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RURAL INITIATIVES

CLIMATE CHANGE

WHITE PAPER DOCUMENT ON

MANGROVE PLANTATION

PROJECT PLAN 2023

AT RAMKRISHNAPUR VILLAGE, SUNDARBANS

RURAL INITIATIVES OF THE YOUNG INDIANS

REPORT SUBMITTED BY | PROF. NEERA SEN SARKAR
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EXECUTIVE SUMMARY

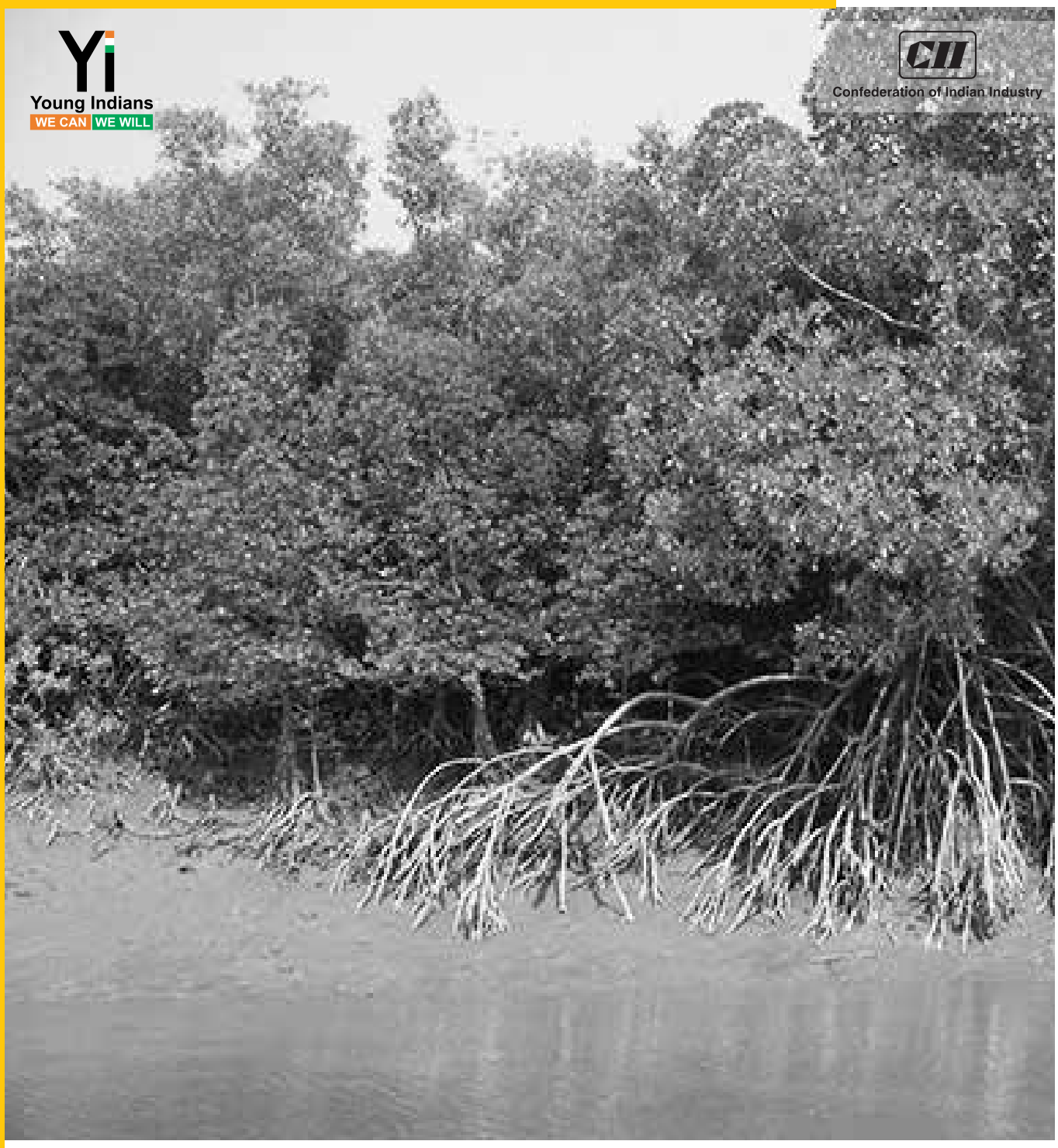
The mangroves of Sundarbans are an integral part of the Indo-Malayan realm of specially attributed plant species that extensively flourish on low shore gradients, while occupying a broader belt on larger tidal range washed shorelines. The development of these mangroves essentially requires sheltered habitats. On exposed coasts they usually become localized in leeward zones of coastal formations. The succession pattern of establishment of tiers of different mangrove species are synergistically controlled by numerous factors including variations in edaphic and water quality parameters, river flow and tidal dynamics among others.

Mud embankments and human habitation have grown hand in hand in the Sundarban islands for the last 250-270 years, post a massive deforestation period of clearing to create human settlements. The process of mud embankment structuring has developed into concrete structures in a few sporadic initiatives, of late, but these have also caused more damage to riverine health.

The siltation course which is normally supposed to happen on the island now happens on the river-bed due to concretization of embankments causing poor navigability of rivers and their subsequent rise above island level. The loss of mangrove patches and sea level rise are synchronous in nature. According to an Economic Times Report dated 24th January 2023, West Bengal has lost 110 sq. Km of mangroves in the Sundarbans in the past two decades due to climate change and global warming. The report also talks about "climate refugees", who have been forced to migrate from various islands in the Sundarbans.

Recurrent tropical cyclones lashing out Sundarbans have further highlighted the failure of embankments in addition to the regular tendency of estuarine rivers to wipe out fragile islands. A possible remedy at times seems to be in retreating the embankments from the absolute edges of the islands to a more interior circumference of the islands leaving appropriate buffer-zone for both growth of mangroves and allowing natural siltation.

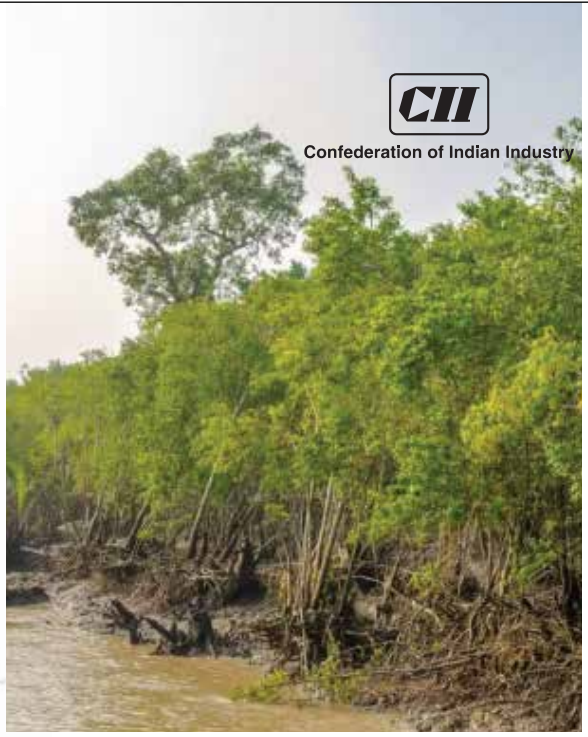
Fortunately enough, mangroves have proven to be efficient guard-zones rather than any artificially engineered concrete structures. This is true not only for Sundarbans but for all mangrove-dominated systems. One of the best examples of mangrove-buffering against natural fury was that of the Picchavaram mangroves of Tamil Nadu that could combat the effects of the 2004 Tsunami of the Indian Ocean.



The present feature is proposal for providing a plan for mangrove plantation in a very site- specific way for the area in question being taken up by the Rural Initiatives of the Young Indians at Ramkrishnapur village in Basanti Island of Indian Sundarbans. The same has been supplemented with a few general aspects, which may have low applicability at this site but are possible key points in others. This is to create wider applicability in regions beyond the said site in future.

But the mangroves are an extremely sensitive and slow growing group of the plant kingdom. Therefore, an initiative to restore or regenerate a mangrove patch is to be extremely carefully planned, designed, and executed.

A recent Wetlands International publication entitled "Mangrove Restoration: to plant or not to plant?" speaks about the popularity of mangrove plantation initiatives world over, but has also raised questions regarding the failing nature of such initiatives too. The report further argues that a more effective approach is to create the right conditions for mangroves to grow back naturally. But experience with field studies have another story to tell, where it becomes imperative to undertake plantations since the leaving the land to grow on its own may take ages to fulfill the requirement of having a mangrove cover on particular sites. Thus once again a clearly defined plan of action that takes in to consideration all possible habitat characteristics for executing a mangrove plantation programme gains importance.



INTRODUCTION

The genesis of the islands of Sundarbans has taken place over a period of less than 10,000 years BP. The presence of mangrove vegetation on these islands has also been part of this natural process, with the coastal physiography and energy conditions providing favourable conditions for the mangrove swamps to develop. Worldwide fossil records also establish the origin of mangroves around the Indo-Malayan realm of which Sundarbans is an integral part. Moreover, these special attribute plant species are most extensively found to flourish on low shore gradients, while occupying a broader belt on larger tidal range washed shorelines; and mangrove development essentially requires sheltered habitats, on exposed coasts they usually become localised in leeward zones of other coastal formations. These have in particular contributed to the formation of natural mangrove region of the entire undivided Sundarbans, making it the largest single tract of mangroves in the world. The succession pattern of establishment of tiers of different mangrove species from the periphery of the islands to the upper littoral regime, within the limits of the intertidal zone has always been synergistically controlled by numerous edaphic and water quality parameters, river flow and tidal dynamics among others.

Therefore a properly designed mangrove plantation programme needs to take into consideration a number of questions along with a clear understanding of the governance and participation :

- What has caused the loss and degradation of mangroves at the plantation site?
- What is preventing natural regeneration at the site of plantation?
- Why do we need to plant mangroves at the site chosen?

In the present initiative, the organisation has selected Ramkrishnapur village in Basanti Island of Sundarbans, District South 24 Parganas as their plantation site. The site was visited on 29th March, 2023, to see the location in terms of its position in relation to the flow of the adjacent river and the present condition of existing vegetation therein.

The location was found to be on the north-eastern side of the Basanti Island but facing the northern flow of Gomor river. With a bend of the river owing to the projected landmass at the location, the river takes a short turn creating a corner landmass. Nevertheless, with all the bends and curves, the plantation site is an essentially north facing embankment.

The plan for mangrove plantation for this particular site shall take into consideration the ecological as well socio-economical aspects of -

1. Maintaining the rich species diversity of the mangroves indigenous to Sundarbans

2. Being in sync with the site-specificity requirements in terms of sand: silt:clay ratio, wave and tidal influences, salinity regimes, sediment load shifts, wind force, etc.

3. Following the inherent patterns of vegetation succession, the proposal has been chronologically planned in terms of species structure suggested for the plantation programme. Succession pattern is initiated in the Sundarbans by the blue-green algae and the green algae which consolidate the ill-consolidated soil paving way for the floating propagules of mangrove species like Avicennia spp., Sonneratia sp., and others to gain ground on this tide washed lands and establish themselves.

4. Promoting enhanced mangrove regeneration rate both naturally and through people's participation by means of providing an alternate livelihood option. The requirement of multi-species nursery raised mangrove seedlings/ mangrove grass turfs/ mangrove propagules/ biomass of mangrove algae (green and blue-green) shall ensure that the mangrove propagules are not wasted as fuel by the fringe area population and shall also provide another livelihood option for the locals in nurturing multi-species nurseries.

This shall contribute to enhancing mangrove regeneration rate both naturally and through local intervention.

The plantation programme designed with solely vegetative solutions in mind have certain prerequisites to be fulfilled. These shall include

(i) mapping of the most vulnerable embankment zones in the entire programme area based on erosion status, distance from the Bay of Bengal, riverine dynamics and the extent of dependence of the local populace

(ii) implementation of pre-plantation bio-engineering remedies in terms of installation of pre-seeded bio-geotextiles made up of jute/coir/ palm leaves

(iii) increasing site-specifically the embankment heights

(iv) ensuring functionality of sluice-gate and flood-gate systems if any of the area

(v) shifting of embankments away from the river to provide space for plantation and when not possible then bio-engineering intervention for arresting sediment on the river bank.

With these in place, the proposed plantation programme can be initiated, a general description of which is given in Figure – 1.

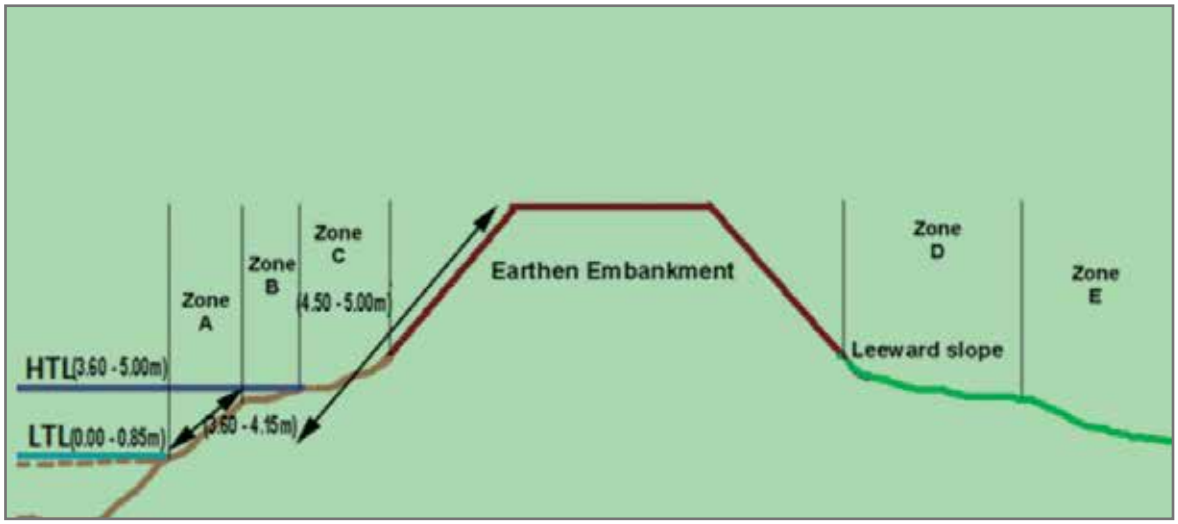


Figure - 1. Diagrammatic View of the multi-layer floral species on earthen embankments of Indian Sundarbans embankment space available for Plantation on River Side & Leeward Side Slopes Zones A, B, and C on the river front side of the embankment and D and E are on the leeward side of the embankment. (HTL: High Tide Level; LTL: Low Tide Level)

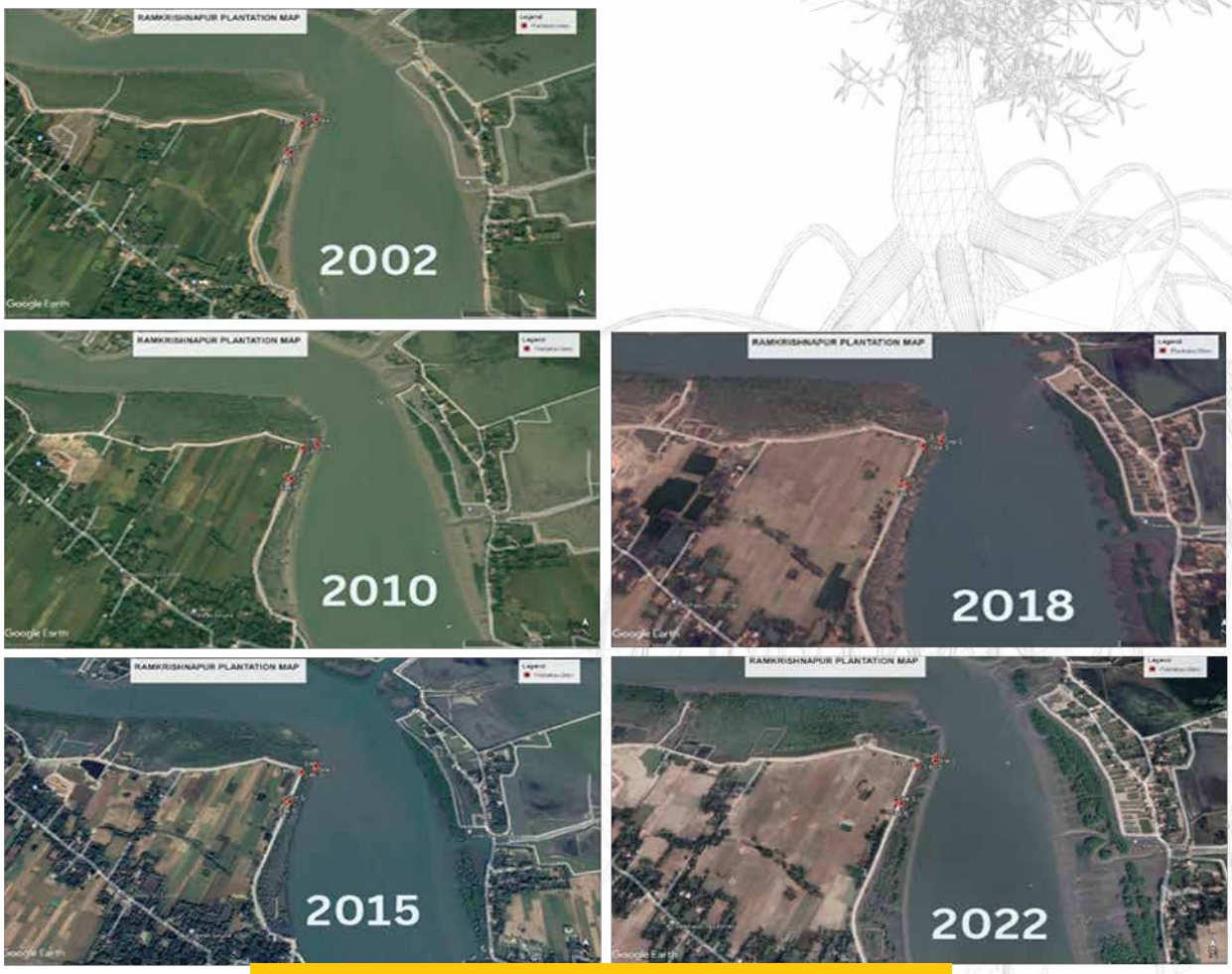
ECOLOGICAL HISTORY OF THE PLANTATION SITE

Any plantation programme in the vulnerable mangrove zones needs to prioritize the understanding of the ecological history of the area to be considered for plantation to serve as background information for the endeavour. Thus a preliminary study was conducted using historical satellite maps available from Google Earth Pro version 7.3. This study helped in understanding the the inherent patterns of vegetation succession at the proposed site during the last 22 years (2002-2022). Information regarding the same was also obtained from the local inhabitants of the area. Succession pattern of the system was observed and the soil found well consolidated for initiating transplantation of specified propagules of mangrove species to gain ground on this tide washed land and establish themselves. The subsequent drafted plan has been chronologically designed in terms of species structure suggested for the plantation programme.

Figure - 2. Sequential Site Maps showing selected site not being densely

vegetated since 2002 & not much change in Post Aila (2009)/post Amphan (2021) scenario.

This can be attributed to the area being a north-east facing embankment. So the area is deemed suitable for the purpose of mangrove plantation.



LANDSCAPE CHARACTERS OF PLANTATION SITE

1

Well consolidated substratum

The soil substratum on the entire plantation site is well consolidated to support plantation of mangrove propagules of different species. And although, the existing vegetation has low species richness, the system appears good enough to support varied mangrove species.

2

River side embankment slope

The river facing slope of the embankment is in a dishevelled state. It is suggested that some amount of soil work be undertaken prior to plantation to smoothen out the slopes in an uniform manner to get a workable slope till where tidal ingress occurs daily during high tide.

3

Leeward side embankment slope

The leeward slope of the embankment is absolutely barren. The soil has been tested for salinity, which amounts to 3.4 mg/kg of soil, which is quite low. This renders the slope suitable for plantation of varied terrestrial tree species that are proven to prevent soil erosion. Trees suitable for fire wood and fruit species can also planted.

SPATIAL EXTENT OF PLANTATION SITE

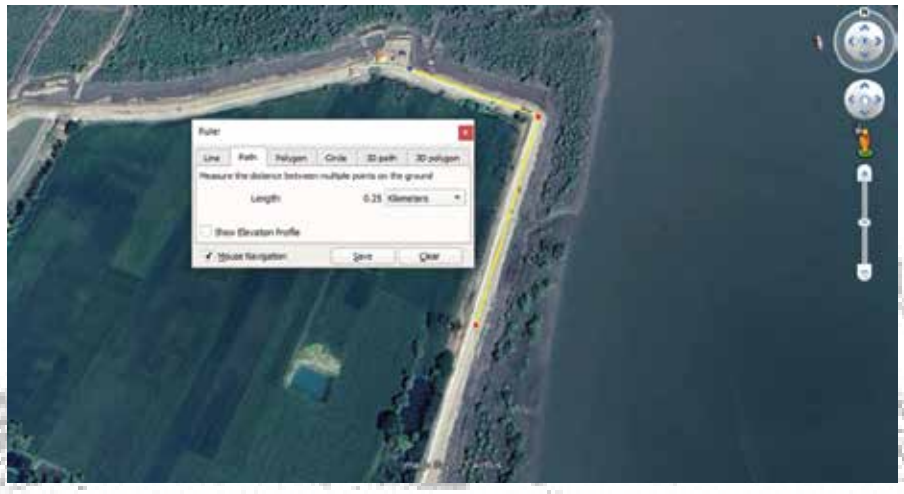


Figure-3a. Map showing selected site transect on an embankment in Ramkrishna- pur village. Embankment space available is a right angled stretch of 0.25 Km

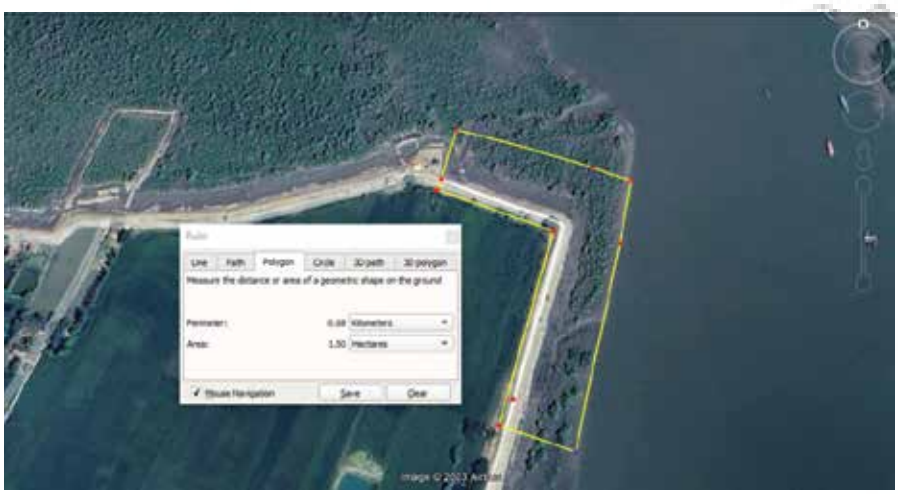


Figure - 3b. Map showing selected site area on either side of embankment (river front side and leeward side) in Ramkrishnapur village. Embankment space available for Plantation iis approximately 1.5 Ha.

AERIAL VIEWS OF PLANTATION SITE

Figure-4a. Aerial view from the approach road towards plantation site transect

Figure-4b. Aerial landward view of the entire plantation site transect

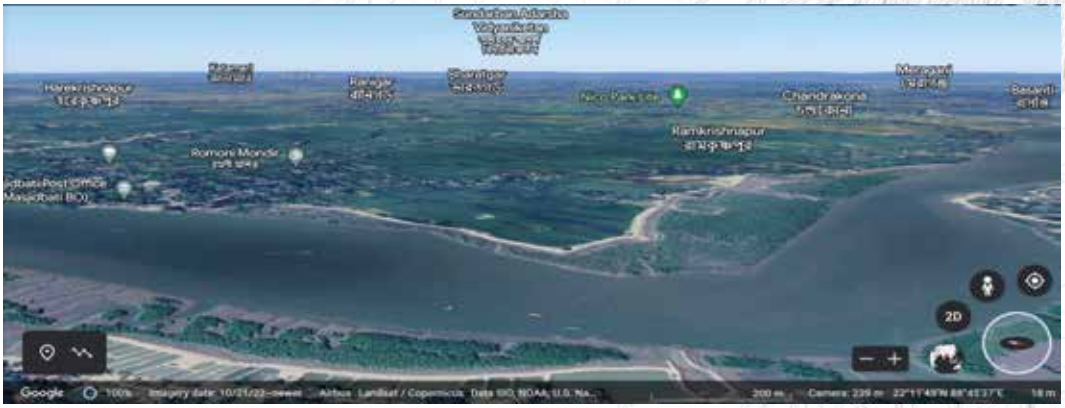


Figure-4c. Aerial river side of the entire plantation site

DEMOGRAPHIC DATA OF BENEFICIARY VILLAGES

The village selected for this particular mangrove plantation is Ramkrishnapur under Basanti Block. But the beneficiary groups are included in five villages of the Basanti Island which have been formally adopted by the Rural Initiatives-Young India team The village population is expected to be the most important stake-holder who would be beneficiaries of this plantation programme in terms of :

a) Protection against environmental hazards
b) Empowerment of villagers through active participation in plantation programmes.
c) Enhancement in terms sustainable natural wealth and resources

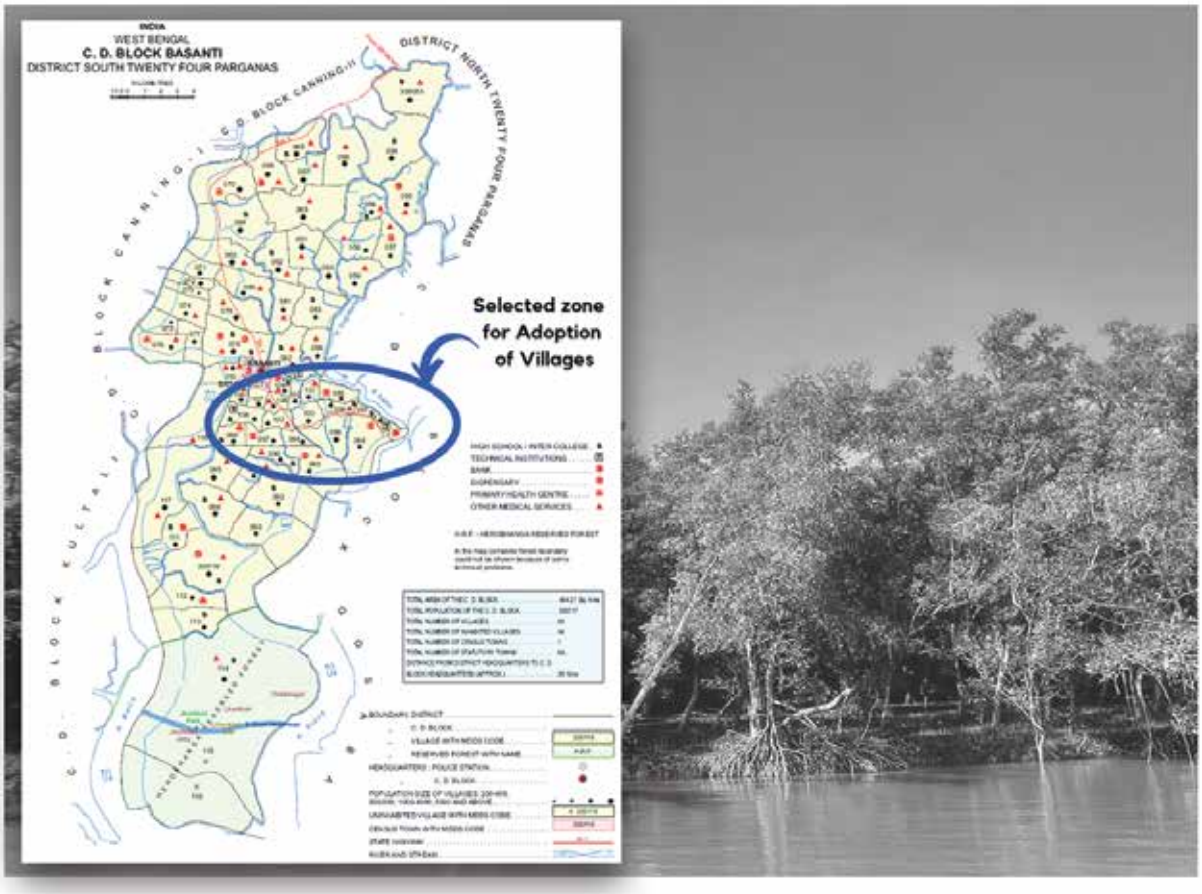


Figure - 5. Map showing zone where adoption of 5 villages has been made

Table - 1. Village - 1. MOKAMBERIA (22.1651° N, 88.7470° E)

Particulars	Total	Male	Female
Total No. of Houses	772	-	-
Population	3,446	1,762	1,684
Child (0-6)	461	215	246
Schedule Caste	2,292	1,168	1,124
Schedule Tribe	229	115	114
Literacy	74.64 %	84.16 %	64.39 %
Total Workers	1,506	1,047	459
Main Worker	881	-	-
Marginal Worker	625	244	381

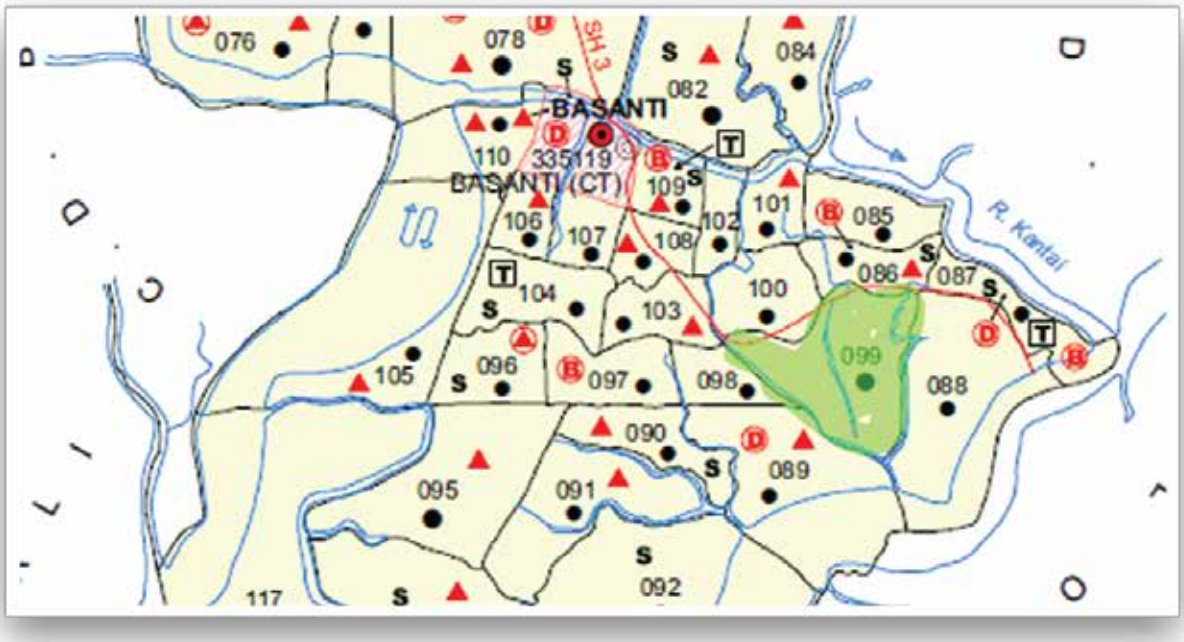


Figure - 6. Village Mokamberia (Dakshin) highlighted with green colour

Table - 2. Village - 2. RAMKRISHNAPUR (22.1889° N, 88.7518° E)

Particulars	Total	Male	Female
Total No. of Houses	467	-	-
Population	2,176	1,108	1,068
Child (0-6)	287	149	139
Schedule Caste	1,620	832	788
Schedule Tribe	0	0	0
Literacy	77.92 %	86.34 %	69.25 %
Total Workers	672	622	50
Main Worker	496	-	-
Marginal Worker	176	156	20

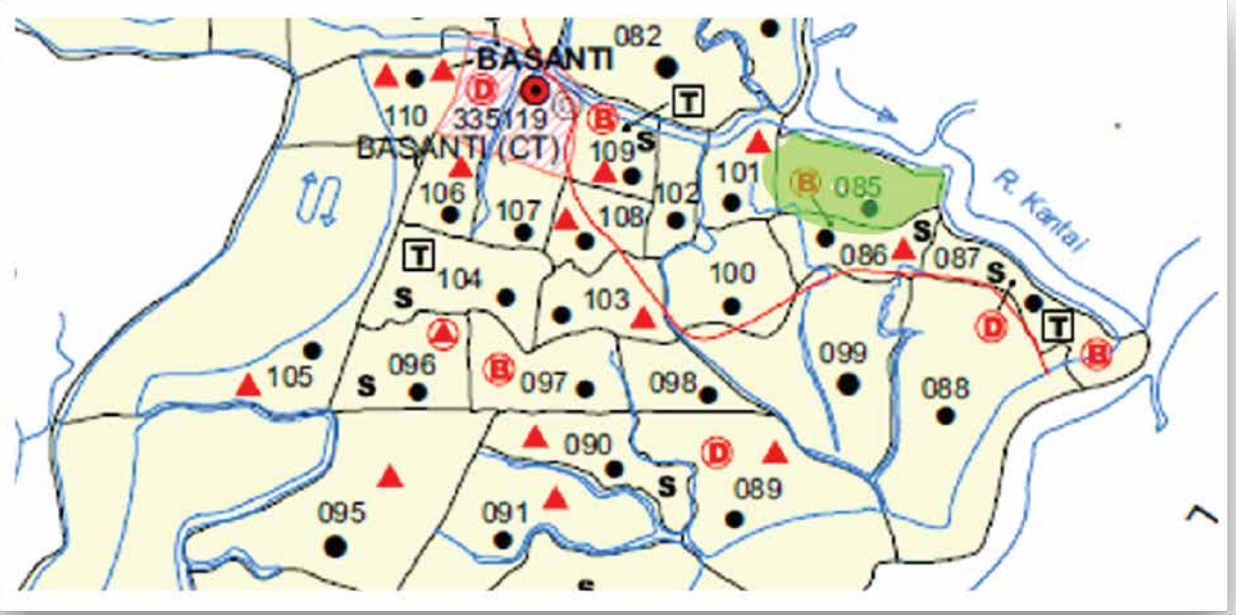


Figure - 7. Village Ramkrishnapur highlighted with green colour

Table - 3. Village - 3. KAMARDANGA (22.1562° N, 88.7638° E)

Particulars	Total	Male	Female
Total No. of Houses	397	-	-
Population	1,673	849	824
Child (0-6)	187	90	97
Schedule Caste	1,260	643	617
Schedule Tribe	0	0	0
Literacy	77.32 %	86.56 %	67.68 %
Total Workers	515	471	44
Main Worker	360	-	-
Marginal Worker	155	138	17

Table - 4. Village - 4. GADKHALI (22.1562° N, 88.7638° E)

Particulars	Total	Male	Female
Total No. of Houses	320	-	-
Population	1,110	605	505
Child (0-6)	116	76	112
Schedule Caste	706	355	341
Schedule Tribe	0	0	0
Literacy	63.98 %	66.01 %	61.90 %
Total Workers	406	312	94
Main Worker	302	-	-
Marginal Worker	112	67	55

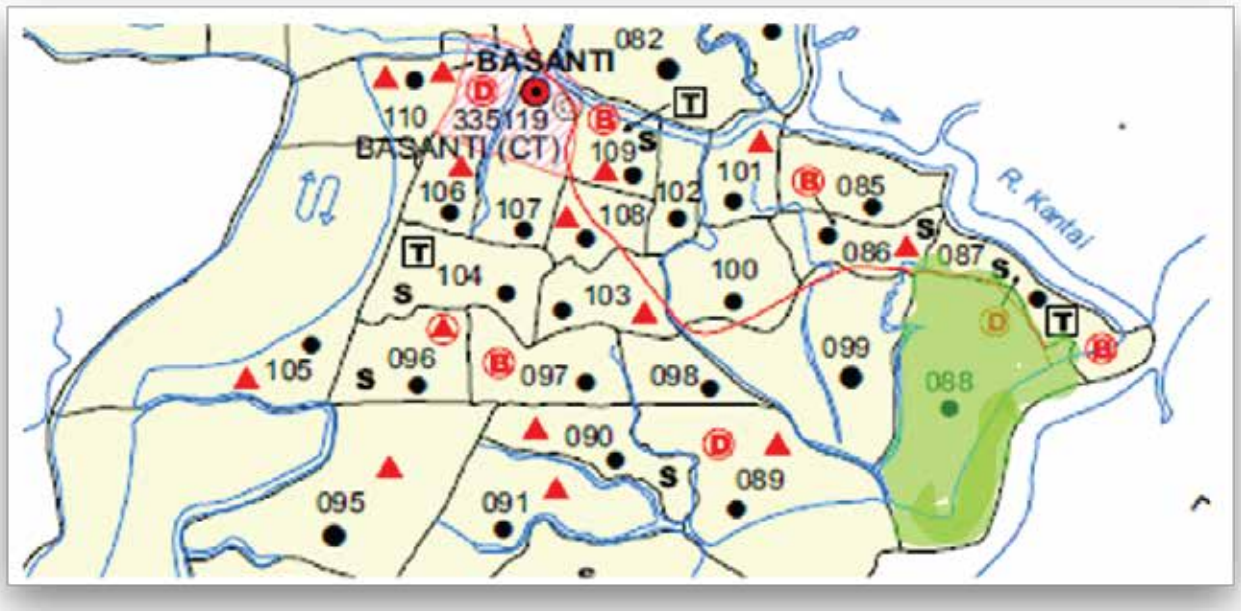


Figure - 8. Village Gadkhali highlighted with green colour

Table - 5. Village - 5. RAMGOPALPUR (22.3716° N, 88.4126° E)

Particulars	Total	Male	Female
Total No. of Houses	318	-	-
Population	1,615	705	810
Child (0-6)	216	81	135
Schedule Caste	1,590	805	785
Schedule Tribe	0	0	0
Literacy	61.98 %	64.01 %	62.90 %
Total Workers	626	435	191
Main Worker	405	-	-
Marginal Worker	212	119	93

SUGGESTIONS FOR PLANTATION

The proposal for site specific species suggestions for plantation purpose categorised under different riverine embankment faces (north and east facing in this case) are tabulated in Table – 6. It is a list of carefully selected species of different mangroves including mangroves, mangrove associates, back mangroves, beach flora, mangrove grasses and the indigenous algae, keeping in mind the naturally rich species diversity of the region. Selection of the species has been made with (i) the specificity of the embankment face and position; and (ii) the distribution and abundance of the species in Sundarbans because the ecosystem promotes rich diversity and can be sustained too by the same. Figure – 1 illustrates different zones on the embankment for the purpose of plantation programme.

The natural regeneration of mangroves takes place by different ways. Propagules of most mangroves can float in the saline waters, and move with the tides for quite a considerable period before the propagules can take root. In the brackish water of the estuaries of Sundarbans the propagules, specially the viviparous and crypto-viviparous propagules (hypocotyls) take a vertical position for their roots to point downward when approaching muddy banks.

After lodging on the river banks, if the soil condition permits its establishment, the propagules quickly send additional roots into the soil for anchorage. With the establishment, growth and maturity of such trees in the intertidal zones, it is not just the trees that grow, rather the land itself builds up and expands as mud collects around the incredible aerial mangrove root architecture slowly leading to creation of shallow mudflats, where more mangroves can establish, mature and create this ecosystem. This entire journey however, is initiated with the luxuriant growth of blue-green algae followed by green algae and subsequently the typical mangrove grasses pave way for the mangrove propagules to establish. Each mangrove species has its own variant in phenology in terms of flowering and fruiting time. Natural mangrove succession and regeneration obviously follows these patterns and it is of importance to keep in mind the phenology of the mangroves while including them within plantation programmes. Table – 7 provides an account of phenology of the species proposed in this multi-species plantation programme that need to be raised in accordance with their flowering and fruiting times.

However, the season for flowering, fruiting and production of propagules may not always be in sync with the planting seasons. For example, the fruiting season of the mangrove species Avicennia alba often used in plantation, is May to September, with mature propagule availability observed during August to September.

Table - 6. Suggested mangrove plantation species for different tidal inundation regimes on different zones of embankment slopes of north facing & east facing embankments in Sundarbans

ZONE - A		ZONE - B		ZONE - C		ZONE - D		ZONE - E	
Scientific Name	Local Name	Scientific Name	Local Name	Scientific Name	Local Name	Scientific Name	Local Name	Scientific Name	Local Name
Riverine Embankment (North Facing)									
Porteresia coarctata	Dhani ghaash	*Avicennia alba*	Kaal baine	*Avicennia officinalis*	Jaat baine	*Xylocarpus granatum*	Dhudul	*Cocos nucifera*	Narkol
Myriostachya wightiana	Naal ghaash	*Avicennia marina*	Peyara baine	*Avicennia alba*	Kaal Baine	*Xylocarpus moluccensis*	Pasoor	*Phoenix sylvestris*	Khejur
Avicennia alba	Kaal baine	*Bruguiera gymnorhiza*	Kankra	*Avicennia marina*	Peyara Baine	*Heritiera fomes*	Sundari	*Borassus flabellifer*	Taal
Avicennia marina	Peyara baine	*Ceriops decandra*	Jele goran	*Sonneratia caseolaris*	Keora	*Brownlowia tersa*	Lata sundari	*Thespesia populnea*	Habul
Suaeda nudiflora	Giria Shak	*Aegialitis rotundifolia*	Tora	*Bruguiera gymnorhiza*	Kankra	*Excoecaria agallocha*	Gneoa	*Acacia nilatica*	Babla
		Acanthus ilicifolius	Harkoch Kanta	*Sarcolobus carinatus*	Baole Lata				

ZONE - A		ZONE - B		ZONE - C		ZONE - D		ZONE - E	
Scientific Name	Local Name	Scientific Name	Local Name	Scientific Name	Local Name	Scientific Name	Local Name	Scientific Name	Local Name
Riverine Embankments (East/ West Facing)									
Blue-Green algae mixture*	Neel Shobuj Sheola	*Avicennia alba*	Kaal baine	*Sonneratia apetala*	Keora	*Xylocarpus granatum*	Dhudul	*Cynometra ramiflora*	Singaar
Green algae*	Sobuj Sheola	*Avicennia marina*	Peyara baine	*Excoeacaria agallocha*	Geona	*Xylocarpus moluccensis*	Pasoor	*Thespesia populnea*	Porosh
Porteresia coarctata	Dhani ghaash	*Ceriops decandra*	Jhamti goran	*Bruguiera gymnorhiza*	Kankra	*Heritiera fomes*	Sundari	*Thespesia populneoides*	Boro Porosh
Myriostachya wightiana	Naal ghaash	*Ceriops tagal*	Moth goran	*Rhizophora mucronata*	Garjan	*Brownlowia tersa*	Lata sundari	*Hibiscus tiliaceous*	Bhola
Salicornia brachiata	Nona shaak	*Aegiceras corniculatum*	Khalsi	*Aegiceras corniculatum*	Khalsi				
Avicennia alba	Kaal baine	*Acanthus ilicifolius*	Harkoch kata	*Aegialitis rotundifolia*	Tora				
Avicennia marina	Peyara baine	*Clerodendrum inerme*	Bon Jui	*Clerodendrum inerme*	Bon Jui				
Acanthus ilicifolius	Harkoch kata								

*Green algae shall constitute vegetative filaments of primarily Rhizoclonium and Chaetomorpha collected from the forest floors of Sundarbans.

However, the plantation can be effective only during July to Mid-October. Thus, implying the necessity of nursery raised seedlings/ saplings, as the nursery raised saplings of the first year can be effectively used for planting in the second year. Moreover, experience establishes the fact that the survival rate of nursery raised saplings is much greater when compared to direct dibbling of seeds.

Table - 7. Phenology, Association and Common Occurrence of some important mangrove species suggested as plantation species

Mangrove species suggested for plantation	Commonly associated with	Common sites of occurrence/ Suggested site for plantation	Phenology												Flowering / Fruiting
			J	F	M	A	M	J	J	A	S	O	N	D	
Avicennia alba	*Avicennia marina, Avicennia officinalis, Sonneratia apetala, Acanthus ilicifolius*	Silt deposited muddy banks, tidal flats, high saline zones, strong sunlight and wind force	J	F	M	A	M	J	J	A	S	O	N	D	
Avicennia marina	*Avicennia alba, Avicennia officinalis, Sonneratia apetala, Acanthus ilicifolius*	Silt deposited muddy banks, tidal flats, high saline zones, strong sunlight and wind force	J	F	M	A	M	J	J	A	S	O	N	D	
Avicennia officinalis	*Avicennia alba, Avicennia marina, Sonneratia apetala, Excoecaria agallocha, Acanthus ilicifolius*	Strong wind, high saline, tidal flats, strong sunlit areas, slightly more consolidated soil	J	F	M	A	M	J	J	A	S	O	N	D	
Bruguiera gymnorhiza	*Avicennia officinalis, Bruguiera cylindrica, Heritiera fomes, Excoecaria, Rhizophora mucronata, Ceriops spp.*	Strong to moderate saline conditions, strong wind and tidal actions	J	F	M	A	M	J	J	A	S	O	N	D	
Bruguiera cylindrica	*Avicennia officinalis, Bruguiera gymnorhiza, Heritiera fomes, Excoecaria, R. mucronata, Ceriops spp.*	Strong to moderate saline conditions, moderate wind and tidal actions	J	F	M	A	M	J	J	A	S	O	N	D	
Ceriops decandra	*Sonneratia apetala, Bruguiera spp., Excoecaria agallocha, Heritiera fomes, Acanthus ilicifolius*	Moderate to strong saline conditions, raised mudflats and forest floors, infrequent tides	J	F	M	A	M	J	J	A	S	O	N	D	
Ceriops tagal	*Bruguiera spp., Rhizophora mucronata, Excoecaria agallocha, Heritiera fomes, Acanthus ilicifolius*	Can grow very closely to each other forming dense stands on river banks and creeks	J	F	M	A	M	J	J	A	S	O	N	D	
Rhizophora mucronata	*Bruguiera spp., Sonneratia apetala, Avicennia officinalis, Xylocarpus spp.,*	Strong to moderate saline conditions, strong wind and tidal actions	J	F	M	A	M	J	J	A	S	O	N	D	
Rhizophora apiculata	*Bruguiera gymnorhiza, Scyphiphora hydrophyllacea, Lumnitzera racemosa*	Mostly of sea beach front of western Sundarbans in India	J	F	M	A	M	J	J	A	S	O	N	D	

The survival rate is higher also because of the fact that nursery-raised saplings have a well-developed root system, as they are maintained for a considerable period of time in the nursery. Therefore, an understanding of the phenology, identification of mature and viable propagules from nature, knowing where to collect the same from and the simple pre-treatment procedures for each mangrove species for increasing its viability, germination and establishment is important for successful nursery raising of mangrove saplings.

It also has to be kept in mind that all mangrove species cannot be raised by germinating their seeds, since each species has its own unique way of regeneration. Thus, artificially raising mangrove saplings for this uniquely designed multi-species plantation programme should include methods like air-layering, stem cutting, turf creation for grass species and the personnel involved must know the methodology of collection of mangrove/ grass/ algal propagules for the purpose along with the specialized nursery techniques of building up nurseries suitable for mangroves.

Table – 8 provides an account of the different methods suitable for plantation of different species, proposed in this multi-species plantation programme for embankment stability.

Table - 8. Plantation methods for mangrove species suggested for plantation

Plantation Method	Suitable plant species (Mangroves/ Mangrove Associate/ Back Mangrove/ Algae...)
Transplanting seedlings raised in nurseries from mangrove propagules	*Bruguiera gymnorhiza, Bruguiera cylindrica, Ceriops tagal, Ceriops decandra, Avicennia marina, Avicennia alba, Avicennia officinalis, Sonneratia apetala, Sonneratia caseolaris, Lumnitzera racemosa, Aegiceras corniculatum, Heritiera fomes, Aegialitis rotundifolia, Rhizophora mucronata, Rhizophora apiculata, Xylocarpus moluccensis, Pandanus sp., Thespesia populnea*
Planting grown up plants raised through air layering	*Excoecaria agallocha, Sonneratia apetala, Xylocarpus granatum, Hibiscus tiliaceus, Acanthus ilicifolius, Thespesia populnea, Pandanus sp.*
Planting grown up plants raised by stem cuttings	*Acanthus ilicifolius, Scyphiphora hydophyllacea, Clerodendrum inerme, Pandanus sp., Thespesia populnea, Sesuvium portulacastrum, Salicornia brachiata, Hydrophyllax maritima, Ipomoea pes-caprae, Opuntia dilleni*
Direct dibbling of propagules collected from the ecosystem	*Sonneratia apetala, Avicennia marina, Avicennia alba, Aegiceras corniculatum, Lumnitzera racemosa, Sesuvium portulacastrum, Clerodendrum inerme, Brownlowia tersa, Cynometra ramiflora, Thespesia populneoides, Suaeda nudiflora, Ipomoea pes-caprae*
Attachment of grass turfs	*Porteresia coarctata, Myriostachya wightiana, Spinifex littoreus*
Adding algal biomass	Mixed biomass of Cyanobacteria, Filamentous green algae: *Chaetomorpha, Rhizoclonium*
Raised mounds in knotted bio-geotextiles	Different propagules of mangroves collected from the estuarine system can be pre-seeded in the bio-geotextiles for covering embankments

Any intervention in the form of vegetative solution in the vulnerable mangrove regions needs to prioritize the uniqueness and fragility of the system in designing the same. It goes without saying that the best options should be selected from the natural vegetation of the region, because the system, as we see it is well capacitated to sustain and regenerate itself. Thus, the probable option would be an attempt to mimic the system in the best possible way as solution, and also find out ways and means to make such interventions sustainable.

Thus, the proposed solutions to be implemented in Ramkrishnapur Mangrove Plantation Project shall take into consideration both ecological and socio-economic aspects of Sundarbans in the context of :

(i) Maintaining the rich species diversity of the mangroves indigenous to Sundarbans;

(ii) Remain in sync with the site-specificity of the mangroves in terms of sand:silt:clay ratio, wave and tidal influences, salinity regimes, sediment load shifts, and wind force;

(iii) Follow the inherent patterns of vegetation succession of Sundarbans: the proposal has been chronologically planned in terms of species structure suggested for the plantation programme. Succession pattern is initiated in the Sundarbans by the blue-green algae and the green algae which consolidate the ill-consolidated soil paving way for the floating propagules of mangrove species to gain ground on this tide washed lands and establish themselves.

(iv) Promote enhanced mangrove regeneration rate both naturally and through people's participation by means of providing an alternate livelihood option. The requirement of multi-species nursery raised mangrove seedlings/ mangrove grass turfs/ mangrove propagules/ biomass of mangrove algae (green and blue-green) shall ensure that the mangrove propagules are not wasted as fuel by the fringe area population and shall also provide another livelihood option for the locals in nurturing multi-species nurseries. This shall contribute to enhancing mangrove regeneration rate both naturally and through local intervention. The basic structure of embankment available for plantation, presently seen in the Sundarbans have a hypothetical structure as depicted in Figure - 1. With this hypothetical structure in mind it is important to mimic the system in question to ensure that the mangrove plantation gains stability. The natural scenario of the embankment slope of Ramkrishnapur plantation site is depicted in Figure - 9.

Figure - 9. (I) Natural succession stages on embankment slopes in Indian Sundarban and (II) suggestions for mimicking the same on the earthen embankment slope selected for plantation at Ramkrishnapur, Basanti Island as the proposed Mangrove Plantation Programme

The final part of the proposal for plantation revolves round the issue of embankment stability. The same can be adopted as a supplementary protocol for ensuring successful plantation as well as a stable embankment but is not an essential component of mangrove plantation.

The said proposal is in the form of a low-cost bio-engineering solution. Where reinforcement of the earthen embankment is initially ensured by covering it with pre- seeded bio-geotextile made up of jute. The diagrammatic representation of this proposed solution for strengthened embankments and ensured survival of planted mangroves is given in Figure - 10.

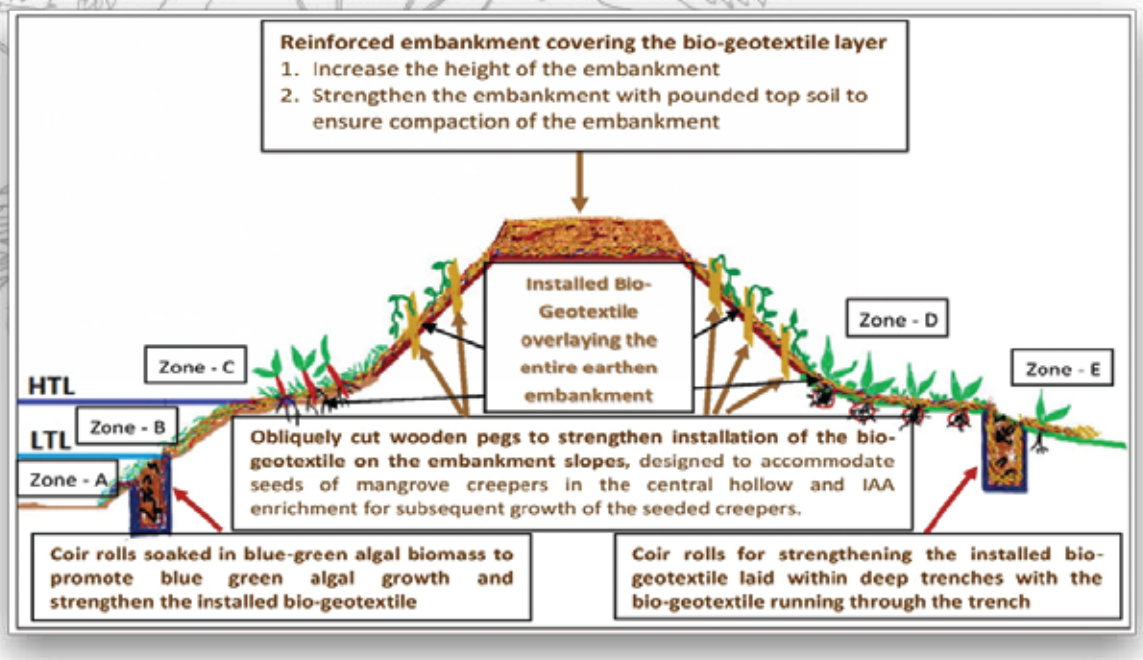


Figure-10. Installation of pre-seeded bio-geotextile (jute/coir/palm leaves) over earthen embankments suggested for providing enhanced stability

Zone -A. Vegetative growth from pre-seeded bio-geotextile: Blue-green algae growth from pre-strewn algal filaments on the bio-geotextile material

Zone -B. Vegetative growth from pre-seeded bio-geotextile:
(1) Green algae filament growth from pre-embedded algae;
(2) Mangrove grasses growth from grass turfs attachment

Zone -C. Vegetative growth from pre-seeded bio-geotextile:
(1) Mangrove grass growth from grass turf attachments;
(2) Mangrove seedling transplantation or germination from pre-seeded propagules

Zone -D & E. Vegetative growth of pre-seeded bio-geotextile: Back mangroves and mangrove associates

The bio-geojute textile proposed has to be pre-soaked with blue-green algae with green algal filaments strewn into the fabric, and mangrove seedlings knotted with the same (Figures – 12 and 13). Raising of nursery items and production of this bio-geotextile can be introduced as an alternate livelihood option for the the villagers under the scheme.

This bio-geotextile has to cover the entire Zone-A to Zone-E and secured and strengthened by means of coir rolls soaked in blue-green algae mixed culture media and inserted into pits in Zone-A and Zone-E and in the upper littoral region, just below the top of the embankment, the bio-geotextile is to be fastened with obliquely cut wooded pegs, pre-seeded with seeds of mangrove climbers and twiners and treated with indole acetic acid (IAA) the growth promoting hormone (Figure – 14). The twiners once established shall augment the binding of soil in the upper littoral regions as well. The top of the embankment covered with the bio-geotextile has to be designed with provision for increasing the height of the embankment. Thus, the top soil of the embankment top shall increase the height of the embankment and when pounded well shall serve the purpose of strengthening of the embankment and making space for brick layering as well, to be further used by the villagers as a pathway.

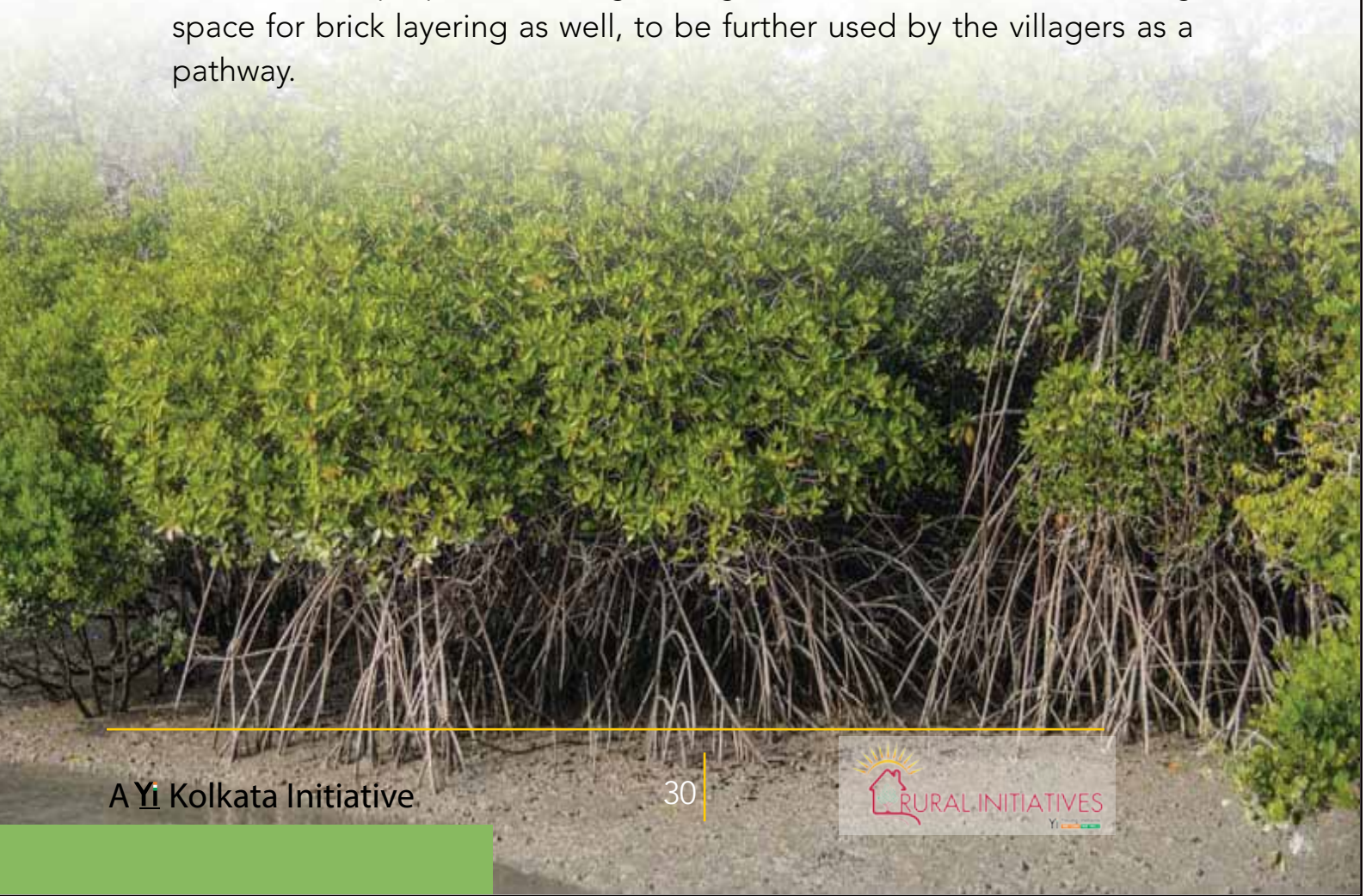


Figure - 12. Proposed methodology of vegetative matting and turfing of earthen embankments with pre-seeded bio-geotextile material

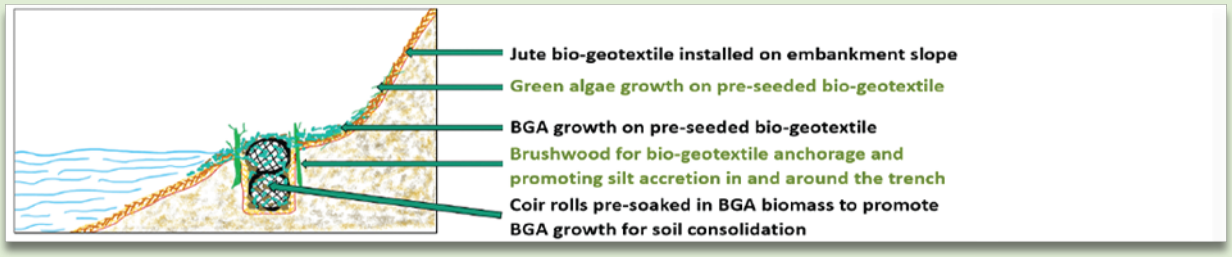


Figure - 13. Proposed methodology of digging trenches to fit in the overlaid bio-geojute textile and secure it with brush wood and coir rolls soaked in blue green algal biomass to trigger blue-green algal growth to consolidate the soil faster.

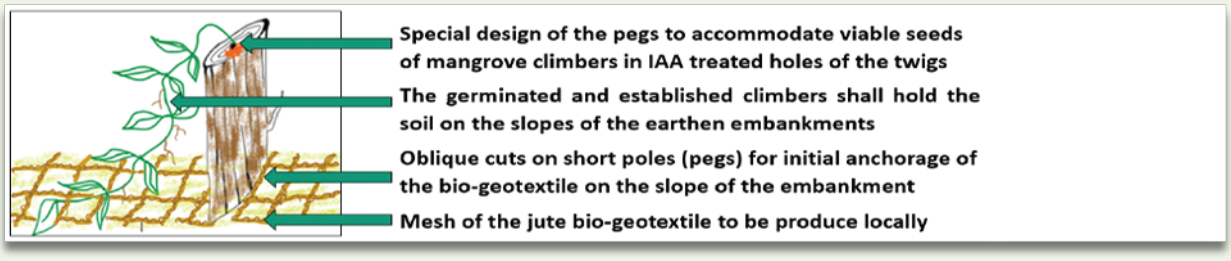


Figure - 14. Proposed methodology of reinforcement of bio-geotextiles on embankment slopes between Zone C and D with short obliquely cut branches of locally collected strong twigs, pre-seeded with climber/ twiner propagules & reinforced with IAA for growth

SWOC ANALYSIS & RECOMMENDATIONS

Some key factors that are expected to influence the mangrove plantation programme and operation of the low-cost bio-geo-remediation of mangrove embankments are listed below as a general SWOC (Strength, Weakness, Opportunities, Challenges) Analysis.

STRENGTHS

a. Multi-institutional access to knowledge and technical knowhow b. Extremely rich mangrove diversity

c. Mangroves prove as efficient bio-shields

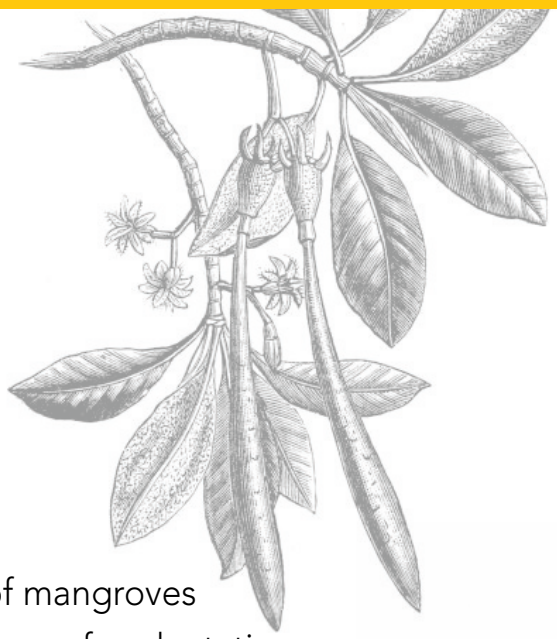
d. Defined translatable floral succession – algae to mangrove.

e. Resource inflow possibilities from Governmental and Non-Governmental sources

f. Biology and Ecology-based simple technique with low installation and maintenance g. Local knowledge, participation and livelihood opportunities

h. Invasive species are not introduced. Only indigenous flora used

i. Would serve as nesting and resting ground of birds and animals in the long run



WEAKNESSES

a. Slow growth rate of mangroves

b. Lack of space at places for plantation

c. Frequent extreme climate events

d. River/ tide dynamics

e. Possible socio-political conflicts of interest

f. Misunderstanding and lack of patience among stakeholders

g. Grazing and other activities hindering initial growth phases

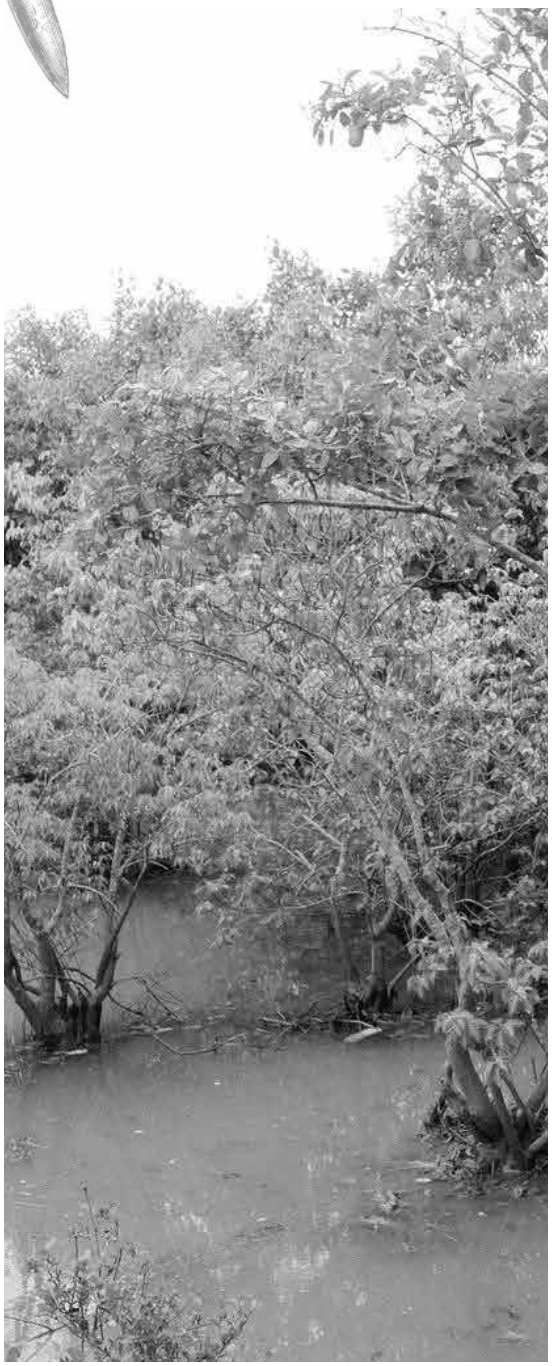
OPPORTUNITIES

a. Livelihood of local people and enhanced people's participation & ALO for local people b. Under standing and "Live with Nature" approach

c. Basic embankment protection mech anism

d. Prevention of siltation and naviga tion related problem pertaining to river bed choking e. Nursery grounds of mangrove diversity in near future by means of patch resto ration f. Robust research results and understanding of ecosystem

g. Many line departments in action if desired

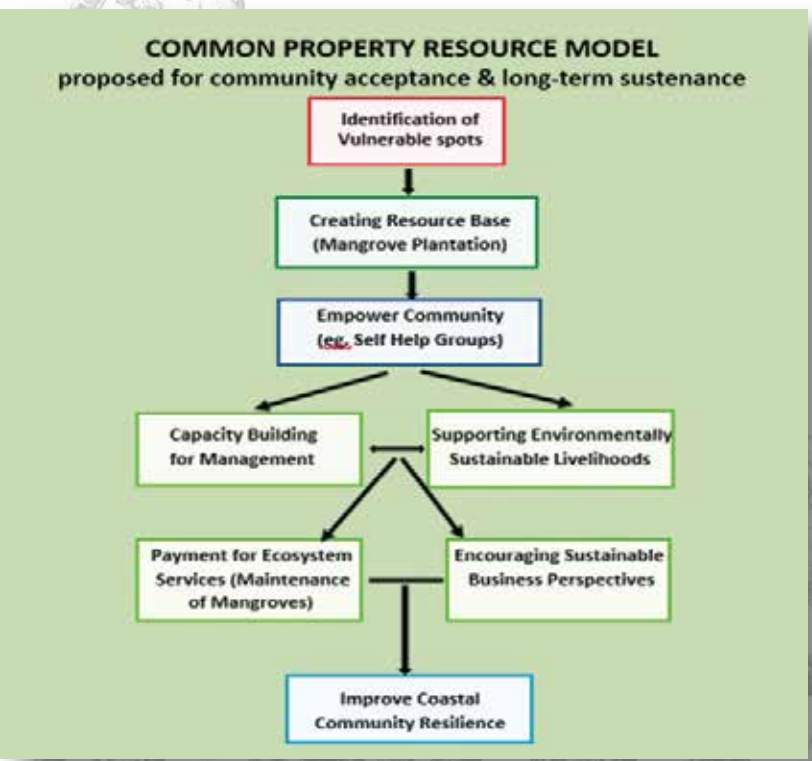


CHALLENGES

a. Large population solely dependent on this ecosystem
b. Natural weather and climatic fury which would challenge the initiation programmes to be executed with extreme care
c. Increasing the social acceptability of program
d. Overtaking local misunderstandings to be handled with care and compassion
e. Capacity building of communities for initiation through multi-species plantation
f. Explaining to policy makers and those involved in plantation programmes the importance of mimicking the ecosystem or else to leave the system to regenerate naturally
g. Explaining to people about patch restoration and "no disturbance" zone concepts during growth of the mangrove embankment successions
h. Overcome socio-political and legal hindrance with utmost care and expertise.

RECOMMENDATION

The recommendations for this project are simple and are depicted in a flowchart. The same has applicability of replication in other vulnerable areas of Sundarbans. The main idea is to create a Common Property Resource Model. This will in the long run help in community acceptance of the project which is extremely important and ensure long-term sustenance of the plantation.



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