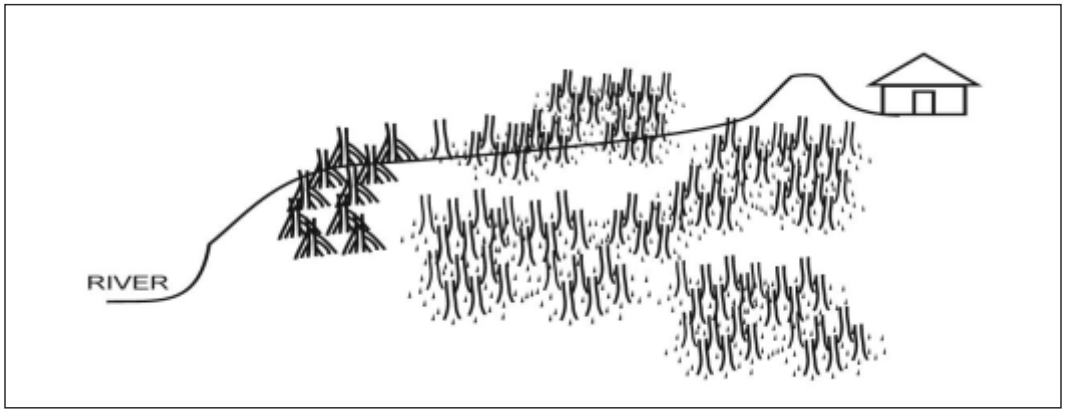


Figure 3.3 Mangrove afforestation model-3

Case-4:

The silted area along the embankment has a gradual gradient but the inundation is less in higher mudflat. Often dominated by hard soil, these areas need plants of tertiary successions in mangroves like *Phoenix paludosa, Xylocarpus* spp, *Excoecaria agallocha* etc. Stratification can be done considering soil firmness, texture and inundation and species selected for the different strata as per the variable parameters. Hydrology management is needed with channel digging to allow fresh alluvium to deposit so that the roots can grow and penetrate.

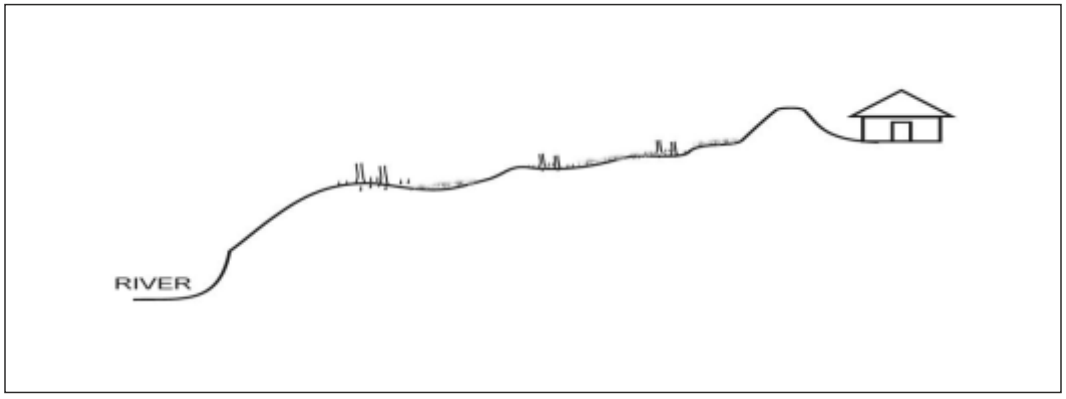


Figure 3.4 Mangrove afforestation model-4

Case-5:

Plantation already exist and the lower mudflat is increasing due to siltation. In this case, the lower plantation line should be carefully marked and scope of natural regeneration should be looked into where, just ensuring protection with communities and local bodies can be conducive for renaturation. After the first year, the natural species selection maybe observed and if it is less than three different species, plantation can be done in gaps to establish a multi species environment, i.e. include other species which can be viable in that typical physico-chemical environment.

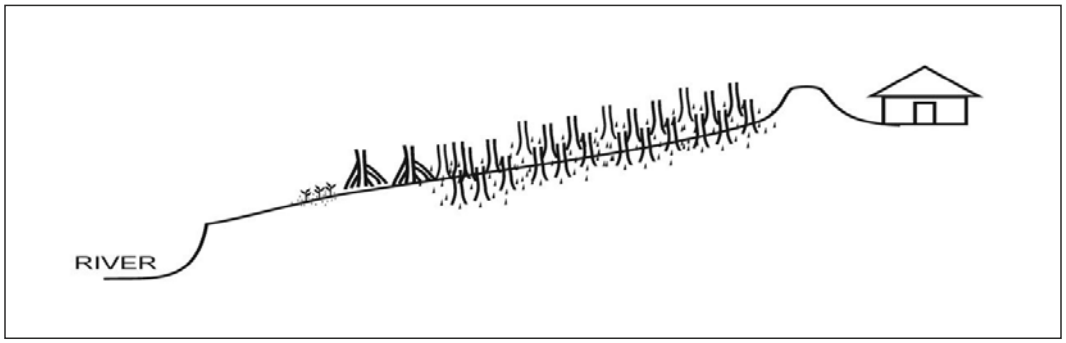


Figure 3.5 Mangrove afforestation model-5

Case 6: Sharp slope and presence of wind/wave action

Wind breaking structures with bamboo maybe made in V shapes in alternate rows, to allow deposition of silt on the inward side of the structures and plantation strategy for the fast-growing anchoring species there like *Rhizophora* spp. may be considered. With the first rows getting stabilized, further plantation strategy in a multi-species environment maybe looked upon.

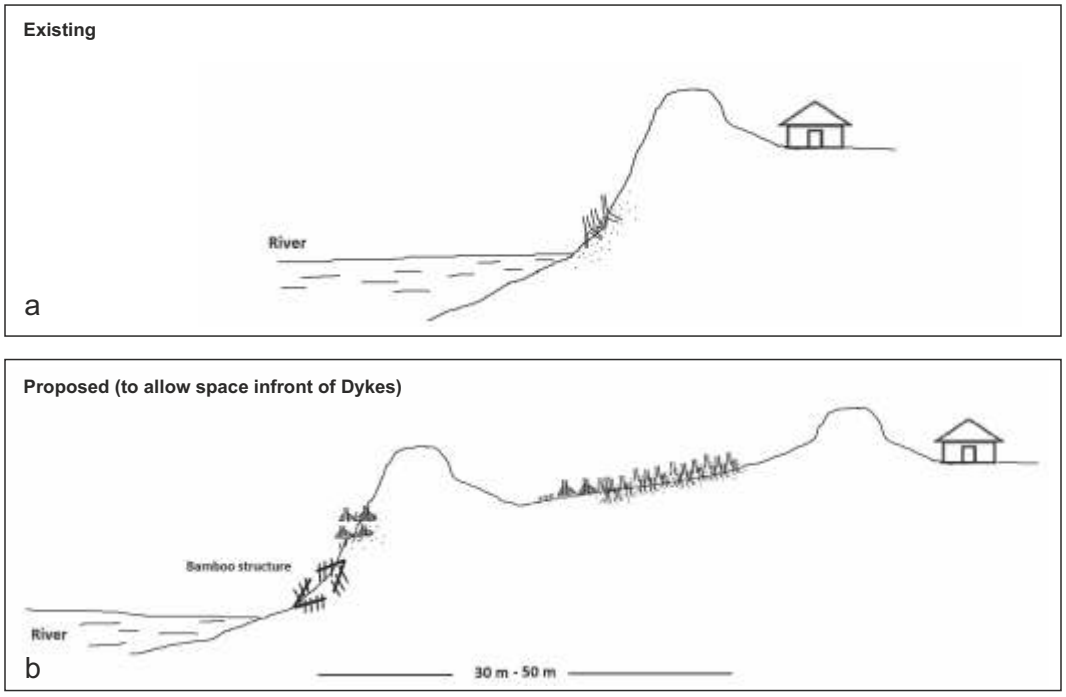


Figure 3.6 Mangrove afforestation model-6: a) Existing Model, b) Proposed Model

In all cases, a minimum of 50 m to 100 m space may be considered infront of the dykes towards the river for mixed species of mangrove renaturation.

4.0 COMMUNITY MOBILISATION

Local communities are the most important stakeholders in renaturation/restoration/afforestation activities. It maybe noted that various departments, NGO's, conservation practitioners can only act as an accelerator in the process, however for long term conservation and protection of the mangroves, local communities especially women involvement are crucial. Women have a natural inclination towards caring, protecting and has been found to tend, prune with greater care in the nurseries. Besides, after managing their household chores, it is easier for them to manage the nurseries. And being attached to them from seed collection stage, nursery preparation, plantation and monitoring instills a sense of ownership in them which when supported with income generation activities and value chain creation around mangroves develop a commitment and bring leadership qualities in them towards conservation; this can be later transformed into mangrove stewardship, when they voluntarily contribute for mangrove watch. The model has been proved to be successful, not only in Sundarban but also in many other areas across the planet.

The diversity of the mangrove and its role in securing lives and livelihood in this desperate delta need to be portrayed and imbibed in them through regular interaction and awareness programmes, collection of monitoring reports, mangrove watch reports, supporting them in integrated mangrove value chains etc.

However, involvement and active participation of all key stakeholders are crucial to successful completion of mangrove plantation activities and Panchayats play an important role in conflict resolution, etc. A diagrammatic representation of the various stakeholders can give an insight into the roles and responsibilities of various co-actors.

Table 4.1 Possible stakeholders and their roles

Sl No.	Stakeholders	Possible roles and responsibilities
1	Local community (preferably women)	Nursery raising, plantation, monitoring and reporting
2	Joint Forest Management Committee (JFMC)	Community mobilization, conflict management, ensure protection
3	Local Panchayat	Concurrence and permission for land use, overall supervision, conflict resolution.
4	Block administration, Bon-O-Bhumi karmadhyokkho	Overall supervision and follow-up report
5	Forest beat office	Resource person for nursery raising, plantation, monitoring and follow up activities
6	Local clubs, CSOs and other agencies	Raising awareness, conflict management

5.0 RISK MAPPING

Afforestation and restoration of mangroves are not a one-time job rather a continuous process addressing, mitigating and adapting to the threats that had jeopardized the natural regeneration in that area. Hence site-specific risk mapping is necessary for continuous mitigating and adapting strategy. It maybe noted that the risks, although may have commonness in their characters corresponding to a particular delta/estuary, however has site specific variations and these uniqueness in micro situations are the typical factors which become responsible for long term management of the afforested areas.

Simple risk mapping tools maybe done in focused group discussions with the community and periodically reviewed and assessed, addressing the most vulnerable risks with proper planning. Let us illustrate an example. One site maybe a fishermen's village and the riverine banks are being regularly used for anchoring boats and the movements of the boat are hindering the natural regeneration of mangroves thereby making the village devoid of bio-shield, exposing it to tidal waves, actions as well as storms and cyclones. If the afforestation activities are planned without taking them into concurrence, the said activities are bound to fail. If however, the risk is mapped then as a mitigating strategy a dialogue can be opened with the fishermen into identifying a particular area where all the boat anchoring movements can be restricted rather than keeping it scattered and open all over the river embankment. This will not only entail their ownership, but also mitigate the risk.

6.0 IDENTIFICATION OF SITE

The plantation strategy adopted by many agencies has been found to be driven by spontaneity and the urge to do something for the mangroves, and often has resulted in a complete failure of the effort because there is a lot of science behind it. Adopting ecosystem based situation specific nature based solutions are the ideal paths for any ecological restoration. It must be kept in mind, that mangrove restoration is a costly exercise, considering the time, effort and finances involved. Hence, to secure the benefits of the activities undertaken, this is the most important part of the plantation strategy.

6.1 Base map generation:

A base map should be prepared and a pre-plantation report made after checking the necessary parameters like salinity, tidal inundation, stratification of plantable areas etc. It is better to prepare it using the Survey of India toposheet, which has all the detailed boundaries and positions of the silted areas, high tideline, low tideline and settlements such as roads. In the absence of such toposheets, simple Google Earth images will also work, wherefrom a preliminary idea about the shoreline can be understood. Quick checks can be made on whether it is an accretion site or an erosion site from the history of the site -

https://support.google.com/earth/answer/148094?hl=en

(if there was any degradation / deforestation / plantation in last ten years).

As soon as the probable sites are shortlisted, environmental parameters are taken into account, such as the soil characters, salinity, tidal inundation, wave actions etc. In all these analysis community participation is a must exercise to ensure inclusiveness. Also, the character of the proposed afforested site, its changing patterns and features need to be considered in discussion with the local people, especially aged persons of the locality.

6.1.1 Plot Assessment Reports:

The baseline position can be documented through reports, which can be later compared to understand the change. An example is illustrated for Sumatinagar and Manmathanagar (South 24 Parganas) in ANNEXURE-1.

6.2 Soil properties analysis:

The substrate, that is the soil texture on which the plantation will be done is a very important feature to be considered in the restoration plan. Although mangrove associates and some trees grow in sandy soil too, but soil with a higher percentage of clay can support a good growth of mangroves as it provides a) good grip for the plants to hold on, b) more nutrient content and c) high moisture keeping capacity.

It can be simply done with a beaker and a stirrer after observing for few hours or simple checking methods through hand feel. Collected soil should be dried off and turned into dust. Then it should be mixed well with distilled water in 1:2 (Soil: Water) and kept for few hours so that the soil can settle down. Silt, sand and clay can be separated easily, after sedimentation allows it to settle down to the bottom of the beaker.

Once the percentage of sand, silt and clay is obtained, the soil suitability is ascertained. Also, the pH with a pH paper is noted, as mildly acidic soils are preferred and plantation should be avoided in highly acidic soils.

The soil can be loose, varying from few inches to few feet. Plantation should be avoided in very loose soils as the propagules or seeds or saplings can easily get washed away. Again very firm soil is not suitable as the root penetration will be difficult affecting the survival and growth. In the latter case, channel managements may be required to allow soft alluvium silt to collect and then proceed for plantation, after site specific analysis.

6.3 Tidal inundation:

We all know that mangrove estuaries experience tidal flushes, twice everyday. Tides occur due to the gravitational pull between the sun and moon. At high tide, the seawater swells up and fills the rivers, rivulets and creeks and at low tide, the seawater recedes. In Sundarban, the tidal fluctuation is high; and even as high as 20m in winter months, particularly in February. Areas which have tidal inundations are only suitable for mangrove propagation and hence plantation. It has been noted that every mangrove species has a preference of salinity and level of inundation. While *Avicennia* spp. prefer to grow in areas where height is 4 to 4.5 metres above mean sea level during the high tide with 25-30 days inundation per month; *Phoenix* sp. prefer higher elevated areas of around 5.5 to 6 m above mean sea level with 2-3days inundation per month. Hence salinity and inundation preference are two important key factors for species tolerance and consequently species selection too.

This tidal inundation of a particular site is given by the tidal amplitude and also slope of the site. It goes without say that we need to take note of the tidal variations in the site and community participation can be an important tool to achieve it.

Sundarban usually has two tides in a day, and the tidal rule although complicated can be simply understood and analysed too. To divide evenly there is a gap of 6 hours. between every tide and on an average the high and low tides are delayed by45 mins everyday, which is determined by the relative position of the sun and the moon. Normally one high tide is different from the other high tide and it reaches peak around full moon and new moon day because the sun and moon will be in the same line and the pull towards each other is also maximum, causing the seawater to swell higher. This highest tide is called springtide. After the spring tide the level of high water starts receding and after approximately seven days, when the moon and sun are at right angles to each other, the high tide level will reach to its lowest level. This lowest tide is called neap tide, when at right angles to each other the sun and moon loses the combined gravitational pull. So, there is highest of the high tides called High tide line (HTL) and lowest of the low tides called low tide line (LTL). Tide tables are available for major cities and ports, but at micro-level it is important to understand the HTL and LTL to analyse the tidal fluctuation, and slope of the mudflat. Communities can be best engaged to measure this.

A group of two or four may be formed and the observation can be made. If the plantation site is long, a group can be positioned at the starting point and ending point of the proposed site. The Spring tides are usually available in vernacular calendar. On the spring high tide day they should be equipped with two poles. As the tidal water during spring high tide enters, the highest point which it reaches can be marked at the upper reaches of the plantation site. Again the line where water level recedes during

spring low tide is also marked. This gives a rough estimation of the intertidal area and the difference in the ground level between the two lines gives an approximation of the elevation. However, after this the monitoring is continued for a period of 15 to 22 days.The area which is flooded by tides around 2-3 days around the tide may be marked as higher tidal area, again the portion of the mudflat which is inundated by tidal water for about 10 days within a period of 15- 22 days is called the intertidal area. The area that is inundated daily can be called the lower tidal area. It maybe noted that the soil texture varies if there is a sharp difference in these intertidal areas. Accordingly soil texture, firmness should be ascertained and stratification may be made for species selection.

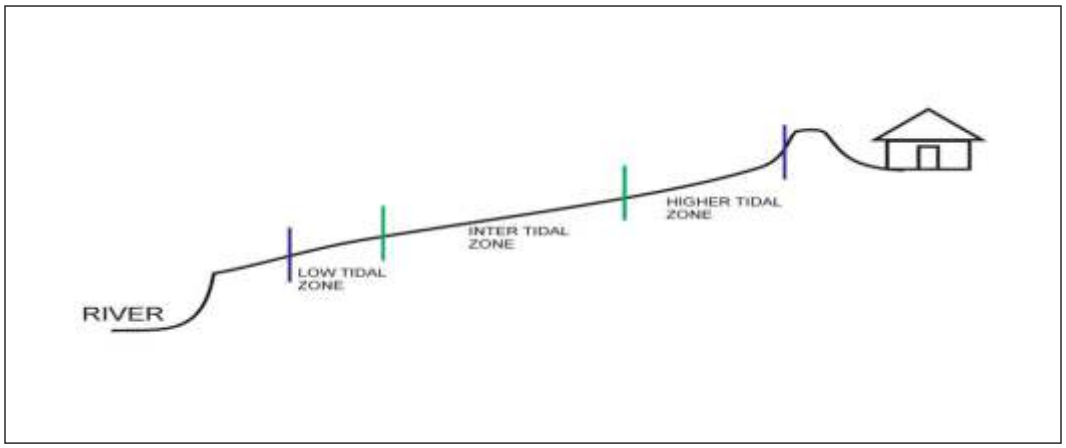


Figure 6.1 Identification of Tidal and plantation zone

In the figure 6.1., there is inundation upto the embankment and hence plantation can be considered.

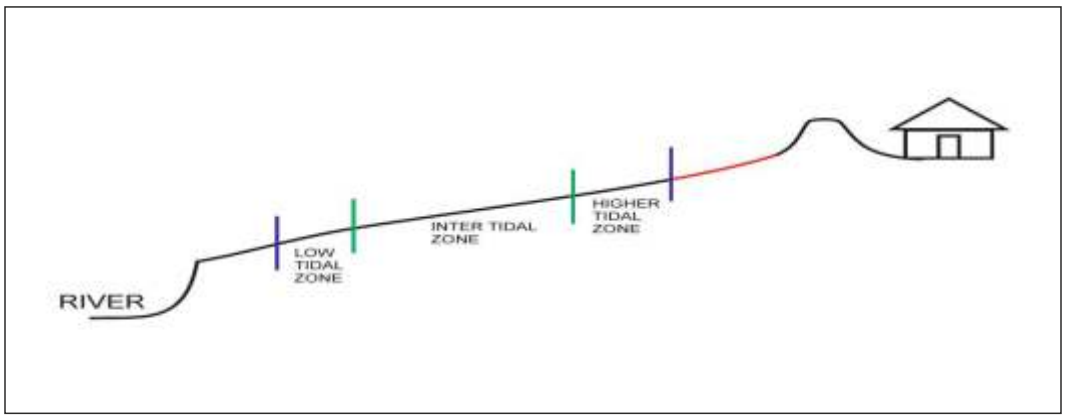


Figure 6.2 Identification of Tidal and no plantation zone

In the figure-6.2., the red colored area shows no plantation zone, as there is no inundation. Here, some common, mangrove associate species can be planted.

7.0 SPECIES SELECTION

In Sundarban, usually 15 to 18 species are considered for plantation and it should be ensured that the plantation is done in a **multi species scenario**.

The salinity preference of mangroves vary to a great extent.

Salinity of the area needs to be measured with a refractometer and as per the tidal inundation and elevation, species can be short-listed based on the following chart.

Table 7.1 Species selection

(Source: Zaman *et al.*, 2014; Mitra *et al.*, 2004; Anirban *et al.*2015; Mitra, 2010; Rahman, 2020; Siddique *et al.*, 2007 and Barik *et al.*, 2018)

Name of species	Freshwater loving plants	Saltwater loving plants	Salinity range (PSU)
Keora (*Sonneratia apetala*)	√		2-10
Ora (*Sonneratia alba*)		√	18-30
Sundari (*Heritiera fomes*)	√		2-15
Geonwa (*Excoecaria agallocha*)	√		0-15
Kalo Bain (*Avicennia alba*)		√	18-30
Peyara Bain (*Avicennia marina*)		√	18-30
Jat Bain (*Avicennia officinalis*)		√	18-30
Chak keora (*Sonneratia caseolaris*)	√		0.5-5
Kankra (*Bruguiera gymnorhiza*)		√	18-30
Bakul Kankra (*Bruguiera sexangula*)		√	18-30
Kankra (*Bruguiera parviflora*)		√	18-30
Garjan (*Rhizophora apiculata*)		√	5-30
Garjan (*Rhizophora mucronata*)		√	5-30
Dhundul (*Xylocarpus granatum*)	√		0-20
Pasur (*Xylocarpus moluccensis*)		√	10-30
Jhamti Goran (*Ceriops decandra*)		√	25-30
Math Goran(*Ceriops tagal*)		√	25-30
Khalsi (*Aegiceras corniculatum*)	√		5-15
Hental (*Phoenix paludosa*)		√	5-18
Golpata (*Nypa fruticans*)	√		5-15

Table 7.2 Plan for planting different mangrove species at different zones of mudflat

Height of Water Level at High Tide (The lowest level of the high tide variations)	**No(s) of days in a month when the mudflat is flooded by water at high tide**	***Suitable mangrove species***
Less than 4 mtr. above sea level	30 days	**Dhanighas** (*Porteresia coarctata*) **Kalo Bain** (*Avicennia alba*)
Less than 4−4.5 mtr. above sea level	25 days	**Kalo Bain** (*Avicennia alba*) **Peyara Bain** (*Avicennia marina*) **Jat Bain** (*Avicennia officinalis*)
Less than 4.5−5 mtr. Above sea level	20 days	**Keora** (*Sonneratia apetala*) **Ora** (*Sonneratia alba*) **Kankra** (*Bruguiera gymnorhiza*) **Garjan** (*Rhizophora apiculata*) **Garjan** (*Rhizophora mucronata*)
Less than 5−5.5 mtr. above sea level	10 days	**Garjan** (*Rhizophora apiculata*) **Garjan** (*Rhizophora mucronata*) **Keora** (*Sonneratia apetala*) **Kankra** (*Bruguiera gymnorhiza*) **Dhundul** (*Xylocarpus granatum*) **Pasur** (*Xylocarpus moluccensis*) **Goran** (*Ceriops decandra*) **Khalsi** (*Aegiceras corniculatum*) **Sundari** (*Heritiera fomes*) **Geonwa** (*Excoecaria agallocha*) **Golpata** (*Nypa fruticans*)
Less than 5.5−6 mtr. Above sea level	2-3 days	**Keora** (*Sonneratia apetala*) **Kankra** (*Bruguiera gymnorhiza*) **Dhundul** (*Xylocarpus granatum*) **Pasur** (*Xylocarpus moluccensis*) **Goran** (*Ceriops decandra*) **Khalsi** (*Aegiceras corniculatum*) **Sundari** (*Heritiera fomes*) **Geonwa** (*Excoecaria agallocha*) **Hental** (*Phoenix paludosa*) **Golpata** (*Nypa fruticans*)
More than 6 mtr. Above sea level	Very occasional	**Hental** (*Phoenix paludosa*)

It is also important to take note of the pre-existing vegetation. Repeated plantations over the years may give an altered and hence a biased composition of the plants around and therefore consultation with local communities, especially elderly persons must be done to take an account of the species that previously existed.

The choice of species having been made as per different preferences, the planning for plantation of seed /propagule or seedling needs to be worked out.

The phenology of the species, as per the germination type is to be considered for collection of seeds or propagules.

On the riverside areas of the embankments, where there are no regular tidal inundation because of raised landmass, the following species may be considered.

List of Mangrove Associates Which Can Be Considered For Plantation In Places Where There Is No Tidal Inundation

1. *Caesalpinia bonduc* (L.) Roxb.(Caesalpiniaceae)
2. *Caesalpinia crista* L. (Caesalpiniaceae)
3. *Calophyllum inophyllum* L. (Clusiaceae)
4. *Cerbera manghas* L. (Apocynaceae)
5. *Clerodendrum inerme* Gaertn. (Verbenaceae)
6. *Derris scandens* (Aubl.) Pittier (Fabaceae)
7. *Derris trifoliata* Lour. (Fabaceae)
8. *Hibiscus tiliaceus* L. (Malvaceae)
9. *Salacia chinensis* L. (Celastraceae)
10. *Tamarix troupii* Hole (Tamaricaceae)
11. *Thespesia populnea* (L.) Sol. ex Correa (Malvaceae)
12. *Manilkara hexandra* (Roxb.) Dub. (Sapotaceae)
13. *Dolichandrone spathacea* (L.f.) K. Schum. (Bignoniaceae)

7.3 Stratification:

It is evident that mangroves exhibit strong preferences towards inundation level, salinity, soil firmness, etc. Hence, after visiting the designated plantation site, stratification (seggregation of areas having similarity in the physico-chemical parameters) of the planting areas is needed to develop both the species selection and plantation strategy.

7.3.1 A typical map generated after site selection with stratification.

On Google Earth , the delineation of the area of the site at Manmathanagar , Gosaba Block

Figure 7.1 Proposed area delineation through Google earth software

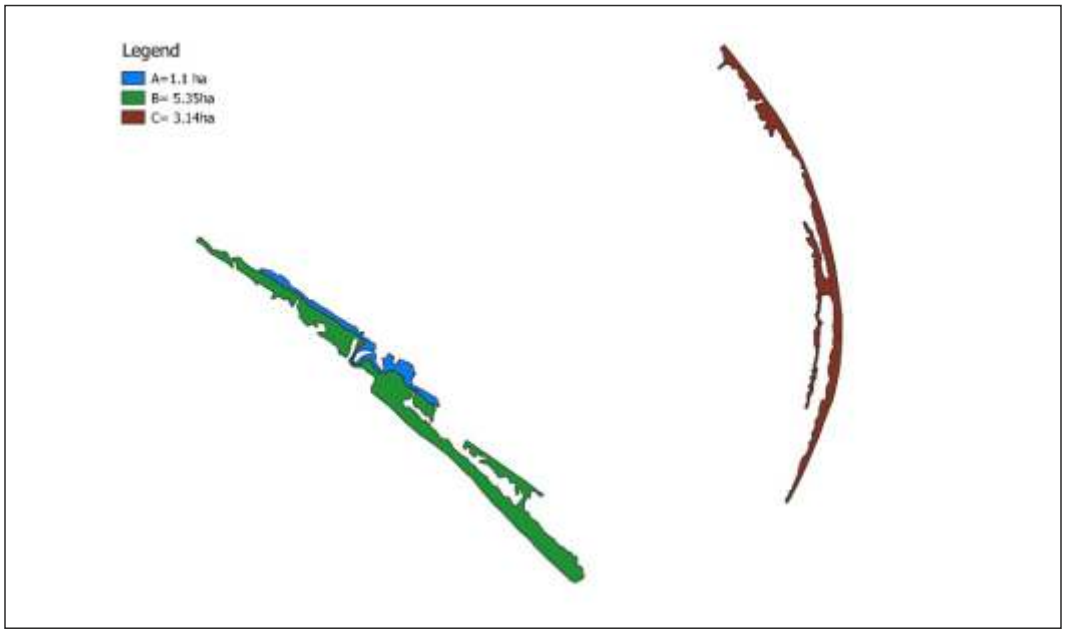


Figure 7.2 Proposed area delineation through GIS software

Table-7.3 Species selection on the basis of soil and hydrology (as referred in Fig 7.2)

Colour & Soil type	Hydrology management	Species Selection
Green – Medium hard soil, presence of 'giria'	Pit digging– saplings and seed plantation	*Bruguiera* spp., *Avicennia alba*, *Rhizophora* spp. (near permanent depressions)
Blue – hard soil, less inundation	Trench – sapling plantation	*Avicennia alba, A. marina, Excoecaria agallocha*
Brown – Soft soil	Direct seed plantation	*Avicennia officinalis, A.alba , Rhizophora* spp., *Sonneratia* spp.

Table-7.4 Species phenology

Species	Local name	Flowering time	Seed material	Germination type	Seed collection time	Seed Storage (Days)
Avicennia alba	Kalo baine	June-August	propagule	Crypto-viviparous	September - October	Approximately 7
Avicennia marina	Peyara baine	April-August	propagule	Crypto-viviparous	July	Approximately 7
Avicennia officinalis	Jat baine	June-August	propagule	Crypto-viviparous	July	Approximately 7
Excoecaria agallocha	Geonwa	April-May	fruit	Non-viviparous	July-August	Approximately 7
Sonneratia apetala	Keora	March-July	fruit	Epigeal	September - October	Approximately 15
Sonneratia caseolaris	Chak keora	March-July	fruit	Epigeal	September - October	Approximately 15
Rhizophora mucronata	Garjan	July-October	propagule	Viviparous	April-May	Approximately 45
Rhizophora apiculata	Garjan	May-September	propagule	viviparous	August	Approximately 45
Bruguiera gymnorhiza	Kankra	Throughout theyear	propagule	Viviparous	July	Approximately 30
Bruguiera sexangula	Bokul kankra	Throughout theyear	propagule	Viviparous	July	Approximately 30
Bruguiera parviflora	Kankra	April-September	propagule	Viviparous	July-August	Approximately 30
Ceriops decandra	Math goran	Throughout the year	propagule	Viviparous	June- July	Approximately 40
Ceriopa tagal	Jhamti goran	March-August	propagule	Viviparous	June- July	Approximately 40
Aegiceras corniculatum	Khalsi	April-September	propagule	viviparous	June-July	Approximately 15

Xylocarpus granatum	Dhudhul	Throughout the year	fruit	Hypogeal	July-August	Approximately 15
Xylocarpus moluccensis	Pashur	April-July	Fruit	Hypogeal	August	Approximately 15-20
Heritiera fomes	Sundari	May-August	Fruit	Hypogeal	June-July	Approximately 12
Nypa fruiticans	Golpata	May-September	Fruit	Epigeal	February	Approximately 60
Phoenix paludosa	Hental	March-August	Fruit	Hypogeal	August	Approximately 25-30

Figure 7.3 Recording the geographical location of the site through GPS software

Accordingly a planning for plantation for each site is made, also diagrammatically as per stratification of the tidal areas including the choice of species, essentially in a multi species environment.

The **plantation design** should consider the availability of seeds and the season for collection.

8.0 NURSERY

Nursery for certain mangrove species, in a multi species environment, are an integral part of plantation programmes as the survival rate is found to vary between 60 to 80 % in case of nursery raised sapling plantation and 40 to 60 % in case of direct seed plantation. In a saline tidal system, it is evident that dispersal and establishment of mangroves are best adapted for the species with viviparous germination namely, *Bruguiera* spp., *Rhizophora* spp., *Ceriops* spp. and crypto viviparous germination like the *Avicennia* spp. However other mangroves which bear fruits and seeds also have their own systems of dispersal, germination and establishment on suitable silted areas. For the former, the nursery preparation is easy while for the latter the process is complex.

8.1 Benefits of nursery preparation:

1) Less mortality due to formation of structured root system: The saplings develop a root system that helps them to anchor easily in the soil. Compared to direct plantation, the protection and supervision for maturing into a sapling is well- managed in a nursery. Activities such as, taking care of seedlings, removal of diseased seedlings, applications of bio-fertilizer and bio-pesticides, checking on pests etc. support better survival of the seedlings.

2) More productivity: By creating a nursery, a large number of seedlings can be managed in a small place for plantation.

3) Community mobilization: Communities, especially women are mostly engaged in nursery formation and they engage in alternative livelihood for a period and also earn in the process.

4) Option for income generation: The plants are reared for minimum two months to a maximum of 1 year. They earn by raising nurseries. Also, stitching jute pouches give them additional revenues.

5) Transfer & consolidation of Conservation knowledge: Through training and interactions, knowledge of mangrove and their conservation is disseminated to the local communities.

6) Optimum time management: The seed availability is maximum during the months of July, August, September and plantation time is also middle to late monsoon, when the salinity gets reduced and the plants are exposed to monsoon splashes. After pit digging and channel management, at least two spring tides are required for optimum deposition of alluvium and this time can be best utilized for raising nurseries.

7) Standardizing the protocol: Studies from the various sites help in standardizing the protocol for nursery raising of various mangrove species.

8.2 Women engagement in the nursery:

Women especially the prawn seed collectors, fisher-women, local groups can be trained to raise nursery of mangrove saplings.

There can be a centralized nursery for display of several species, however the community-based models will surely include the local women in organizing the nursery at the site level. It ensures their

involvement from the very beginning of the process, thereby ensuring ownership and sustainability. Thus, training for raising nursery of mangroves for different mangrove species, as selected, is an important initial step for mangrove afforestation and restoration, where communities are trained especially the local women. The training intends to impart the technical and scientific knowledge on mangrove sapling rearing and also aware the local communities about the various benefits that it brings to the life and livelihood of local communities.

The following steps, activities and discussions need to be carried out to train local people on mangrove nursery raising.

8.2.1 Explaining the need for afforestation programme:

The training starts with an introduction to the programme. In this section, the trainers discuss about different aspects of the programme including what it aims to achieve at a larger scale, how the initiative is much required in the project area, the ecosystem services that are available in the mangrove landscape, role of local communities in conservation and sustenance of the initiative and the benefits of communities in the long term.

8.2.2 Selecting site for nursery:

Selection of appropriate place is the first step for this nursery raising. Required land area depends on the number of saplings to be raised. Site selection criteria is demonstrated to the participants. Care should be taken to include availability of appropriate land and other relevant parameters, like, availability of sunlight throughout the day, proper aeration and close access to both fresh and saline water.

8.2.3 Selecting mangrove species for building plantation strategy:

Species selection is a pre-nursery procedure for plantation. The plantation design that has already been developed in consultation with local communities are explained to the trainees so that they know the characteristics of plantation site and the time when the seeds of mangrove species need to be collected and raised in the nursery.

Figure 8.1 Jute pouches with seedlings

8.2.4 Grow bags for nursery-- jute pouches are ideal choice:

There are two options for raising saplings in the nursery - the poly-bags and jute pouches. It has been found out from previous experiences that in case of poly-bags, when the saplings with soil is taken out of the poly-bags, the tender roots which are vital for the initial anchoring of the mangroves get disconnected, broken and the mortality for saplings occurs mainly due to this. Besides, the poly-bags generate non-biodegradable waste in the village. Jute pouches are bio-degradable and can be directly put into the plantation site, thus the mortality is less. Besides the jute fibres are strong, coarse and provide organic, low thermal conductivity and heat resistant base for the saplings to anchor, absorb nutrients from the soil and grow on the selected sites. Jute is eco-friendly, and a locally available resource in southern part of West Bengal. Hence, jute pouches are promoted as carrier bags for nursery saplings. Women are trained to make these jute pouches as per the required size. Bales of jute are provided to the women and cut into a fixed size (10"x8"),and stitched to form the pouches of approx. 6" X 4". These pouches are then purchased from the women ensuring a financial flow into them.

The poly-bags are made of various sizes – 10" x 4"/8"x 6"/6" X 4" and a hole is made in the lower corner to allow drainage of excess water. It may be noted that poly-bags are much cheaper option than jute pouches. Also, for species which need more than 8 months of nursery rearing like *Sonneratia* spp., *Ceriops* spp. etc the jute pouches are not recommended as they tend to start decomposing and rot after 3-4 months. In spite of this, use of the jute pouches should be included in some percentage of the total sapling rearing to encourage the concept of sustainability and women engagement.

Figure 8.2 Women making Jute pouches

Figure 8.3 Stitching of Jute pouch

8.2.5 Filling pots:

Soil required for nursery bags are collected from the village side - grinded, made loose and then mixed with required amount of organic compost and put in the pouches.

8.2.6 Preparing nursery beds:

Ideally, 5 cm mud-raised beds are prepared for nursery and stretched east-west for exposure to sunlight throughout the day. Each bed of approximately 3 feet width shall be separated from each other by a 1.5 feet wide space which could be used as a canal to drain water or as a passage to move

around during maintenance. Once the bed is prepared, soil containing jute bags are placed in an organized way on the bed. Keeping in mind the draining provision, pruning and maintenance activities, disease control and also scarcity of available land, the ideal bed should not be more than 15ft long. They need to be protected from grazing and any other anthropogenic activities by putting nets around it.

For plants with non-viviparous germination, germination beds need to be prepared. These germination beds should be on the village side and choice of site varies from species to species.

Figure 8.4 Ideal Nursery Bed

8.2.7 Collection of seeds:

Collection of seeds depends on their availability in the nearby rivers. Local women will collect seeds available from the rivers. Selection of seeds during collection is also important and there shall be a screening on the basis of proper germination, health, and presence of insect and viability status of seeds.

Figure 8.5 Collection of seeds by local women through netting

Ripe fruits of *Sonneratia* spp., *Phoenix* spp. can be collected directly from trees, fruits can be treated to obtain seed.

Seeds of *Avicennia* spp., *Ceriops* spp., *Rhizophora* spp., *Bruguiera* spp., *Heritiera* spp., *Nypa fruticans*, *Xylocarpus* spp., *Aegiceras corniculatum*, *Excoecaria agallocha* can be collected through netting in the rivers.

Care should be taken for collections of seeds -

- Healthy Seeds: The collected seeds should be healthy enough to fight against different diseases. It should be devoid of any kind of infection. Presence of insect borer or any other pests should be checked during the collection.
- Well germinated seeds: Seeds that are well germinated should be collected as it ensures the survival of the planted trees.
- Mature seeds: Mature seeds need to be collected for the plantation as they are more viable for germination.

8.2.8 Storing seeds/propagules:

For Viviparous and crypto-viviparous seeds: Propagules or germinated seeds are placed inside a *hapa* (a structure constructed for easy seggregation of germinated seeds) for obtaining mature propagules.

For non-viviparous plants, fruits are collected and the seeds are segregated through different processes and then sowed or scattered in the germination bed. As soon as the seeds germinate, the healthy ones are transferred to nursery beds.

8.2.9 Sowing of seeds:

After collecting and screening, seeds or propagules are planted in soil filled jute bags in a way that one-third of the seeds will be inside the soil and two-thirds above the surface soil, with one seed in one pot.

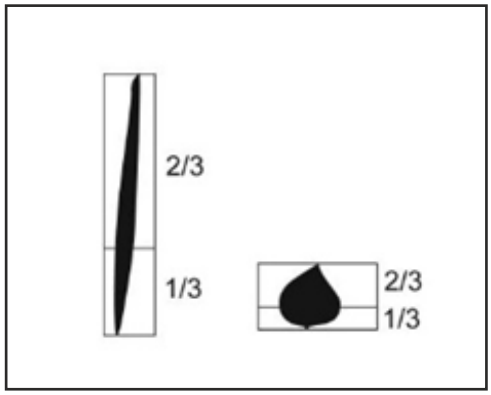


Figure 8.6 Seed sowing method in bags/pouches

Figure 8.7 Sowing of propagules

8.2.10 Maintaining Nursery:

Nurseries are regularly watered and maintained, after planting seeds, till they become saplings. Then they are planted on the mudflats. If there is no rainfall initially during the nursery period then fresh water shall be sprinkled and afterwards the nursery saplings has to be inured with saline tidal waters. Occurrence of pest or disease have to be checked often. In case there is a disease spread, it should be sprayed with bio pesticides, locally prepared with Neem (*Azadirachta indica*). Initially, the nursery beds shall be shaded to avoid scorching sunlight.

Figure 8.8 Nursery bed after saline water inundation

Figure 8.9 Watering of nursery bed

8.2.11 Preparing for salinity tolerance:

After the first 30 days, saplings initially raised with fresh water will have to be kept at riverine banks for another 30 days where the saline inundation takes place for 1-1.5 hours/day. The saplings are placed again at further lower mudflats with inundation of 2-4 hours/day. The lowering of height of the nursery depends on the species and the preferred inundation level where it thrives.

After approximately 1-2 months of acclimatization to saline water, saplings, depending on the species of mangrove, becomes suitable for plantation within 3 to 6 months.

Thus the nursery raised mangrove species experience a clear initial freshwater phase and a saline phase later.

Figure 8.10 Nursery beds with seedlings

8.3 Precautions & Monitoring:

- Storage of water: Stagnant water can cause harm to the mangrove. So, water stagnation in the nursery bed should be avoided.
- Removal of wastes: Wastes that come towards the shore due to the tidal actions need to be removed manually in a regular manner.
- Checking for pests: Seedlings and saplings need to be checked often to look for the pests.
- Replacing dead saplings: The dead saplings need to be replaced by rearing a new seed or propagule.
- Preparation of bio-pesticide: In case of pest-attack, bio-pesticide should be used to control it. Mainly Neem extracts and liquid compost (mixture of cow urine, cow dung and molasses) are sprayed.
- Frequent change of place: The position of the saplings along with pots need to be changed frequently to stop the downward penetration of roots into the nursery soil bed.
- Duration for seedlings to attain maturity: Approximately 90 days are needed for the seedlings to be ready for the plantation, depending on the species.
- Protection against grazing & other anthropogenic activities – Cattle grazing is a big problem for the nurseries and fencing with nets with height of about 3-4 ft is recommended.
- Monitoring format: The entire period should be carefully monitored. In the initial phase every 15 days, and monthly thereafter. A format for reference is given, which may be adapted according to the situation.

8.4 Nursery raising process of different species:

8.4.1 *Avicennia* spp.

8.4.1.1 Kalo baine (*Avicennia alba*):

Kalo baine or ***Avicennia alba*** grows in the matured river banks in Sundarban that have a lower water level, dominated by tidal activity. So they have a lot of breathing roots or pneumatophores to adapt with the anaerobic conditions. From the beginning of monsoon to the end of the rainy season, the buds of the species germinate. A growth of about one meter in height is observed every year. Flowers can be seen in three to four years. In Sundarban, it is also referred as 'Lanka Baine' (shaped like green chillies), due to the typical shape of the seeds.

Propagation

Usually in the months of April-May(Chaitra / Baishakh), flowers bloom in trees and in the months of June-July (Ashar/ Srabana), the ripened seeds get detached from the tree, fall into the river water, float to the nearby river banks, get settled as per tidal level and develops into new saplings. In the natural process, the mature fruits turn yellow and drops down into the river water. Within approx. 48 hrs, the seed sprouts and floats for about 6-7 days before getting anchored on the surface of the soil. It is observed that the *Avicennia* seed gets dispersed from the parent plant during spring tide and floats in the horizontal position in the initial phase and within seven days it becomes vertical to get anchored during the neap tide. When the seeds float and get vertical it is collected through netting in the rivers,

for raising nurseries or for direct plantation. After segregation of healthy and matured seeds, they are taken in two's for *A. marina* and *A officinalis* and in 2-3's for *A. alba*. If there are no other factors disturbing the afforestation process like huge waves, excess silting phenomena etc, it is advisable to plant *Avicennia* seeds directly.

Selection of nursery space

Nursery space should be able to withhold a lot of rain, at the same time be devoid of stagnant water. The soil mixed with organic manure is good for nursery generation. The place opposite to the river bed with the availability of freshwater should be preferred for plantation. The river beds should be spacious enough to accommodate the saplings and should be gently swept by the tidal activity every day. The land needs to be free from anthropogenic interference.

Preparation of soil

Two inches of soil has to be lifted from the nursery bed. Fourteen / fifteen baskets of old organic mixed soil would be needed for every one thousand poly-pot saplings. It should be mixed with two kg powdered mustard oil cake & five kg vermi-compost, mixed with little water and covered with black polyethylene sheets. After three days, the soil should be ground and mixed with a shovel and broken down to tiny particles in a shaded place, rolled and filled up in poly packets or sacks.

Preparation of Nursery bed

Nursery beds should be three feet wide in east- west direction. The four sides of the bed should be surrounded by wooden thickets or wooden log, so that the poly- pots remain erect and look straight upwards. A poly pack (4 x 6 inch), opened at one

Figure 8.11 *Avicennia alba* a) Fruits b) Flowers c) Tree

end and perforated at two corners on the other end for water drainage should be arranged in such a way that it points upwards. Jute pouches or clay pots can also be used.

Figure 8.12 Leaves of *Avicennia alba*

Seed collection and purification

Seeds should be collected during the months of June-July (Ashar / Sravan).

Plantation of seeds in nursery bags

Prior to the planting of seeds in nursery pots , it is advisable to soak the pouches thoroughly with water in the evening, one day before. In the morning, two seeds should be sown in each pouch. Thereafter the pouches should be kept in a light & shade environment. After three or four days, the pouches have to be removed and kept in a place with a soft light. In this case the saplings will remain for one full month in freshwater (Salt water can be provided if fresh water is unavailable).

Tolerance in salt water

Nursery beds should be exposed to tidal salt water only a month after sowing. The nursery pouches will be kept for one month in a place where there will be not more than fifteen days of high tide water in a month. Then the saplings need to be placed again for a month in a place where the high tide saline water is limited for twenty five days in a month. After a three month period the saplings of *Avicennia alba* will have one month of fresh water and two months of saline water and then they will be ready for plantation.

8.4.1.2 Peyara Baine *(Avicennia marina):*

Avicennia marina grows on the river banks in the Sundarban that have mid- level water. The soil being characterised with anaerobic nature, the trees possess numerous breathing roots or pneumatophores. During the monsoon period, propagation of *Avicennia marina* is completed. Crypto-viviparous germination is observed in this species. About one meter growth is observed in *Avicennia marina* sapling, every year in the initial years. Flowers bloom in three to four years.

Propagation

Usually in the months of April May (Chaitra / Baishakh), flowers arrive in the trees and in the months of June-July(Ashar / Srabana), the seeds ripen, are discharged from the trees, fall into the river water and float onto the banks to settle there and grow into new saplings.

Figure 8.13 Leaves of *Avicennia marina*

Growing saplings in nursery

The same process as in the case of *A. alba* maybe followed.

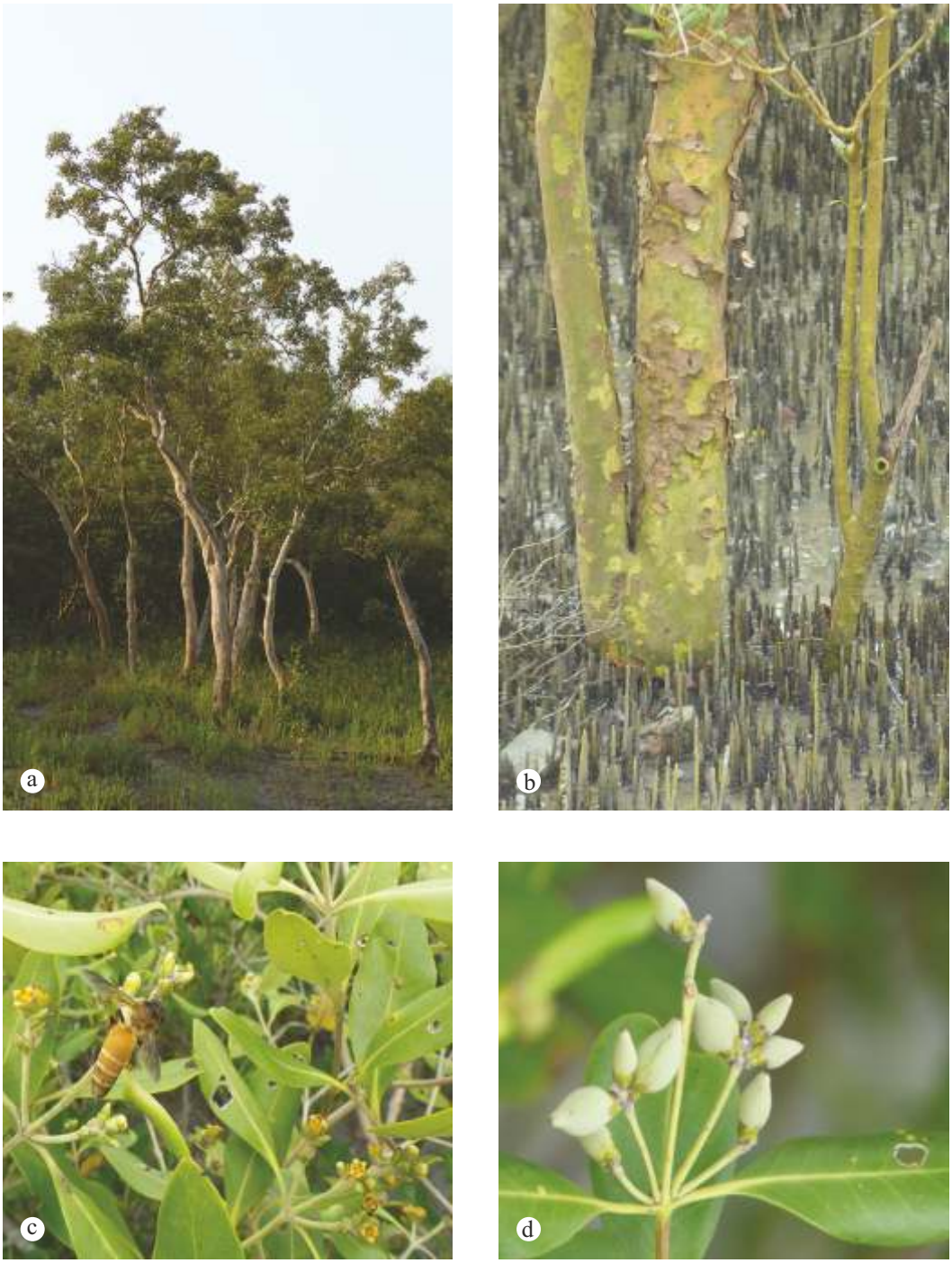


Figure 8.14 ***Avicennia marina*** **a) Tree b) Roots c) Flowers d) Fruits**

8.4.1.3 *Jat Baine (Avicennia officinalis):*

Avicennia officinalis grows in the medium to high water level intertidal zone mudflats and sandy shores, estuaries and tidal river bank areas and are characterized by its 'pneumatophores'. During the monsoon period propagation is completed. Crypto-viviparous germination is observed in this species. About one meter growth is observed in *Avicennia officinalis* saplings every year, in the initial years. Flowers can be seen after three to four years.

Propagation

Usually flowers appear in the months of April/May (Chaitra / Baishakh), seeds ripen and get detached from the mother tree in the months of (June-July) Ashar / Srabana, fall into the river water and float to intertidal zones of mudflat areas and settle to grow as new saplings. A dense plantation can be observed.

Growing saplings in nursery

The same process as in the case of *A. alba /A. marina* maybe followed.

Figure 8.15 *Avicennia officinalis* a) Leaves b) Flowers c) Fruits d) Exposed branching root system

Figure 8.16 ***Avicennia officinalis*** **tree**

8.4.2 *Bruguiera* spp.:

The nurseries are practiced mainly for the three species of *B gymnorhiza, B cylindrica* and *B parviflora.*

After viviparous germination, the propagules fall from the parent plant into the river.

8.4.2.1 Kankra *(Bruguiera gymnorhiza):*

The propagule is very colorful, characterized by a green stem like structure with a bright pink helmet shaped persistent calyx. It also floats horizontally and after 2-3 days the calyx drops and the propagule starts orienting vertical with maturity, having the shoot opening on the exposed side. Women can collect through netting and sow in the nursery beds or can also be directly planted, checking on the inundation level, soil texture, salinity and other parameters of the river banks. In the nursery beds, after 1 month in the fresh water phase, it is carried down into the inundation level of 8-10 days and then to a maximum of 20 days inundation.

The seeds of *Bruguiera* spp. look a lot like writing pens, so many people call them "Pen fruits".

Figure 8.17 *Bruguiera gymnorhiza* a) Leaves b) Flower c) Sapling d) Fruit

8.4.2.2 Bakul Kankra *(Bruguiera cylindrica* and *Bruguiera parviflora):*

B cylindrica and *B. parviflora* have thinner germinated stem, with green helmet or cap shaped persistent calyx. With maturity the calyx turns light yellowish for *B. cylindrica* and brownish for *B. parviflora*. *Bruguiera cylindrica* or Bakul Kankra seeds are 5-6 inches long, sleek like pencil and cranked.

Bruguiera sexangula seeds look like cigars and are about 5 inch long.

For growing saplings in nursery, the same process maybe followed while selecting nursery space, preparation of soil, nursery beds, as in the case of *Avicennia* spp.

Seed Collection

It maybe noted that seeds of *Bruguiera* are available throughout the year in Sundarban, but considering the magical monsoonal effect on the growth and survival of mangroves, the seeds are usually collected from July to September.

The seeds should be drained out from water.

Cleaning of seeds

Seeds collected from rivers or trees should be washed in clean water, mixed with one litre of cow urine in nine litres of water. (Ratio 1:9)

Plantation of seeds in nursery bags

It is best to soak the pot thoroughly with water in the evening before the day of seed planting. In the morning, one seed should be planted in each pouch. After that it will be kept in a little shade. After ten/ twelve days, the pouches should be placed in an area with a soft light. First the helmet shaped calyx will fall off and then the leaves will come out from the seeds and become seedlings. If seeds are spoilt, good seeds need to be sown again. In this case the saplings will remain in freshwater for one month.

Figure 8.18 *Bruguiera* sp. a) Flowers b) Propagules

Tolerance in salt water

Nursery beds should be kept in the tidal activity of salt water after one month of sowing. The seedlings will be kept in a place for about a month, where there will be not more than ten days of high tide water availability in a month. Then the saplings will be kept for a month at a place where the high tide water is limited to twenty days in a month. After a period of three months, when one month is spent in fresh water and two months in salt water, *Bruguiera* saplings will be ready for plantation.

Figure 8.19 *Bruguiera* spp. a) Saplings b) Trees

8.4.3 *Ceriops* spp.:

The nursery practice is done for the two species namely *C decandra* and *C tagal*.

Being viviparous, the propagules get detached from parent plant after germination, slender hypocotyl with green cap like persistent calyx in the initial stage turning orange- brownish at the later stage. First it floats horizontally, then vertically. The calyx drops and the propagule gets matured for collection. It can be directly sown in the plantation site but due to very slow growth rate it is advisable to go for nursery raising.

8.4.3.1 Jhamti Goran (*Ceriops decandra*):

The ***Ceriops decandra*** seeds are long, curved and ribbed.

Collection of Seed:

Seeds are available throughout the year but they are more plentiful in the months of May and June. Seeds are collected from the water and drained with the help of fine mesh nets. Seeds are then washed and stored. Sometimes, mature seeds are also collected directly from trees.

Seed treatment:

Seeds must be washed with clean water mixed with cow urine and water in 1:9 ratio. Thereafter the water is drained out.

For growing saplings in nursery selection of nursery space, soil preparation and planting seeds in the nursery pots, the same method maybe followed.

Figure 8.20 Propagules of *Ceriops decandra*

Tolerance in salt water

Nursery beds should be kept in the tidal activity of salt water after one month of sowing. The nursery pouches will be kept for one month where there will be not more than five to six days of high tide in a month. Then the saplings will be placed again for a month in a place where the high tide water remains for fifteen days in a month. This way, in a total of three months, the saplings remain one month in fresh water and two months in saltwater. After the acclimatisation, the three months old *Ceriops decandra* saplings will now be suitable for planting.

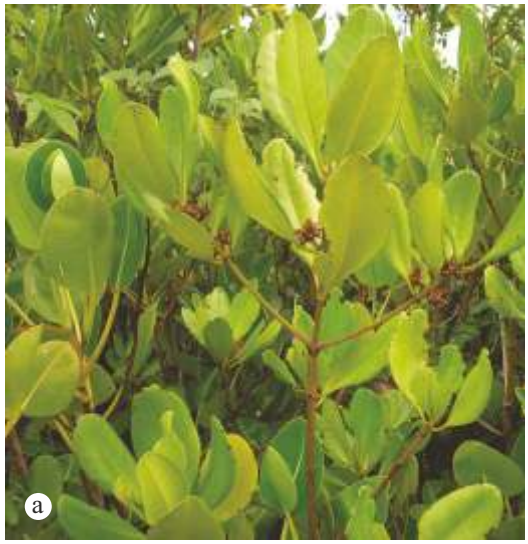


Figure 8.21 *Ceriops decandra* a) Leaves b) Trees

8.4.3.2 Math Goran (*Ceriops tagal*):

The ***Ceriops tagal*** seeds are 8/9 inches long, curved and ribbed.

Collection of Seed:

Seeds are available throughout the year but they are more plentiful in the months of July and August. After collection the same process maybe followed as in the previous case of *C. decandra* for cleaning and washing.

Similarly, for growing saplings in nursery**,** selection of nursery location, preparation of soil, preparing nursery beds, planting seeds in the pots, acclimatisation with saline water, the same process maybe followed as in *C decandra*.

Figure 8.22 Roots of *Ceriops tagal*

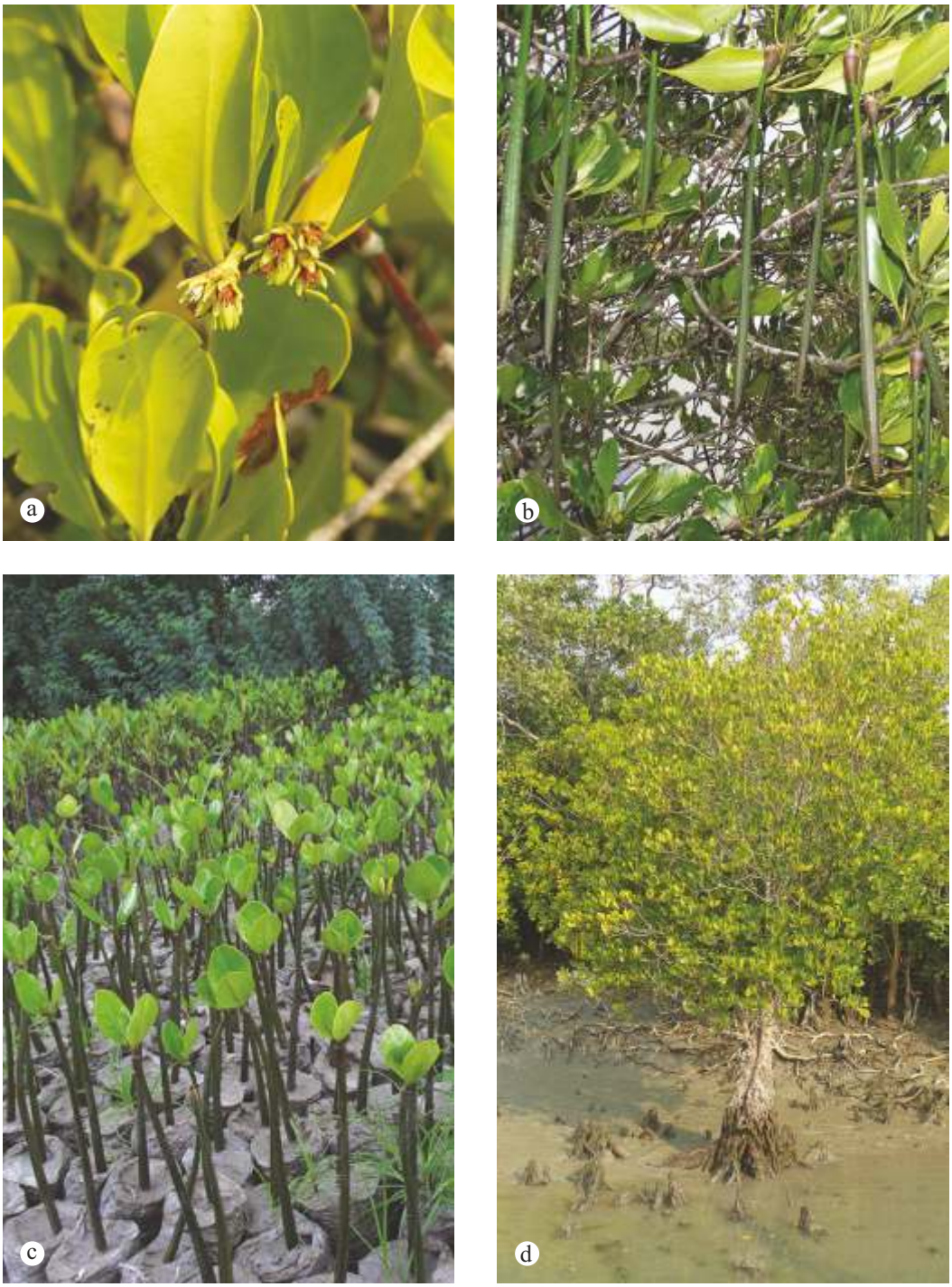


Figure 8.23 ***Ceriops tagal*** **a) Flower b) Propagules c) Saplings d) Tree**

8.4.4 *Xylocarpus* spp.:

The fruits ripe and drops in the water, it ruptures and the pinkish seeds float on the water, the seed coat disappears and the seed turns dark brown. It starts germinating, settles on the river banks and new alluvium help in the growth of seedlings. When the seeds are collected and sorted, it is found that they are prone to insect attack. It is advisable to apply bio-pesticide at the seed stage, particularly for this species.

Two species of *Xylocarpus* sp. has been successfully reared in nurseries.

8.4.4.1 Dhudul (*Xylocarpus granatum*):

Dhudul or *Xylocarpus granatum* can be seen in the river banks of Sundarban which has a medium water level. As per Bengali calendar the flowering and fruiting happens in between Magh to Shrabon month (mid-January to mid-August). The seeds are of lighter shade and looks like a three dimensional triangle. The tree can grow three to four ft. in a year, in the initial years.

X. granatum grows in medium quality soil or hard soil. This belongs to true mangrove species. New seedlings grow in monsoon season.

Figure 8.24 Tree of *Xylocarpus granatum*

The collection of seed:

The matured fruits are collected from the trees. Afterwards the seeds are separated from the fruits.

After collection, the seeds need to be planted in the nursery bed immediately. The seeds shouldn't lack moisture before plantation.

Nursery bed preparation:

For nursery bed preparation, soil preparation, the same process for other species maybe followed.

Plantation of seeds in nursery bags :

Single seed need to be planted in each pouch. The germinating point is identified and placed delicately in the soil of the nursery pouches. Within two weeks the seedling starts growing. The shoot that comes out is about 1 ft in height within 15-20 days with 2-4 leaves at the top.

The things that need to be kept in mind :

1. The nursery is to be covered by transparent polythene sheet.

2. Watering needs to be done with a *Jhari* (Watering pot with the strainer).

Nurturing:

As soon as the leaves become strong enough the polythene sheet need to be removed. The seedlings with leaves, are ready to test the tolerance in saline water. During this time, the seedlings are found to be infected with pests, therefore preventive measures should be taken beforehand.

Figure 8.25 *Xylocarpus granatum* a) Fruit b) Flowers

Saltwater tolerance:

The seedlings need to be separated from the nursery as saplings grow one month old or have at least four leaves, whichever is earlier. Afterwards, those saplings need to be placed in the river bed for a month which gets at least 9 to 10 days of tidal waves (usually after 40-45 days). Then the seedlings need to be relocated to the river bed for another month that gets at least 15 to 16 days of tidal waves. Within 60-70 days, the sapling is ready for plantation. As a result, the seedlings get three months old before transplantation. In this process, the seedlings survive one month in fresh water and two months in salt water.

Figure 8.26 *Xylocarpus granatum* a) Fruits b) Leaves

8.4.5 *Rhizophora* spp.:

After viviparous germination, the propagule gets detached from the parent plant and floats horizontally. However, before anchoring into the soil it gets vertical, settle on the optimal tidal level on the river bank and settle there to produce saplings. Sometimes seeds are spread naturally close to the trees and then the growth of the saplings is dense. Many stilt roots are generated. However, considering other parameters especially the inundation level, it can be also planted on the identified river banks directly and innovatively as the first layer from the river/creek for anchoring effect with its stilt roots.

8.4.5.1 Garjan (*Rhizophora mucronata):*

The ***Rhizophora mucronata*** seeds are long, about 1.6 ft in length, and many people call them "Khamu", locally.

For growing saplings in nursery, selection of nursery location, preparation of soil, preparation of nursery beds, etc. the same process maybe followed as described for other species.

Seed Collection

Rhizophora mucronata seeds are available throughout the year but the numbers increase in the months of January and September. As soon as the seeds are collected from the rivers through netting, it is stored in the river waters in a hapa (a structure constructed for easy seggregation of germinated seeds). The horizontal seeds appear to orient themselves in a vertical position, then they should be washed and stored. Ripened seeds can also be collected from the trees.

Cleaning of seeds

Seeds collected from rivers or trees should be washed in a solution of one litre of cow urine in nine litres of water (1:9) and then suitably dried.

Figure 8.27 Leaves of *Rhizophora mucronata*

Plantation of seeds in nursery bags

It is best to soak the pots thoroughly with water in the evening prior to the day of seed planting. In the morning, one seed should be planted in each pot. Gradually, the seed cap will fall off. After 15 days of sowing, two leaves appear. If seeds are spoilt, fresh seeds need to be sown again. In this case the saplings will remain in fresh water for one month. Saline water should be used if fresh water is not available.

Tolerance in salt water

Nursery beds should be kept in the tidal activity of salt water after one month of sowing. The nursery pots will be kept for one month there, where there will be not more than fifteen days of high tide in a month. Then the saplings will need to be placed again for a month in an area where the high tide water remains for twenty five days in a month. This way, in a total of three months, the saplings remain one month in sweet water and two months in salt water. After the acclimatization process, the saplings will now be suitable for planting.

Figure 8.28 *Rhizophora mucronata* a) Flowers b) Propagules

8.4.5.2 Garjan Vara *(Rhizophora apiculata):*

Rhizophora apiculata seeds are long, about 1.6 ft in length, and so many people call them Garjan "Vara".

River banks with low to medium water levels will be selected for plantation of *Rhizophora apiculata* seeds. It would mean that high tide water would reach this river bed 25-30 days in a month, every year.

Collection of Seeds:

Seeds are available throughout the year but they are more plentiful in the months of January and September. Seeds are collected from the river by water draining process with the help of fine mesh nets. Seeds are then washed and stored. Sometimes, mature seeds are also collected directly from trees.

Cleaning of seed:

Seeds must be washed with clean water after collection and then immersed in a mixture of cow urine and water in 1:9 ratio. Thereafter the water is drained out.

Selection of nursery location

The process for selection of nursery location, preparation of soil, preparation of nursery beds will be done as described earlier.

Plantation of seeds in nursery pot along with acclimatisation with saline water will be same as in the case of *R mucronata.*

Figure 8.29 *Rhizophora apiculata*

8.4.6 Geonwa (*Excoecaria agallocha*):

Geonwa can be found in the Mangrove ecosystem of Sundarban in places where the water level is maximum, i.e. on hard soil. As per the Bengali calendar, flowering and fruiting start in between Falgun & *Ashar* months (mid- February to mid- July). In the months of *Shrabon* and *Bhadro* (mid-July to mid-September) the fruits mature, drop down onto the river water and float with tidal waves. Then the seeds come out from the matured fruits and settle on the river banks. The seeds are of round shape, similar to Okra (Lady's Finger) seeds. New seedlings come out during monsoon. Rain helps in the growth of seedlings. The trees grow up to 1ft. to 1.5 ft., in a year in the initial years.

Seed Collection:

The matured fruits are collected either from the trees or from the river. Very often the germinated seeds float with the tidal wave and come to the river beds. It is then washed and cleaned as prescribed earlier.

Nursery bed preparation:

For the nursery bed preparation, the soil and vermi-compost need to be mixed properly. Then the mixture needs to be stored in a 4ft x 6ft bag till it is used to prepare the nursery bed. The breadth of the bed will be 3 ft and the length could be as per convenience, keeping in mind the conditions described earlier.

Plantation of seeds in nursery bags:

In each pouch, two to three seeds need to be planted and covered with a transparent polythene sheet. Within two weeks the seedling comes out from the pouch. Fresh water needs to be provided with the help of a *Jhari* (Watering pot with the strainer). A shade made with the leaves of Palm, Date or Coconut should be given over the saplings.

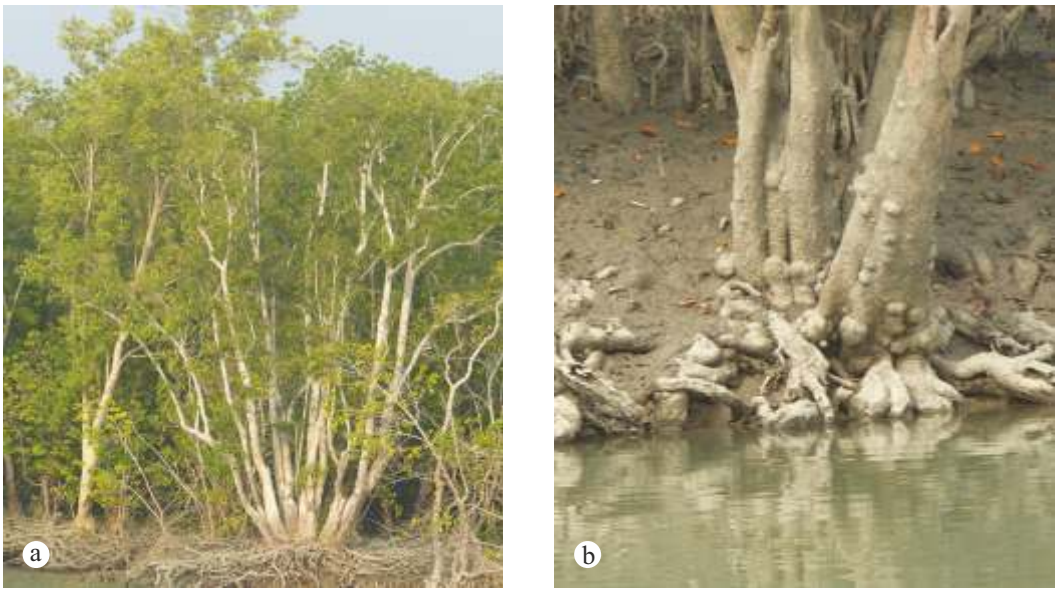


Figure 8.30 *Excoecaria agallocha* a) Tree b) Roots

Nurturing:

As soon as the leaves are well developed, the polythene sheet needs to be removed. The seedlings with the leaves are ready to be acclimatised in saline water. The crucial aspect is that if the seedlings are placed in deep water (beyond permissible level), the seeds might float away with the tide.

Saltwater tolerance:

The seedlings are taken out of nursery beds when the saplings grow one month old or have four leaves at least, whichever happens earlier. Thereafter these saplings need to be placed on the river banks for a month where they get at least three to four days of tidal waves. Then the seedlings need to be relocated to such a location in the river bed for another month where they get at least eight to ten days of tidal waves. As a result, the seedlings get three months old before transplantation. In this process, the seedlings survive one month in fresh water and two months in salt water and the acclimatization process is complete.

A special technique for the propagation of *Geonwa:*

Stem cuttings of *Geonwa* can also be directly planted either in pouches or in the river banks. However it needs close monitoring.

Figure 8.31 *Excoecaria agallocha* a) Leaves b) Flowers c) Fruits d) Saplings

8.4.7 Keora *(Sonneratia apetala):*

Keora has been identified as the mangrove that thrives in an area with the maximum water-level. However, they can be seen in areas with low water-level also. They have tall breathing roots. With these breathing roots, it collects the alluvium. Keora can be seen growing on soft or hard rugged soil almost everywhere in the Sundarban ecosystem. As per the Bengali calendar, the flowering and fruiting start in the months of *Falgun* to *Ashar* (mid- February to mid-July). In the months of *Bhadro* and *Ashwin* (mid- August to mid-October) the fruits mature , drop into the river waters and float with the tidal waves. Then the seeds come out from the matured fruits and settle down onto the river bed with the alluvium. These seeds are often found to settle down as a colony at the bottom of the water level. With time some seedlings die out and the colony gets sparse. The surviving ones later grow up to become sturdy trees.

Figure 8.32 Tree of *Sonneratia apetala*

The tree grows up to three to four feets. in a year, once stabilized after the initial years.

The colony of ***Keora*** mangroves are very often seen in Sundarban. The Ganges-Brahmaputra deltaic system, brings in an enormous amount of the alluvium sediments which favours the growth of Keora. In the two months (mid July-August), the river water is less saline due to the effect of monsoon. All these contribute to the luxuriant growth of Keora in the silted areas.

The collection of fruits:

The matured fruits are collected from the trees and stored in gunny bags / earthen pots, plastic drums for 3- 5 days with splashing of fresh water. The fruit rots and the seed come out. It is washed and arranged closely for germination. As the buds come out, they are scattered in a seed bed, made of soil with compost. After 6-7 days, two leaves come out and then it is transferred to nursery pots.

Process of Germination:

The seeds need to be collected while they have enough moisture within. Thereafter, these seeds are required to be kept in jute bags for at least the next two to three days for germination. Storing in jute bags would help the seeds to gather the required warmth, humidity & air.

Figure 8.33 Flower of *Sonneratia apetala*

Nursery bed preparation:

For nursery bed preparation the soil and vermicompost need to be mixed properly. Then the mixture needs to be stored in a 4ft x 6ft bag till such time it could be used to prepare the nursery bed. The breadth of the bed will be 3 ft and the length could be as per convenience, keeping in mind the conditions required to support care and monitoring.

Plantation of seeds in nursery bags:

In each pot, three to four seeds need to be planted. Within one week the seedling grows out from the pot. It is covered with transparent polythene sheet to protect from direct sunlight. Fresh water needs to be sprinkled with a *Jhari* (Watering pot with the strainer).

Nurturing:

As soon as the leaves become strong, the polythene sheet needs to be removed. The seedlings with the leaves are ready now for acclimatisation.

Saltwater tolerance:

The seedlings are taken out from the nursery when the saplings grow one month old or have four leaves at least, whichever is earlier. Then those saplings need to be placed on the river bank for a month in such a way that they get 10-15 days of tidal waves. Then the seedlings need to be relocated to the river bed for another month where they get 20-25 days of tidal waves. It has to be kept like this for approximately one month where it will achieve a height of 6 inches and it will be ready for plantation. However, it takes almost a year to have a matured seedling for *Sonneratia apetala*.

Figure 8.34 *Sonneratia apetala* a) Fruits b) Pneumatophores

8.4.8 Khalshi (*Aegiceras corniculatum):*

This species is available in large colonies in the low lying areas of Sundarban mangrove ecosystem. Flowering and fruiting seasons extend from January to August.

Fruits mature between, mid- May and mid- July, and then produce seedlings. Growth is up to 1.6 ft. in a year. Good flavored honey is extracted from Khalsi or *Aegiceras corniculatum* flowers.

Propagation:

The seeds ripen in the months of *Jyashtho* and *Ashar* in the Bengali Calendar (mid- May to mid- July) and after germination of seed, seedlings appear settling in the low lying areas of the river banks enriched with fresh alluvium or silt. New silt formation is helpful in growth of seedlings.

Seed collection and preparation:

Mature seeds of *Aegiceras corniculatum* should be collected from the river water. Then the seeds should be drained out of the water through fine-mesh nets, washed in clean water and then treated with a mixture of one litre of cow urine in nine litres of water (1:9).

Preparation of Nursery beds:

Jute bags (4ft x6ft) filled with soil and vermi- compost mixture should be used in the nursery beds and the dimensions of the beds will be 3ft wide with the length as per necessity, keeping in mind the conditions, as stated earlier.

Plantation of seeds in nursery bags:

Each pouch should contain two germinated seeds. Seedlings emerge within one and half week and need to be sprinkled with fresh water. If not available, saline water may be used.

Figure 8.35 Tree of *Aegiceras corniculatum*

Care:

Seedling should be accustomed with saline water when new leaf is stable.

Tolerance in salt water

Nursery beds should be kept in the tidal activity of salt water after one month of sowing. The nursery pots will be kept for one month in a place where there will be not more than fifteen days of high tide in a month. Then the saplings will need to be placed again for a month in a place where the high tide water remains for full month. This way, in a total of three months, the saplings remain one month in fresh water and two months in salt water. After the acclimatisation, the three month old *Aegiceras corniculatum* saplings will now be suitable for planting.

Figure 8.36 *Aegiceras corniculatum* a) Flowers b) Saplings c) Fruits

8.4.9 Pashur (*Xylocarpus moluccensis*):

Xylocarpus moluccensis mainly grows in Sundarban, in areas that have a medium water level. As per the Bengali calendar, the flowering and fruiting start between the months of *Magh* & *Shrabon* (mid-January to mid-August). In the month of *Ashar* and *Shrabon* (mid- June to mid-August) the fruits mature, drop down into the river water, the seeds come out from the matured fruits and settle down in the river banks. The monsoon rain and new alluvium help in the growth of the seedlings.

Propagation:

Xylocarpus moluccensis grows in medium quality soft or hard soil. This belongs to the true mangrove species.

Collection of seed: The matured fruits are collected from the trees. Thereafter the seeds are separated from the fruits, cleaned, washed properly (as described earlier) and planted in the nursery bed immediately. The seeds shouldn't lack moisture before plantation.

Nursery bed preparation: For the nursery bed preparation, soil preparation, the same process maybe followed, as described earlier.

Figure 8.37 Tree of *Xylocarpus moluccensis*

Plantation of seeds in nursery bags:

A single seed needs to be planted in each pouch. Within two weeks the seedling germinates from the pouch. The following points may be noted.

1. The nursery should be covered by a transparent polythene sheet/ or a shade with leaves of palm/coconut trees.

2. Watering needs to be done with a *Jhari* (Watering pot with the strainer).

Nurturing:

As soon as the leaves are well developed, the polythene sheet/shade can be removed. The seedlings with the leaves are ready to be acclimatised in saline water. At this time seedlings often get pest attacks and therefore preventive measures should be taken beforehand.

Saltwater tolerance:

The seedlings need to be separated from the nursery when the saplings grow one month old or have four leaves at least, whichever is earlier. Then those saplings need to be placed in the river bed for a month in such a way that they get at least ten days of tidal waves. Then the seedlings need to be relocated to such a location in the river bed for another month where they get at least 15 to 16 days of tidal waves. As a result, the seedlings are three months old before transplantation, surviving one month in fresh water and two months in salt water.

Figure 8.38 *Xylocarpus moluccensis* a) Flowers b) Roots

8.4.10 Sundari (*Heritiera fomes*):

It is believed that the Sundarban has derived its name from 'Sundari' mangrove tree. Sundari can be seen in places where the water level is generally high. As per the Bengali calendar, flowering and fruiting start in between the month of *Chaitro* & *Shrabon* (mid- March to mid-August). In the months of *Shrabon* and *Bhadro* (mid- July to mid-September) the fruits mature and drop onto the river water and float with the tidal waves. Then the seeds come out from the matured fruits and settle down on the river banks. Rain and new alluvium help in the growth of seedlings. The seeds are of a lighter shade and look triangular in shape. In the natural process, the seedlings start coming out from the matured fruits. Sundari grows in medium soft or hard soil. This belongs to true mangrove species.

The fruits are originally green, ripes into golden colour and drops in the water and floats. It turns brown and is collected and kept in shade, however maybe exposed to rain. After few days the mouth of the fruit split opens and the seed germinates.

When the fruits are collected and sorted, it is found that they are prone to insect attack. It is advisable to clean it properly with a mixture containing 1 part of cow urine and 9 parts water (1:9). Also, application of bio-pesticides like Neem (*Azadirachta indica*) is suggested at the seed stage, particularly for this species.

Figure 8.39 *Heritiera fomes* a) Leaves b) Flowers

The collection of seed:

The matured fruits are collected from the trees. Thereafter, these fruits are covered with straw or dry leaves and occasional watering is done.

Nursery bed preparation:

For nursery bed preparation the soil and vermi-compost are mixed properly. Then the mixture needs to be stored in pots/bag of needed shape to prepare the nursery bed. The breadth of the bed will be 3 ft and the length could be as per convenience, noting the necessary conditions to be maintained, as described earlier.

Plantation of seed in nursery bags:

A single seed needs to be planted in each pot. The area is covered with a transparent polythene sheet. Within two weeks the seedling emerges from the pot. Fresh water is administered with the help of a *Jhari* (Watering pot with the strainer).

Nurturing:

As soon as the leaves are well developed, the polythene sheet covers should be removed. Within 15-20 days, the shoot with the leaves reaches a height of around 1 ft. The seedlings with the leaves are ready for acclimatisation in salt water. This is the time when seedlings usually get pest attacks and therefore preventive measures should be taken beforehand; spray with bio-pesticides are recommended.

Saltwater tolerance:

Within 30-45 days of sowing, when the saplings grow one month old or have four leaves at least-whichever is earlier, the pots are transferred to river banks to ensure that they get at least five to six days of tidal waves. After another month, they are again transferred to a place where they get at least 10 to 12 days of tidal waves. As a result, the seedlings get three months' time for getting used to the saline water before transplantation. In this process, the seedlings survive one month in fresh water and two months in salt water.

Figure 8.40 *Heritiera fomes* a) Fruits b) Seedlings

8.4.11 Golpata (*Nypa fruticans*):

The Golpata colony is usually found in the Sundarban at moderate water level on the soft tidal slopes of the river. Mostly, they are found in small colonies. The leaves resemble coconut trees.

No pneumatophores can be seen, they prefer to live in low-salt water conditions in the estuaries. Rhesus Macaques in Sundarban can be seen eating the fruit of this tree. A stretch of Golpata is a visual attraction for all, with its beautiful foliage.

Propagation

Usually, the flowers appear during Falgun / Chaitra (mid-February to April) and Bhadra / Ashwin (mid-August to mid-October), and the seeds ripen in Shravan / Bhadra (mid-July to August) and Magh / Falgun (mid- January to March). It is also possible to see some trees flower and bear fruit throughout the year. The seeds ripen and fall into the river water and float on the specified water level, settle on the river banks in muddy areas and turn into seedlings. Sometimes it is seen to be densely spread and sometimes it is sparsely distributed.

Seed collection and purification

The seeds from the waters are collected during Sravan/ Bhadra (mid-July to August) and Magha/ Falgun (mid-January to March). Seeds need to be good and healthy. The collected seeds can be washed well in clean water, soaked in the mixture containing one litre of cow urine mixed with 9 litres of water (1:9) and dried in the air.

Figure 8.41 Tree of *Nypa fruticans*

Seed germination method

As a ripe coconut soaked in rainwater during the month of Bhadra (mid-August) or kept floating in the pond water at other times of the year, sprouts in one and a half / two months, Golpata seeds are germinated in the same manner.

Making seedlings in the nursery location selection

A suitable place that does not water-log even if it rains is needed. It is better if the land is mixed with old organic soil. Lands, where freshwater can be found, which is opposite to the river beds should be preferred. The riverbanks closer to the land should be kept empty for the saplings and the tidal activity should be allowed every day. The land needs to be free from all kinds of anthropogenic disturbances.

Soil preparation

Three-inch soil can be taken out from the nursery bed. To produce one thousand poly pots (6"x7") for the seedlings, about thirty / thirty-two baskets of old organic mixed soil should be taken. It should be mixed with five kg of mustard oil and ten kg of vermicompost and covered with black polythene. After three days, the soil should be crushed and mixed with a shovel in a shaded place and broken into particles, rolled, and filled up in poly packets and sacks.

Making Nursery Beds

Nursery beds should be three feet wide and aligned in an east-west direction. The sides of the bed should be surrounded by wood or clamps so that the silt pots remain straight. For a 6"x7" poly packet size, one edge should be open which is kept upwards facing the sky and the two corners of the opposite side have to be cut to allow drainage; next it is filled with the mixed soil, and arranged in straight rows. Jute bags or earthen pots can also be used.

Planting seeds in nursery bags

Before the seed is planted into the pouch, it is better to keep the pot wet and soaked well with water in the previous day. In the next morning, one seed should be planted with two-thirds inside the soil and one-third above having the eye of the seed facing the sky. The germination takes place after few days, the shoot and root comes out. For germinated seeds, shade should be provided. After about a month, the shade should be removed and gradually seedlings should be exposed to sun. In this condition, the seedlings will be nurtured in freshwater for two months. (If the seeds do not germinate, they should be kept in the pots for two more months and covered with straw.)

Tolerance in saltwater

Nursery beds should be removed as soon as the seedlings are two months old. Where tidal water does not rise for more than ten days a month, they will be kept for one month. After that, the seedlings should be displaced again and kept in a place where the tide is available for an average of 20 days a month. It turns out that two months of fresh water and two months of light saltwater will make these four-month-old Golpata saplings suitable for plantation on the silted areas along river banks. However, seedlings can be kept in the nursery till the age of six months.

Figure 8.42 Fruit of *Nypa fruticans*

8.4.12 Hental *(Phoenix paludosa):*

Hental tree grows at the highest water level in the Sundarban and represent the tertiary succession of the mangroves. They grow on the hard banks of the river with regular tidal activities. They look a lot like date palms or *Areca* trees. They usually have many shoots in one clump and look like a colony together. In most places it is dense and sometimes it is also seen single on the river banks.

Propagation

Usually, this tree flowers in the month of Falgun/ Chaitra (mid-February to April), and new seedlings are born in the month of Jyastha / Ashar (early May to mid- July). Hental propagation can also be observed sometimes through seed dispersion by animals/birds.

Growing seedlings in nurseries and planting on river banks

Nursery location selection

The selection for nursery sites, soil preparation and nursery beds preparation can be done as described for the other species.

Figure 8.43 a, b) Tree of *Phoenix paludosa*

Seed collection and purification

In the month of *Jyastha* / *Ashar* (early May to mid-July), the seeds ripen and fall into the river water and float together; which should be collected. Seeds need to be healthy and strong. Collected seeds can be planted by rinsing them thoroughly in clean water, soaking them with a mixture containing one litre of cow urine in nine litres of water (1:9), and drying the seeds in the air.

Special germination method of seeds

A vacant high place may be considered where drains can be constructed with open ends to allow water drainage. The seeds will be put in the drain and covered with straw to allow moisture retention as well as provide the necessary warmth to accelerate germination. In about 30/35 days, part of the seeds will germinate and the process can be continued for the rest.

Planting germinated seeds in a nursery bags

It is better to keep the pot wet in rainwater, if dry, it should be soaked well in water before planting. In the next day, two sprouted seeds should be planted in each pot. After planting the seeds, extra care should be taken that the shoots that have come out of the seeds do not break in any way. Sticks can be used for support if necessary. It is necessary to provide a shade to the bed for about a month. Then it can be exposed to sunlight for at least a month and saplings will bear two leaves. In this condition, the seedlings will stay in freshwater for full three months.

Tolerance in saltwater

Once the leaves of the seedlings are mature, the nursery beds should be removed in the saltwater tide. Where the tide rises less than ten days a month, they will be kept there for two months. The seedlings will be then suitable for planting.

Figure 8.44 *Phoenix paludosa* a) Flowers b) Fruits

8.5 Mangrove Nursery monitoring format:

Table 8.1 Format of mangrove nursery monitoring

1. Name of Information Collector:	**2. Date:**
3. Information on seed collections:	
a)Name of Riverine bank:	b) Name of River:
c) Latitude:	d) Longitude:
e) Name of the seeds collected:	f) Seed collected from plant/water:
g) Age of mother plant:	
h) In which month and season flowering started in the mother plant:	
i) In which month fruits ripened:	
j) In which month the tree saplings are noticed growing in naturally on the mudflat:	
k) Quantity of the collected seeds:	
l) Remarks:	
4. Nursery related information:	
a) Address:	
b) Name of Group:	c) Number of group members:
d) Latitude:	e) Longitude:
f) Number of Poly-bag:	g) Size of Poly-bag:
h) Number of Jute-pouch:	i) Size of Jute-pouch:
j) Number of saplings:	k) Nursery in fresh water:(Yes/No)
l) Nursery in saline water: (Yes/No)	
m) Date of soil preparation for filling the pots:	
n) Date of nursery bed preparation:	
o) Size of nursery bed:	p) Size of land:
q) Remarks:	
5. Sowing of seeds and propagules in Nursery related information:	
a) Number of pouches where seeds are planted:	b) Propagules planted in pouch: Yes/No
c) Number of pouches in which propagules are planted:	
d) Number of saplings produced from seeds (with two leaves):	
e) Number of healthy saplings of one-month age (with more than two leaves):	
f) Remarks:	
6. Nursery care and maintenance related information:	
a) Date of seed collection:	b) Date of seed bed preparation:
c) Date of sowing of seed:	
d) Whether water is applied in the bed on a regular basis to prevent dryness: Yes/No	
e) Date from which the nursery was relocated to saline water region:	
f) Which species were relocated in the saline water:	
g) Date of relocation before Plantation:	
h) Height of seedlings:	i) Date of plantation of seedlings:
j) Remarks:	

9.0 SAPLING PLANTATION:

Seeds – Some seeds or propagules can be directly sowed with one third beneath the soil and two-thirds above the soil. The density varies with the species. However, density varying from 6000-20000 seeds per hectare is prescribed, depending on the site specific physico- chemical parameters.

Figure 9.1 Plantation activities by women

Seedlings

Incase of the seedlings in the jute pouches, it can be readily planted along with the jute pouches in the mud. In case of seedlings with poly bags, the poly sheet need to be removed carefully with the help of a sharp blade and then it is ready to be planted. The discarded poly sheets should be carefully collected separately in waist bags and must not be thrown or deposited randomly in the plantation area. In case of seedlings, a density varying from 3000- 20000 per hectare is prescribed, depending on the species and the site specific physico- chemical parameters.

9.1 Plantation strategy: Direct planting

Propagules of viviparous plants like *Rhizophora* sp, *Bruguiera* sp, *Ceriops* sp and seeds of crypto viviparous plants like *Avicennia* spp. can be directly planted.The one- third sowing mechanism should be strictly adhered to because the propagules has lenticels which allow gaseous exchange to take place. If the communities are not aware of the fact, then propagules /seeds die quickly which accounts for greater mortality for propagule / seed plantation. Usually the soft mud is pressed with the thumb to create depression and *Avicennia* seeds sowed while propagules of *Rhizophora* sp, *Bruguiera* sp, *Ceriops* sp are directly planted in the soft soil.

Digging channels or trench - For hard soil or areas of high tidal zone where the soil is relatively harder, channel management is a way to reduce the firmness of the soil as soft clayey soil with good amount of silt is the most suitable substratum for growth of mangroves. In this case several channels parallel to the waterflow need to be created for silt deposition with a gap of around 12 ft , called trench.

The width and height can be 1 ft each. After few days (approximately 30 to 60 days), when the silt is deposited properly in those channels, it is ready for plantation for seed plantation, one seed /propagule at a distance of 1- 6 ft can be sown.

Digging pits: Pits of size 1ft by 1 ft by 1ft at a distance of 6 ft from each other (horizontal and vertical to the river flow) are also useful to allow the deposition of silt in cases of hard soil in the intertidal zone or for seedling plantation. After the proper deposition of the silt in those pits, it will be ready for planting saplings. Thus seedlings can be imagined to be planted at the four corners of a 6X6 feet square, for a density of 3,000/ha.

9.2 Planting designs

Line designs– In silted areas, for ease in the planting process, line plantation strategy are adopted. A thick rope with knots tied in a gap of 6 ft., is laid along the line to be planted. To secure optimum result, for every 9 women planter, 1 person can be engaged to supervise the depths of seed planted and the distance in between. Such critical planning reduces mortality, thereby saves time, energy and money.

Zig-zag design- In planting sites where wave action is high, the plantation strategy maybe in a zig zag way. The pits or plantation are done in a way that the waves get obstructed repeatedly and the wave energy is dissuaded. The minimum distance of sowing or digging pits can vary around 5-6 ft. If the wave action is too high, V shaped bamboo structures maybe placed to trap sediments and subsequently plant saplings there.

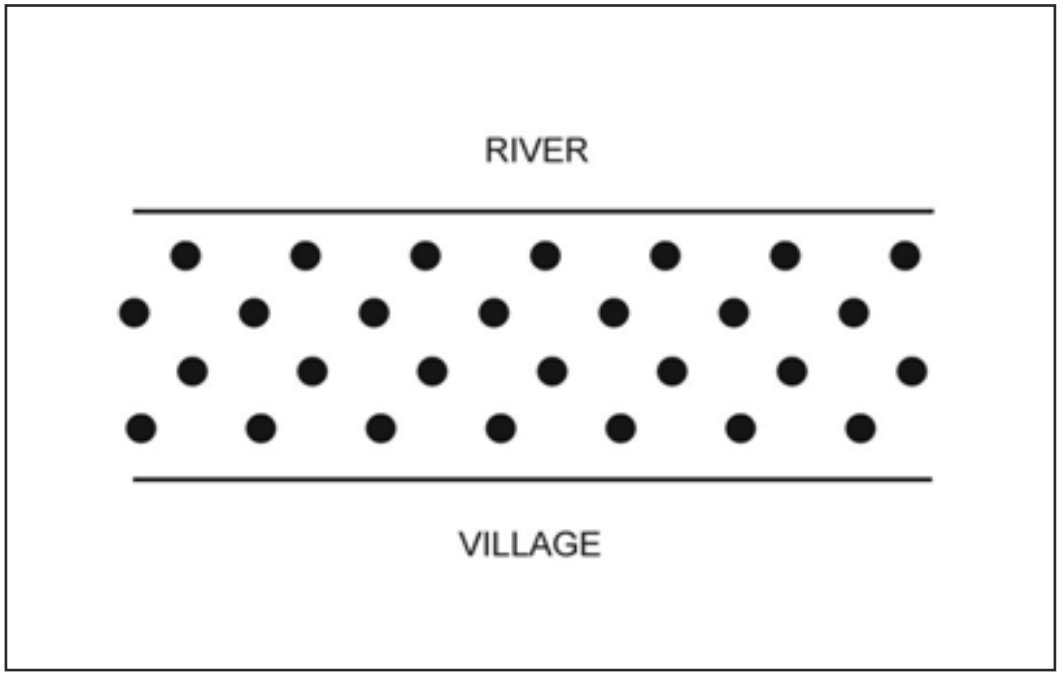


Figure 9.2 Zigzag pattern of plantation

Figure 9.3 Single V and Double V model

Stratification- Due to varying soil firmness, the different layers should be stratified and accordingly strategy determined, for selecting species and doing hydrological corrections.

Figure 9.4 Mangrove growth after plantation (2 years)

10.0 MONITORING OF MANGROVE

It is the key part of any afforestation/restoration programme, more so for mangroves. There are various factors that contributes to the mortality of the mangroves planted-natural and anthropogenic. The species and site selection strategy has essentially taken into consideration all these elements, which has to be done through a group exercise with the nursery/plantation/monitoring team. Groups can be formed with women and men and protocols designed in discussion with them. It is found that purely volunteering initiative is not acceptable nowadays in Sundarban. Hence, it is beneficial for both if some allowance is given to the groups for ensuring protection against imminent threats, at least in the initial three years.

The threats on mangroves in Sundarban can be classified as grazing, felling, prawn seed collection, crab collection, pest/spider attack, erosion, wave action, over siltation, illegal encroachment for fishery / playground etc. Use of simple risk mapping tools by the communities can assess, address and mitigate the risks. The most vulnerable areas can also be mapped thus and relevant mitigation measures can be taken. Joint Forest Management Committees (JFMC) need to take part, wherever possible, and Badabon Suraksha Committee or Biodiversity protection committees can be formed, in place where JFMC is not present.

Even school children can be innovatively enthused to take part in cleaning spiders/pests in plantation. Regular awareness programmes and Mic-campaigns can be done to create awareness about the mangroves, especially in the plantation timings to make others aware of this important activity that is going on in their vicinity to protect the islands and that everyone should be vigilant for successful outcome of the plantation.

One again to remind that at least three years of monitoring protocols must be embedded in the plantation activities from the very beginning, else we continue to pay the price for unmonitored plantations.

Also, livelihood programmes around sustainable natural resource management with value chain creation in mangroves maybe integrated for long term protection strategy, where the women groups engaged in nursery, plantation can be empowered further to continue with the activities even after the initial years.

Success of the plantation depends on the survival of the planted species and also natural regeneration, colonization of other species. Hence, in the first year, focus should be given on lessening the mortality and every quarterly (as per suitability), just counting of the planted species and noting of colonization of other species may be done. A format named Mangrove Watch Report MWR (Annexure III) can be generated monthly to document the estimation of the survival rate and mortality factors, risks for conflict resolution. General information related to the mudflats with its ecological condition along with the observations on loss of trees, erosion, excess siltation, encroachment, natural regeneration, disease and pest attack, soil and water salinity should be recorded using the Mangrove Watch Report (MWR). This can give an overall view of the threats, general health of the mangroves throughout the plantation area.

From the second/third year onwards, mangrove measurement formats are taken into consideration for monitoring the mangrove vegetation. For monitoring the mangroves with this format, the sample plots can be laid out systematically in the planted area. The circular type of sample plots (preferably

with 2 m/3 m radius) are suitable for vegetation monitoring in the mudflats of mangrove ecosystem. For selection of these sample plots sufficient assessment may be made to have proper representation of species planted, typical site characters, etc. These points will be considered as fixed sample points for future monitoring purpose.The latitude and longitude will be used for reaching the proposed sample plot by using GPS, within defined accuracy factor. After reaching the place a circled sample plot with 2 m/ 3 m radius (to be decided prior and uniform for the entire scheme under consideration) will be laid out. Then the Mangrove measurement format (Annexure II) will be used to record the data of all the trees and saplings in the sample circular plot. For tree measurement the name of species, distance from centre, height of the tree, Girth at Breast Height (GBH) along with variation if any, can be recorded and for sapling the name of species and average height can be recorded. The benefits of this proposed monitoring are: Species-wise survival mortality analysis, change in the species composition in different sites and a comparative analysis with their physico- chemical characters, assessment of the various risks related to multiple sites as well as to different species, assessment of growing stock of the vegetation through the calculation of the biomass, comparative analysis of growth and biomass of different species, enumerate the carbon sequestration for each species as well as for the forest patch.

Mangrove monitoring application: A user friendly application, 'Mangrove Watch' on digital platform is available (contact NEWS office/MGNREGA Cell, South 24 Parganas district). It may be noted that the app can be used in both online and offline mode.

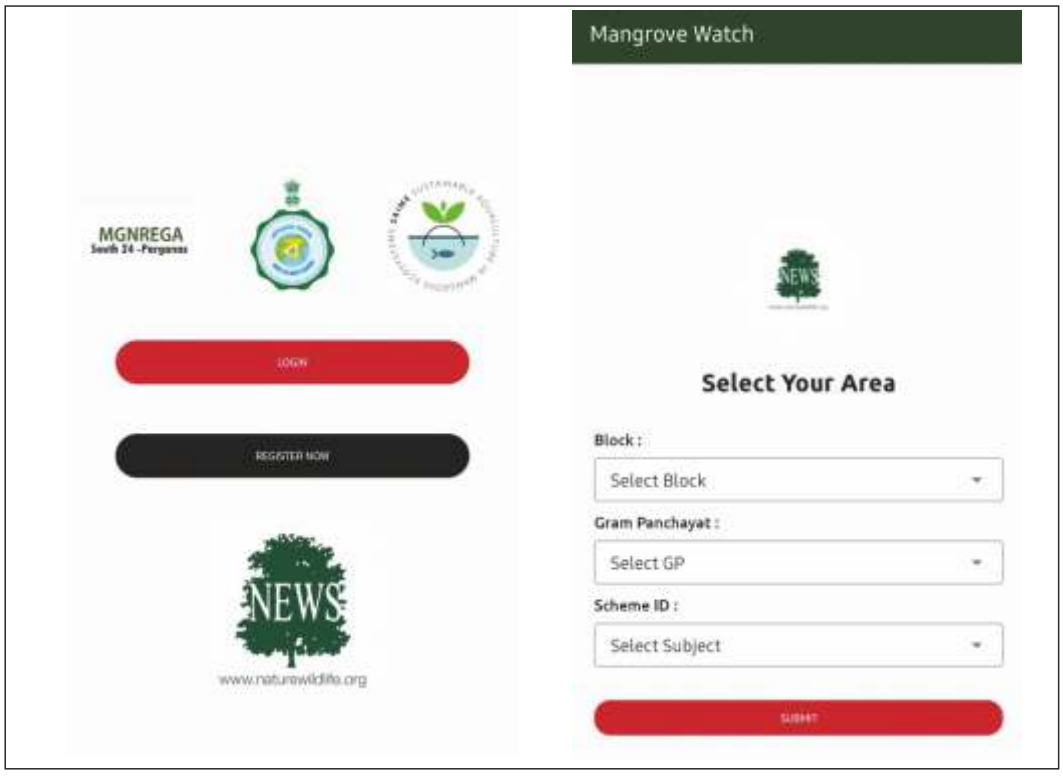


Figure 10.1 Mangrove monitoring app- 'Mangrove Watch'

10.1 Mangrove Monitoring Schedule:

The monitoring schedule of 3 consecutive years are given in the flow chart below:

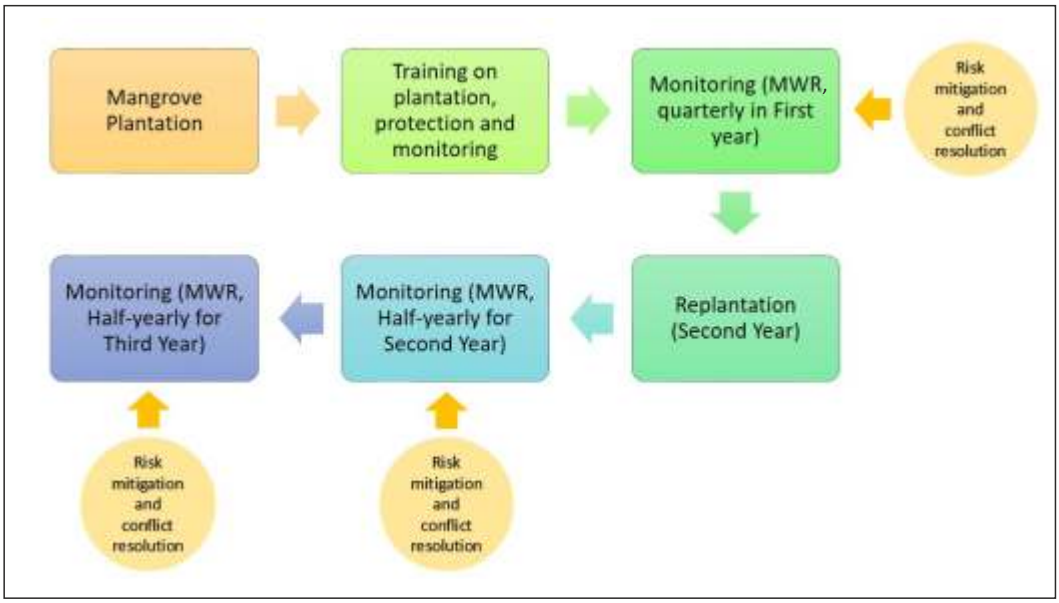


Figure 10.2 Flow chart of Mangrove monitoring schedule

10.2 Training on Monitoring:

An orientation on the needs of monitoring and the responsibilities, processes needed may be explained and worked out considering the situation-specific strengths and risks.

Uses of various instruments, like measuring tape, vernier callipers, poles, GPS, etc. need to be demonstrated and training imparted.

Hand-holding training in the plantation sites will be needed to train them on field and build their confidence.

Gradually, the 'Mangrove Watch' app training also can be imparted, being very user-friendly.

Regular sharing of data with the Panchayat members, Block administration and Forest Beat offices will encourage all the co-actors to remain engaged in the activities, amidst their other responsibilities and a sustained co-operation at all levels will continue to exist.

11.0 REFERENCES

1. Alongi, D. M. 2012. Carbon sequestration in mangrove forests. *Carbon management* 3(3) : 313 - 322.
2. Anirban, M., Mondal, P., Barik, J., Chowdhury, S.M., Ghosh, T. and Hazra, S. 2015. Changes in mangrove species assemblages and future prediction of the Bangladesh Sundarbans using Markov chain model and cellular automata. *Environmental Science: Processes & Impacts* 17: 1111-1117 doi: 10.1039/c4em00611a
3. Barik, J and Chowdhury, S. 2014. True Mangrove Species of Sundarbans Delta, West Bengal, Eastern India. *Check List* 10 (2): 329–334.
4. Barik, J., Mukhopadhyay, A., Ghosh, T., Mukhopadhyay, S.K., Chowdhury, S.M. and Hazra, S. 2018. Mangrove species distribution and water salinity: an indicator species approach to Sundarban. *Journal of Coastal Conservation*. 22(1): 361 - 368. doi:10.1007/s11852-017- 0584-7.
5. Chandra, K.., Alfred, J.R.B., Mitra, B. and Chowdhury, B.R. 2017. *Fauna of Sundarban Biosphere Reserve*. Zoological Survey of India, Kolkata. Pp. 240.
6. Dahdouh-Guebas, F., Jayatissa, L.P., di Nitto, D., Bosire, J.O., Lo Seen, D., Koedam, N. 2005. How effective were mangroves as a defence against the recent tsunami? *Current Biology* 15, (12) 443-447. doi: 10.1016/j.cub.2005.06.008.
7. Das, P., Das, A. and Roy, S. 2016. Shrimp Fry (*meen*) Farmers of Sundarban Mangrove Forest (India): A Tale of Ecological Damage and Economic Hardship. *International Journal of Agricultural and Food Research* 5(2): 28 – 41.
8. Elmqvist, T., and Cox, P.A. 1996. The Evolution of Vivipary in Flowering Plants. *Oikos*, 77(1): 3-9. doi:10.2307/3545579
9. Director, Sundarban Biosphere Reserve, 2021. Sundarban Biosphere Reserve. Published online at www.sundarbanbiosphere.org/html_files/introduction.htm (accessed on 25.07.2021)
10. Ghosh, A., Schmidt, S., Flickert, T. Nüsser, M. 2015. The Indian Sundarban Mangrove Forests: History, Utilisation, Conservation Strategies and Local Perception. *Diversity*, ,7(2): 149-169. doi.org/10.3390/d7020149.
11. Hutchinson, J., Spalding, M. and Zu Ermgassen, P.2014. *The Role of Mangroves in Fisheries Enhancement.* The Nature Conservancy and Wetlands International. Pp. 54.
12. IPCC 2019. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC). September 25, 2019. Available online at https://www.ipcc.ch/srocc/. Accessed 25.09.2019.
13. Islam, M. T. 2014. Vegetation changes of Sundarbans based on Landsat Imagery analysis between 1975 and 2006 . *Landscape & Environment* 8(1): 1-9
14. Kathiresan, K. & Bingham, B. 2001. Biology of Mangroves and Mangrove Ecosystems. *Advances in Marine Biology*. 40: 81 - 251. doi: 10.1016/S0065-2881(01)40003-4.
15. Kathiresan, K. and Rajendran, N. 2005. Coastal mangrove forests mitigated tsunami. *Estuarine, Coastal and Shelf Science* 65: 610-606.
16. Lepage, D. 2021. Avibase – The World Bird Database. Published online at https://avibase.bsc-eoc.org/checklist.jsp?region=INggwb03&list=howardmoore (accessed on 25.07.2021).

17. Mallick, J.K., 2011. Status of the mammal Fauna in Sundarban Tiger Reserve, West Bengal - India. TAPROBANICA 3:(2): 52-68. doi:10.4038/tapro.v3i2.3961.

18. Mitra, A., Banerjee, K. 2010. Pigments of Heritiera fomes seedlings under different salinity conditions: perspective sea level rise. *Mesopot. J. Mar. Sci.*, 2010, 25(1): 1-10.

19. Mitra, A., Banerjee, K., Bhattacharyya, D.P. 2004. The other face of Mangroves. Department of Environment, Government of West Bengal. Pp. 185.

20. Naskar, K. R., Sarkar, N. S., Ghosh, A. Dasgupta, M., and Sengupta, B. 2004. *Status of the mangroves and mangrove ecosystem of Sundarbans in West Bengal: Its impact on estuarine wetland fisheries.* CIFRI-ICAR, Bulletin No.134. pp. 85.

21. Ng, P.K.L. & N. Sivasothi (eds.). 1999. *A guide to the mangroves of Singapore I: The Ecosystem and plant diversity.* Singapore Science Centre. Pp. 160.

22. Rahman, M.M.2020. Impact of increased salinity on the plant community of the Sundarbans Mangrove of Bangladesh. *Community Ecology*. 21: 273- 284. doi: 10.1007/s42974-020-00028-1.

23. Siddique, M.R.H., Saha, S., Salekin, S. and Mahmood, H. 2017. Salinity strongly drives the survival, growth, leaf demography, and nutrient partitioning in seedlings of *Xylocarpus granatum* J. König. *iForest* 10: 851-856. doi: 10.3832/ifor2382-010

24. Spalding, M, Kainuma, M. and Collins, L. 2010. *World atlas of mangroves*. Earthscan, London. Pp. 310.

25. Suratman, M. N. 2008. Carbon Sequestration Potential of Mangroves in Southeast Asia. In: Bravo, F. *et.al*., (eds.) *Managing Forest Ecosystems: The Challenge of Climate Change*. Springer Science. Pp. 297 – 315.

26. Suriya, S. and Hari, N. 2018. Leaf anatomical adaptation of some true mangrove species in Kerala. *International Journal of Pharmaceutical Science and Research* 2(3): 11-14.

27. Trivedi, S., Zaman, S., Chaudhury, T.R., Pramanick, P., Fazli, P., Amin, G. and Mitra, A. 2016. Inter-annual variation of salinity in Indian Sundarbans.*Indian Journal of Geo-Marine Sciences* 45(3): 410-415.

29. Wildlife wing, 2021. Sundarban NP. Published online at www.wildbengal.com/sundarban-np.php (accessed on 25.07.2021).

30. Zaman, S., Bhattacharyya, S.B., Pramanick, P., Raha, A. Chakraborty, S. and Mitra, A. 2014. Rising Water Salinity: A Threat to Mangroves of Indian Sundarbans. *Water Insecurity: A Social Dilemma Community, Environment and Disaster Risk Management* 13: 167 – 183. doi: 10.1108/S2040-7262(2013)00000130.

Annexure I

A brief 'Plot-Assessment Report' on the proposed sites for Mangrove afforestation

Introduction

Home to India's one of the largest concentrations of Royal Bengal Tigers on the planet, the 2585 sq km Sundarban National Park is a network of channels and halophytic mangrove forests which is a part of the world's largest river delta. This ecosystem merges with the Sundarban delta of Bangladesh towards the East along the same shoreline. Due to its immense biological diversity and dynamic ecosystem, it is scripted as a UNESCO World Heritage site in 1987. Mangrove systems have contributed significantly to the well-being of coastal communities through a wide array of ecosystem services which have been classified into regulating, provisioning, cultural and supporting services. Thus the restoration of mangrove forest is key to establishing a functioning ecosystem in this region.

Proposed site: Sumatinagar mudflat, G.P- DS2, Block- Sagar, District- South 24 Parganas and Manmathanagar mudflat, G.P- Biprodaspur, Block- Gosaba, District- South 24 Parganas. The environmental and biophysical settings of the proposed site in both Sumatinagar and Manmathanagar are given in Table 1 and Table 2 respectively.

Fig: 1 Google Earth image showing the location of the Proposed area of Sumatinagar mudflat.

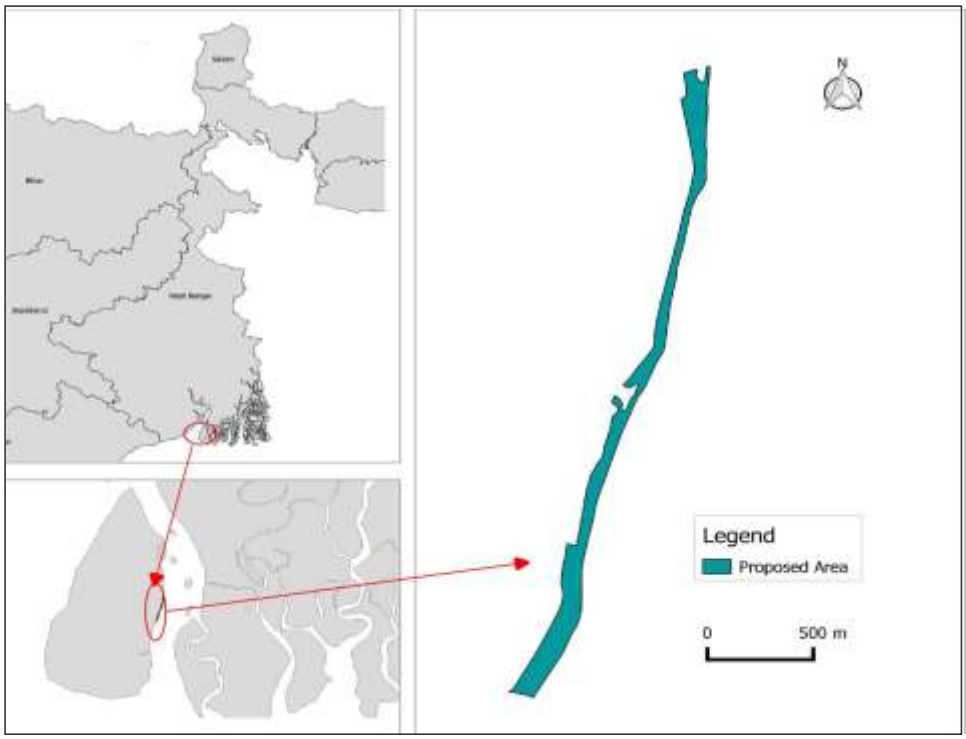


Fig: 2 Map showing proposed area for mangrove afforestation in Sumatinagar.

Fig:3 Google Earth image showing proposed area in Manmathanagar.

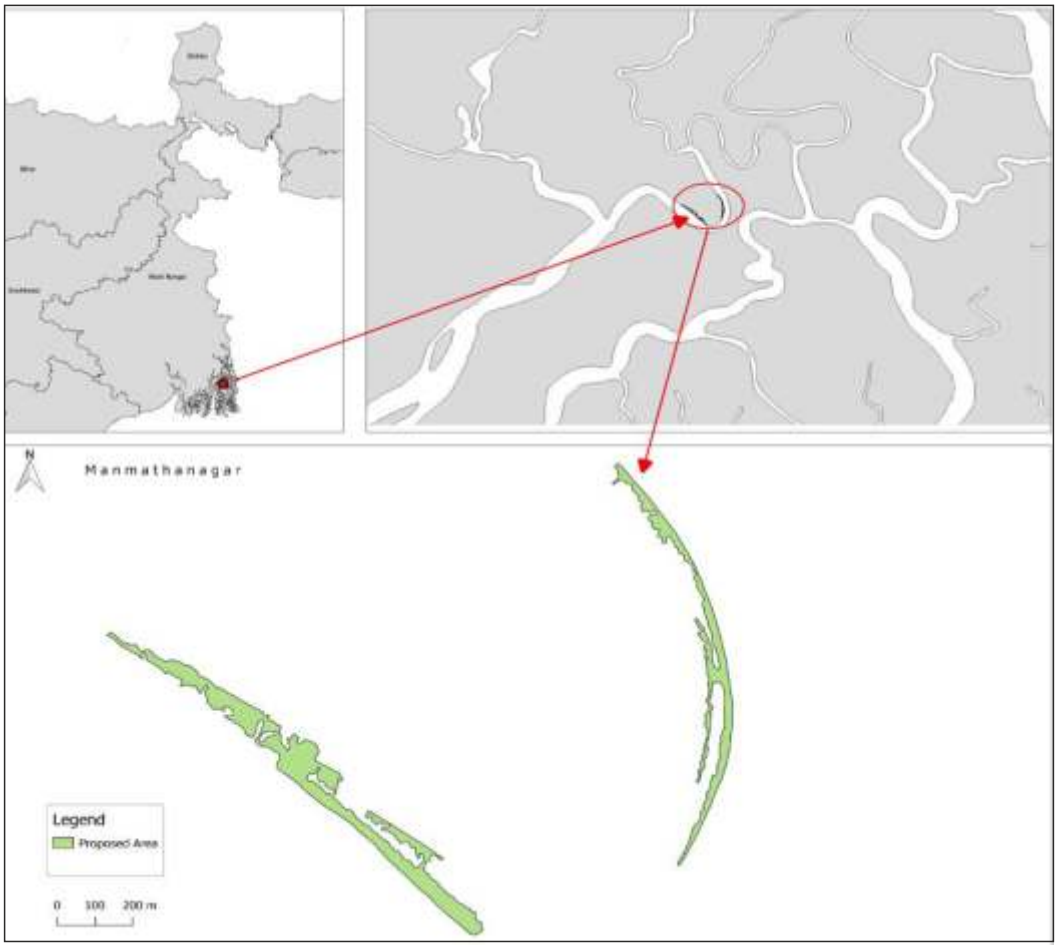


Fig:4 Map Showing proposed area for mangrove afforestation in Manmathanagar.

Environmental and bio-physical properties of the proposed sites

Presence of tidal waves: Extreme tidal wave resists the young saplings to grow as it does not give them time to hold the soil properly with their roots.Because of its geographic location,our proposed areas in Sumatinagar and Manmathanagar are devoid of extreme tidal waves that destroy the growth of young saplings.

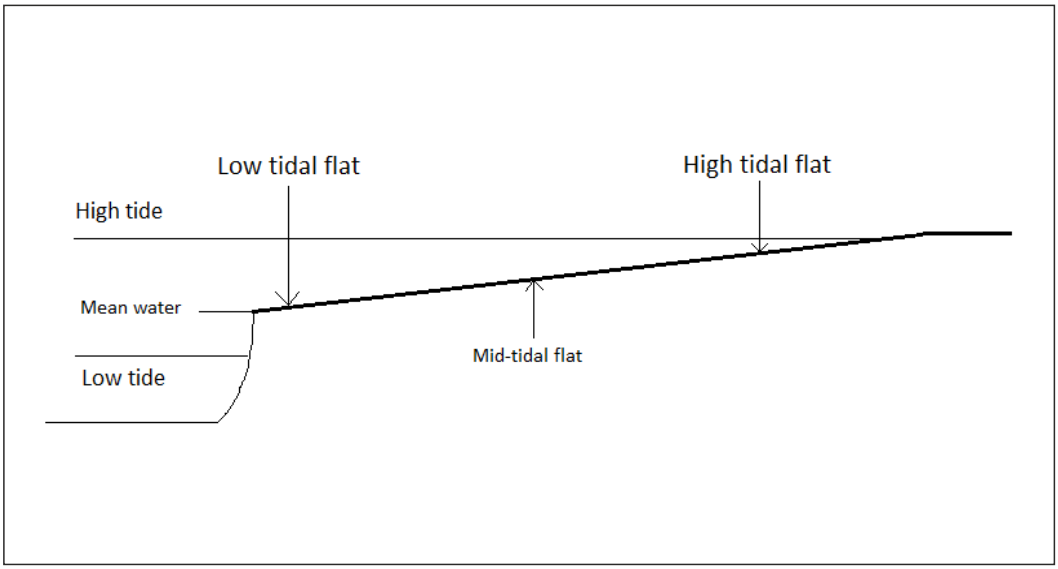


Fig: 5 Different portions of intertidal area- Low tidal zone, Mid tidal zone and High tidal zone in the proposed sites.

Elevation: For every mangrove plantation, elevation of the site is necessary as it allows the water to flow in and out during the high and low tide. The mean elevation of our proposed site in Sumatinagar is 3.83 m as land in Manmathanagar is 4.25 m as which allows good tidal influx.

Slope: The average slope of our proposed site in Sumatinagar is 0.7% and in Manmathanagar is 0.9%which supports a good water inflow during the high and low tides as it help the mangroves to grow.

Analysis of salinity: Salinity is an important factor that decides the success of mangrove plantation. We recorded salinity of soil and tidal water of the proposed study area. Salinity was measured with the help of salinometer at the site.

The soil salinity of the proposed site was measured 8 parts per thousand (ppt) whereas the water salinity was 18 ppt in Sumatinagar. Soil salinity of the proposed site in Manmathanagar was measured 7 ppt and water salinity was measured 12 ppt, which is optimum for mangrove plantation.

Soil texture analysis: Texture of the substrate or soil texture is important factor to be analyzed for mangrove plantation. Soil with a higher percentage of clay can support a good growth of mangroves as it provides a) good grip for the plants to hold on, b) more nutrient content and c) high moisture retaining capacity.

Laboratory analysis of the soil sample from the proposed site of Sumatinagar showed mainly clayey soil (Sand= 10%, Silt= 36% and Clay= 54%) which is favorable for mangrove plantation.

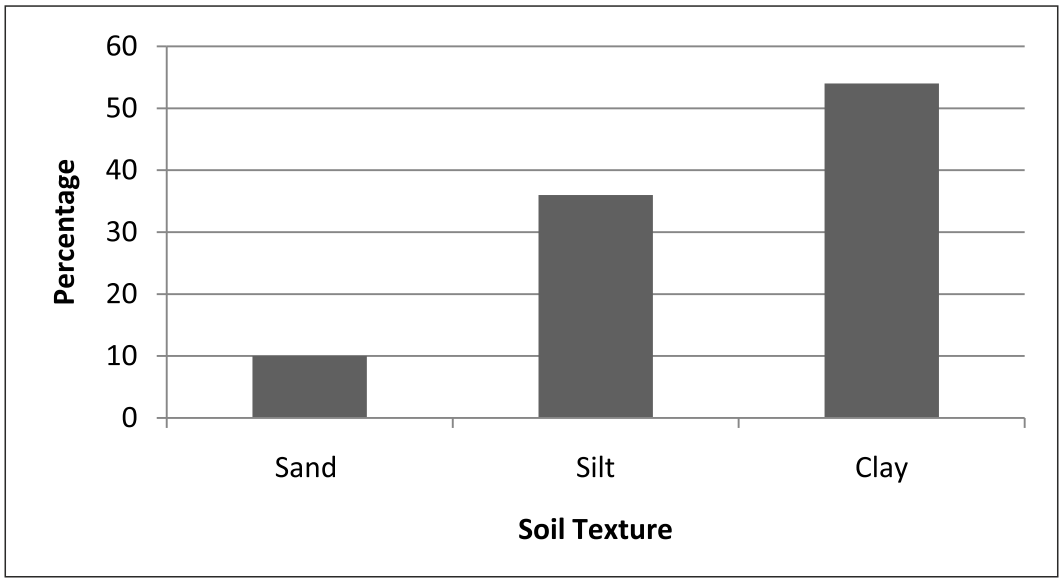


Fig: 6 Graph showing soil texture percentage from the proposed site in Sumatinagar.

Laboratory analysis of the soil sample from the proposed site of Manmathanagar also showed mainly clayey soil (Sand= 8%, Silt= 25% and clay= 67%) which is suitable for mangrove plantation.

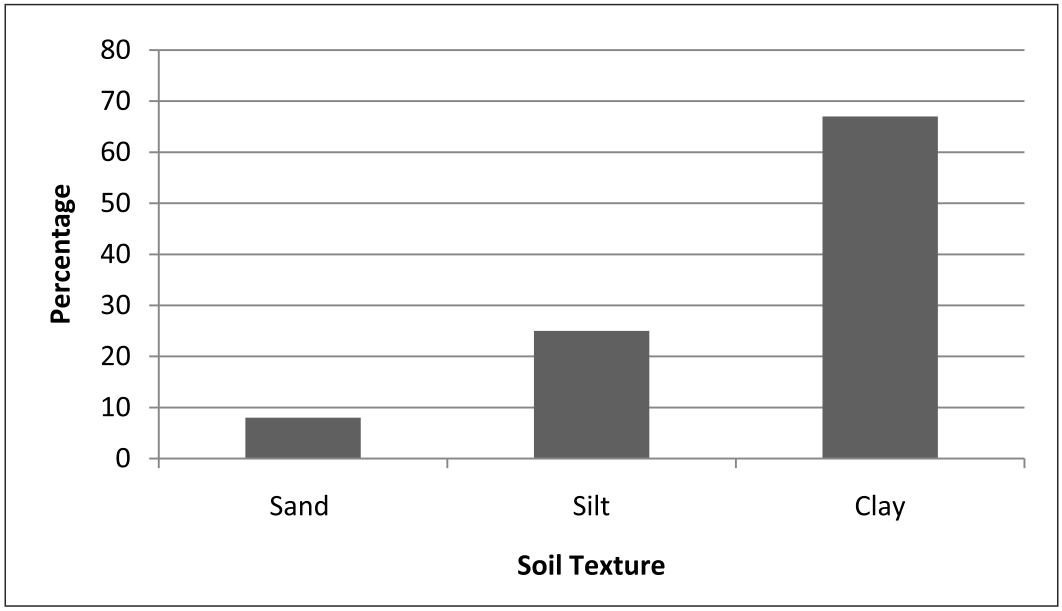


Fig: 7 Graph showing soil texture percentage from the proposed site in Manmathanagar.

pH of soil and water: Soil pH and water pH is an important factor that controls the growth of mangrove forests. Mostly it requires mildly acidic soil and water for its growth. The soil pH in our proposed area in Sumatinagar was recorded 8 while the water pH was 7 which are mildly acidic. In Manmathanagar, soil pH and water pH was recorded as 9 and 8 respectively. This type of soil and water is perfectly favorable for mangrove plantation.

Table: 1.Environmental and bio-physical setting of proposed project site in Sumatinagar.

Name of site	**Sumatinagar**
Patch Area	24.68 hectares approx
Location	21º 43' 55.69" N 88º 09' 59.63" E
Gram Panchayat	Dhaspada- Sumatinagar 2
Block	Sagar
District	South 24 pgns.
Zone Name	Sagar
Substrate type	Medium
Elevation	3.83 m asl. (avg.)
Slope	0.7%
Water inundation	Average 24 days throughout the year
Soil salinity	8 ppt (Season- Spring)
Water salinity	18 ppt (Season- Spring)
Soil Texture	Sand= 10%, Silt= 36% and Clay= 54%
Soil pH	8 (Season- Spring)
Water pH	7 (Season- Spring)
Pre-existing mangrove trees	*Avicennia alba*, *Avicennia marina*, *Sonneratia apetala*, *Bruguiera gymnorhiza*

Fig: 8 Plot status in proposed site in Sumatinagar.

Table: 2 Environmental and bio-physical setting of proposed project site in Manmathanagar.

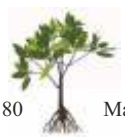
Name of site	**Manmathanagar**
Patch Area	9.5 hectares approx
Location	22°10' 20.17" N 88° 49' 37.60" E and 22° 10' 28.05" N 88° 50' 17.26" E
Gram Panchayat	Biprodaspur
Block	Gosaba
District	South 24 Parganas
Zone Name	Bidya
Substrate type	Medium
Elevation	4.25 m asl (Avg.)
Slope	0.9%
Water inundation	Average 20 days throughout the year
Soil salinity	7 ppt(Season- Spring)
Water salinity	12 ppt(Season- Spring)
Soil Texture	Sand= 8%, Silt= 25% and Clay= 67%
Soil pH	9 (Season- Spring)
Water pH	8 (Season- Spring)
Pre-existing mangroves	*Avicennia alba*, *Avicennia marina*, *Sonneratia apetala*

Selected species: Mangrove species selected for Manmathanagar were *Heritiera fomes, Xylocarpus moluccensis Excoecaria agallocha* for plantation near the embankment, *Bruguiera gymnorhiza*, *Bruguiera cylindrica*, *Sonneratia apetala*, *Avicennia officinalis*, *Avicennia marina*, *Avicennia alba* were selected for plantation in strata 1 and 2. Strata 2 need some hydrological correction for better plantation and accumulation of new clay to support natural regeneration.

In Sumatinagar *Avicennia alba*, *Avicennia marina*, *Avicennia officinalis*, *Sonneratia apetala*, *Bruguiera gymnorhiza* were selected for plantation in the designated strata (1 and 2).

Proposed methodology: Pit digging for silt deposition in medium hard mudflat and direct plantation on soft soil is recommended. All the species to be planted at 6'X6'distance, i.e. density will be 4500 plants/ Hectare.

Boundary demarcation: Waypoints were taken by GPS (Garmin etrex 30) in the field along the boundary, editing was done on the Google earth and area determination was done by Qgis software. Area determined is 24.68 hectares in Sumatinagar and 9.5 hectares in Manmathanagar with a total of 34.18 hectare. Plot boundary is available in kml and shp format.



Community participation towards the mangrove afforestation

People from local community should be involved in mangrove afforestation and restoration activities as they know the inside out of the local environmental and social conditions of the proposed plantation site and also sustain protection. To ensure the participation of the local communities, we followed a qualitative approach. We used methods that include group discussions, open ended with informal interviews and direct interviews for our sites. In order to collect the qualitative data, we used stratified purposeful sampling based on socio- economic status, formal education level and community activism of the local people. In our proposed areas, several pilot-tested oral surveys were conducted to understand the willingness of the local people towards the afforestration and accordingly ratings were given.

On an average, 15-20 people were interviewed in several repetitive surveys where they had shared their views about the importance of planting and protecting mangroves. Interaction with local communities helps us to assess their support and responsible thinking towards the afforestation programme in the long run.

Local Governments' response towards the afforestation

Several meetings were organized with the members of the local governing body (Gram Panchayat) to make them understand about the importance of our project and its future perspective. Those meetings were also conducted to ensure the land ownership of our proposed study sites.

Fig: 9 Images showing interaction with local community about the mangrove afforestation.

Annexure II

Nature Environment and Wildlife Society (NEWS)

Mangrove Monitoring Format (Quarterly/Half-Yearly)

Place:	
Name of the mudflat:	Date:
Radius of the circle: 2 m	Start time:
Type of mudflat: (High/Middle/Low level)	End time:
Forest Cover: (Dense/Open/Scrub)	Name of the group:

Sl. No.	Tree	Sapling	Name	Distance (m)	Height (m)	DBH (Cm)	Deviation (m)	D-30 (Cm)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								

Remarks-

Annexure III

NATURE ENVIRONMENT & WILDLIFE SOCIETY

(Mangrove Steward & Supervisor Monthly Report)

For the month of _____

Name		Mangrove Steward	Supervisor (zone)
Survey of mudflats	Name of the mudflat		
	Date of last visit		
	Area (Bigha)		
	Percentage (%) of trees present (Tick √) (0-20,20-40, 40-60, 60-80,80-100)		
Ecological conditions of the mudflat	Canopy closure(Tick √) Dense/ Thin/ Scattered		
	Condition of soil- Hard/ Soft/ Mixed		
	Inundation- No. of days per month		
Measures of trees	Average Height (ft.)		
	Density- No. of trees/bigha		
Observation	Felling/ grazing/ prawn seed collection (Tick √)		
	Erosion- Yes/ No (Tick √)		
	Excess Siltation- Yes/ No (Tick √)		
	Any Encroachment? - Yes/ No (Tick √) If yes, how much area has been encroached? (approx.)		
	Natural Regeneration- Yes/ No (Tick √)		
	Pest Attack- - Yes/ No (Tick √) Percentage of infestation (approx.) Recovered - Yes/ No (Tick √)		
	Water salinity & pH (13 & 26)		
	Soil Salinity & pH (13 & 26)		
GPS	Information sent to the GPS with the picture		
Other Information	Comments	Comments	
Signature