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Reforestation de la mangrove à grande échelle par la finance carbone pour un impact significatif sur la biodiversité – un nouveau paradigme parmi les modèles de conservation de la biodiversité

Aumento de la reforestación de manglares con la financiación del carbono para crear un impacto significativo en la biodiversidad: un nuevo paradigma en los modelos de conservación de la biodiversidad

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Scaling of mangrove afforestation with carbon finance to create significant impact on the biodiversity – a new paradigm in biodiversity conservation models

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Abstract. Sunderbans has undergone a huge loss of forest cover in the past century. Population pressure ever increasing, the administration is more intent on developing economic activities in the area. However no economic activities will sustain if the environmental vulnerability of the region is not properly addressed. Mangroves form the basis of the ecosystem and large scale restoration of this mangrove cover on a scientific basis can create the necessary impact on the biodiversity and mitigate climate change. The carbon finance approach adopted by "Livelihoods" is a tool to create biodiversity-core social business models. This writing reviews into the theory and practices of such a model implemented in Sunderbans and identifies the prospects and challenges.

Keywords. Mangrove, Climate change, India, Carbon finance, Clean Development Mechanism, Forest, REDD+, Ecosystem, Biodiversity, Sustainability

1. "Why and how" of carbon finance model for mangrove afforestation

Global Warming and climate change posing a rather gloomy picture for the future of the planet earth, thousands of people living in the coastal region, which happen to be the hub of economic activities, have been exposed to the threats of sea level rise. The last decade has seen tsunami, cyclones, tornadoes, of such magnitude and dimension that those suffered are still struggling with the impact and the world has learnt it in the other way. The question was apparent- how nature balanced these hazards in her own way? It is the mangroves that creates a bio-shield, helps stabilizing the tidal estuaries, sequester huge amount of carbon-di-oxide (both below and above ground bio-mass), dissipates and dissuades wind and wave energy. Sunderbans, world's largest mangrove delta has witnessed sharp decrease in mangrove cover since last one hundred years. The huge population pressure along with human interventions like dams in upper reaches of the Ganga-Bhagirtathi river has created a huge impact on the entire hydrology of the system and thus has also affected the mangroves. Thus, the importance of conservation of mangroves have increased manifold in this context.

The task is challenging. Mangroves form the basis of Sunderbans ecosystem and mangrove management – plantation and monitoring constitutes a major task of the administrative bodies – mainly the Forest Department and Sunderban Development Board (SDB). The Forest Department is more concentrated on managing the protected area with limited resources of staff and funds, while SDB is more focused on supporting socio-economic activities like agriculture, rainwater harvesting, electrification and social forestry activities with additional tasks of mangrove plantation on the village mudflats. Thus we have seen mangrove planting initiatives in the past, but they are generally a one or two year bound project which do not in the design of it hold the sustainability over a longer period. In spite of few cores of investment in mangrove plantation over last ten years, except for some very few areas like in "kanchan dwip" in Bidya River, we find there is no significant patch of mangroves regenerated on the areas outside the protected area, degradation of the same being the order of the day. Hence the tools necessary to develop to grow it into a forest is lacking. A yearly engagement of the departments during monsoon time for plantation of seeds,

mostly mono-species, is noticed. The continuous and assured flow of funds for the growth and monitoring is also a prerequisite for the sustenance of such activities. We also do not come across GPS use to define areas of plantation, bathymetry-salinity specifications of the mudflats, survival-mortality data , growth curves, changing pattern in the forest cover and finally the engagement of the communities in decision-making and monitoring of this process.

Since afforestation through carbon financing is a mechanism which in its course holds a period of growing and maintaining the carbon stock of the trees over ten or twenty years of time, hence preservation and consolidation of the carbon pool of the mangroves becomes critical for the existence and continuance of the project. The carbon-finance model is an upfront investment that assures the flow of funds for the plantation to grow into a forest cover. It is a long-term investment, high-scaled and creates long term impact, especially the one from Livelihoods mission that support the efforts of agricultural and rural communities to live in sustainable ecosystems which serve as the foundation for their food security and provide the resources that ensure their sustainability. Hence it also looks at the economic and social well-being of the vulnerable communities.

Thus we have a win-win situation for all the stakeholders .It is for the interest of the investors, who invests in funds mobilizing in particular carbon offset mechanisms, that the project is addressed and dealt with all the challenges to maximize the sequestering capacity and hence the growth of the forest cover.

The NGO who is implementing the project gets a long term commitment for the implementation of their mission of protecting ecology and environment and lastly the community gets increased forest cover that protect them from the natural hazards like storms, cyclones and daily tidal influences, as also bring livelihood securities by means of increased quality fish and crab catch.

2. The project vision

Nature Environment & Wildlife Society (NEWS) has been working as a non-profit association for protection of wildlife, ecology and the environment in various ecosystems in India through research orientation programmes and also mobilizing communities dependent on ecosystems for security of sustainable livelihoods and engages them in the conservation process.

Livelihoods' mission is to support the efforts of agricultural and rural communities to live in sustainable ecosystems which serve as the foundation for their food security and provide the resources that ensure their sustainability, acting as a platform providing the means to restore or preserve ecosystems that are degraded or threatened by mobilizing in particular carbon offset mechanisms.

The project funded by Livelihoods and implemented by NEWS in Sundarbans, the world heritage site has the vision of:

- Afforestation of mangroves and restoration of the vibrancy of the wetlands ecosystem
- Community mobilization and engagement in restoration process
- Developing a carbon offset strategy on wetland restorations to reduce impact of greenhouse gas emissions

The project aims to:

1. Plant 6000 ha of mangroves in the vulnerable areas in a multi-species environment that will protect the embankments from the tidal surges, protect the huge population of southern Bengal from the onslaughts of cyclones, storms ;increase the fish catch , crabs and reestablish the functioning ecosystem thus helping the community to build resilience against climate change .
2. Engage the community in the implementation process at every level through intense stakeholders meetings, institutionalize the process by involving the panchayats – the grass root platforms of the Government and develop mechanisms to create "change agents" especially among women by patronizing self-help group activities.
3. Contribute to the Danone carbon offset strategy and collect carbon credits ,as per the guidelines of Kyoto protocol under the Clean development Mechanism ,to an agreed value beyond which the added values will be shared between community to the extent of 50%.

4. Project: at a glance

The entire project area of 6000 ha is divided into four zones: Bidya-Raimongol, Matla, Saptamukhi-Thakuran and Sagar Island.

4.1 History

The Indian part of Sundarbans cover an area of 9630 sq km which is bounded in the north by an imaginary line called Dampier-Hodges line, in the south by Bay of Bengal : in the east by Icchamalti Raimongol river and Hughly river in the west. It falls within the districts of 24 Parganas, South and North.

It has been declared a Tiger Reserve in 1973, a National Park in 1984, a Biosphere Reserve in 1989 and a World Heritage Site in 1987.

4.2 Terrain and river systems (geomorphology)

Sunderbans is formed by the alluvial deposits carried on by the mighty rivers from Himalayas. Ganga River originating in the Goamukh glacier in the Himalayas traverses through the breadth of the country building rich fertile lands along its banks and is joined by numerous snow-fed rivers from the Himalayas. In its lower course the main distributary is Hughly while the river continues flowing east into Bay of Bengal. River Brahmaputra originating from the Himalayas flows through China and enters India through north-eastern borders and pours into Ganga, about 120 km upstream from the mouth of river Ganga. This river system with Hughly in the

East and River Ganga in the west creates the delta of Sunderbans in the lower reaches of the river with innumerable creeks and channels forming a criss-crossed network.The main rivers that constitiute this system in India are Matla, Thakuran, Bidyadhari, Raimongol, Saptamukhani , Goasaba, Icchamati.

Table 1

SITE	PLANTING 2010	PLANTING 2011	PLANTING 2012	PLANTING 2013
BIDYA-RAIMONGOL	292	132.5	776.6	375
MATLA	409.3	617.3	371	150
SAPTAMUKHI-THAKURAN	64.9	156.4	847	500
SAGAR-PATIBONIA		590	243	475
TOTAL (in ha)	**766.2**	**1496.2**	**2237.6**	**1500**

Plantation plan until 2012 covers the following villages, panchayats and blocks of Sunderbans.

Table 2

SITE	BLOCKS	PANCHAYATS	VILLAGES
BIDYA-RAIMONGOL	4	17	23
MATLA	4	13	17
SAPTAMUKHI-THAKURAN	5	17	27
SAGAR-PATIBONIA	2	6	9
TOTAL	**15**	**43**	**76**

4.3 Influences

A close network of rivers, channels and creeks intersects the whole area, thus forming numerous flat islands which are submerged completely during high spring tides and partially during ordinary high tides. The Hughly River, although a major tributary of the Ganga River, receives a limited and specified discharge from its main constituent river because of the Farakka Barrage and treaty with Bangladesh. "It is fed mainly by the Rupnarayan and is also connected with the Ganga through the Jalangi River.

But the estuary of the Hughly remains brackish even during the rains on account of its great width. During the rains, Raimongol receives a considerable quantity of local drainage. The rivers Matla, Saptamukhi and Thakuran have practically no connection with their original parent stream and are now creeks of the sea" (Government of West Bengal, 2010).

Freshwater flow is almost non-existent in the dry season and silts and sediments that enter the estuary from the Bay of Bengal is not flushed. Siltation is a major threat that is even challenging the navigability of such big rivers. Thus the natural processes of erosion and accretion, influenced by tilts and shift of tectonic movements along with human interferences, like embankment construction, have made this dynamic deltaic system more complex, added to it is the threat of predicted sea level rise. Because of this embankment the river is dissuaded from natural erosion and accretion process, for which many a time it is found some narrow channels like Durgaduani deepening and cutting its banks sharply and big rivers like Bidya, Thakuran silting heavily.

Figure 1a. Embankment ©hellio-vaningen 1b. Construction of embankment ©hellio-vaningen

Thus in present situation identification of stable, accreting lands for afforestation is a key task.

4.4 Tides

High tides and ebb tides occur twice daily and current changes direction every six hours. The spring tides which occur at vernal equinox (March / April) produce the maximum rise and fall as there is then very little current in the rivers. The tidal current passes from west to east. The velocity of tidal current increases in the northern part of the tract where the rivers are narrow and the maximum rise and fall occur where the speed is the highest. Near the sea coast the average rise and fall is about 2.15 m. While a south wind prolongs the period of the flow, the north wind shortens the same.

TABLE 3

SITE	MAXIMUM TIDE	MINIMUM TIDE
SAGAR	5.68 m	0.96 m

However as a rule the flow tide in estuarine system lasts a little more than the ebb tides. In the resulting effect, unless there is excess river energy from upstream flush, the decantation of traction load sediments take place. Thus, these backwater channels are getting silted up day by day.

The tidal wave makes its way across the Sundarbans from west to east and consequently the tide changes earlier in the west than it does in the east. In large rivers the velocity of the current usually varies from 3 km an hour near the sea surface to 6.5 km an hour higher up in the forests. The speed increases further inland on account of gradual narrowing of river channels. The average rise and fall near sea face is about 2m further up it is 3m and where the tide has little or no stream to contend against, an average rise and fall of 5 to 6.5 m is common.

The *heights of tidal variations on the mudflats* are dependent on the accretion pattern, appropriate slope, bathymetry and these *are key for the selection of species* on a particular mudflat that extends even upto 500 m inside the river or lower but then extends over a longer stretch even upto 10 km.

5. Plan for planting different mangrove species at different zones of mudflat

5.1 Salinity

"The variation of salinity in pre-monsoon, monsoon and post-monsoon season shows significant variations (Mitra et al, 2010). The surface water salinity values ranged from 8.66 psu (at Sagar, south in the western sector during 2010 monsoon) to 26.59 psu (at Canning in the Central sector during the 2008 premonsoon). The salinity values were significantly higher ($p < 0.01$) in the central sector compared to the western sector irrespective of seasons and year (Table 5).

Table 4

HEIGHT OF WATER LEVEL AT HIGH TIDE	NO OF DAYS IN A MONTH WHEN THE MUDFLAT IS FLOODED BY WATER AT HIGH TIDE	SUITABLE MANGROVE SPECIES
Less than 4 m above sea level	30 days	*Porterasia coarctatq* *Avicennia alba*
Less than 4-4.5 m above sea level	25 days	*Avicennia alba* *Avicennia marina* *Avicennia officinalis*
Less than 4.5- 5 m above sea level	20 days	*Sonneratia apetala* *Bruguiera gymnorrhiza* *Rhizophora apiculata*
Less than 5- 5.5 m above sea level	10 days	*Rhizophora apiculata* *Sonneratia apetala* *Bruguiera gymnorrhiza* *Xylocarpus granatum* *Xylocarpus mekongenesis* *Ceriops decandra* *Aegiceras corriculatum* *Heritiera fomes* *Excoecaria agallocha*
Less than 5.5- 6 m above sea level	2-3 days	*Sonneratia apetala* *Bruguiera gymnorrhizA* *Xylocarpus granatum* *Xylocarpus mekongenesis* *Ceriops decandra* *Aegiceras corriculatum* *Heritiera fomes* *Excoecaria agallocha* *Phoenix paludosa* *Nypa fruiticans*
More than 6 m above sea level	Very occasional	*Phoenix paludosa* *Casurina marina*

Table 5. Salinity values in different sectors

A: Sagar South (Western Sector) / B: Canning (Central Sector)

SEASONS	2005		2006		2007		2008		2009		2010	
	A	B	A	B	A	B	A	B	A	B	A	B
Pre-monsoon			26.10	26.50	25.12	26.00	29.11	26.59	24.04	26.08	23.58	25.95
Monsoon	09.16	10.44	09.02	09.65	09.30	09.98	08.76	09.90	09.08	10.02	08.66	10.13
Post-Monsoon	22.32	23.10	21.67	23.10	21.80	23.88	20.73	24.06	20.04	24.32		

Seasonal variation of surface water salinity (in psu) in selected stations during 2005-2010 (Mitra et al, 2010)

Mangroves are typical inhabitants of brackish water environment and salinity is a major factor in growth and survival of mangroves and different species adapt in a different way to diverse saline conditions. Based on the physiological studies, Bowman (1917) and Davis (1940) concluded that mangroves are not salt lovers, rather salt tolerant. So selection of species is also guided by the salinity conditions prevailing in that particular zone.

Table 6. Salt tolerance of species (Iftekhar et al, 2008)

SPECIES	SOIL SALINITY (PPT)	WATER SALINITY (PPT)	SUCCESSIONAL STAGE
Avicennia spp.	7-9	85	Pioneer
Bruguiera spp	8-11	37	Mid-seral
Ceriops spp	*7-13*	*72*	*Mid-seral*
Excoecaria spp.	*5-17*	*85*	*Mid-seral*
Sonneratia spp.	*3-8*	44	Pioneer
Xylocarpus spp.	3-10	34	Climax

5.2 Climate

Rainfall: Average annual rainfall is 1920.3 mm, humidity about 82% and is more or less uniform. Average annual temperature is 25°C.

The climate of Sunderbans is changing in a pattern consistent with the global climate change models and suggestions for India are:

- A rise of 2.3° to 4.8°C in average for annual temperature between 1980 and 2040.
- A long-term increase in the frequency of tropical depressions and cyclones. In the case of the North Indian Ocean it is estimated that the average number of tropical disturbance days could increase from 17 to 29 per year by 2040 (Sundarban Development Board, 2003).

5.3 Flora and fauna

The Sunderbans harbors the most diverse mangrove ecosystem of the world with 26 True mangrove species, 29 Mangrove associates and 29 Back mangrove species supporting 40 Families, 60 Genera and 84 species. But it may be noted that although this largest mangrove chunk is quite pristine and protected in the core forested areas, it is all the more degraded in the inhabited areas.

The Sunderbans mangrove ecosystem plays a vital role in breeding and nursery phases of many riverine and marine species of commercial value. The nutrient rich muddy waters of mangrove vegetation provides shelter, food and spawning ground to innumerable species of finfish and shellfish. The Sunderbans fishery comprises 18 prawn species, 34 crab species and 120 fish species besides 10 species of turtles. The ecosystem supports frogs and toad species, around 23 snake species and lizards, crocodiles and water monitor. Other diversity include more than 200 species of birds and mammals like wild boars, spotted deer, porcupines, otters , monkeys. The food chain culminates in Royal Bengal tiger, which is a critically endangered species. Among the faunal distribution, 11 species are rare and endangered.

5.4 Human Settlements and socio-economic profile

Although there are evidences of human settlements in Sunderbans from 300 BC to 1200 AD, yet many a time population was wiped out due to extreme natural disasters. However sources of last human settlements date around 1700 AD. In 1756, when in battle of Plassey, the Nawab of Bengal was defeated by East India Company, the 24 Parganas was handed over to the East India Company. The company leased land to individuals in 1770 to reclaim land for cultivation and timber supply. Life was difficult in this salty marsh lands with dense forests and tigers and crocodiles; it failed to attract people from nearby districts to settle in Sunderbans. Forests were cleared, business for timber, honey, paraffin , salt and fish grew. Santhals, Orao, Munda, Kurmi, Bhumij and other tribes came as labourers and gradually settle down. Settlers and embankments were built to sustain living on the submerged islands. Thus Sundarbans has a high representation of minority or less developed groups. Scheduled castes and tribes comprise 39% and 7% of the total population resp.

5.5 Population analysis and vulnerability

After Bangladesh war of independence, Sundarbans became choice of hundreds and thousands of political refugees and there was a sudden population splurge. Population growth is very high and is still continuing. As per 2001 Census, the total population of Sundarban region was about 3.7.million. The decennial growth rate during 1991-2001 was 17.4% against the state average of 17.77%. The population density as per 2001 census was 845 per sq. km which is more than the

average for rural West Bengal, reported as 676 per sq. km. The present population is 5.1 Million (2011 census). They have settled in 54 islands out of 102 islands in Sunderbans, the rest 48 are uninhabited and protected where no human activities except forest patrols are allowed. The inhabited islands are protected from tidal flows, twice each day by 3500 km long earthen unstable embankment, which happen to form the lifeline of the people of Sunderbans.

5.6 Employment pattern

"*One of the characteristic statements used to describe the people of Sunderbans is that 85% of the people depend on agriculture. The proportion of the population without work in 1991 was 70% with only 3% in part-time or marginal employment and 27% in main employment categories. Of the main employment, only 10% are employed in agriculture as cultivators and another 10% as labourers. Only 20% of the workforce is employed in agriculture. The Sundarbans, while having 85% of the population involved in agriculture is not as dependent upon this sector as claimed"* (Sundarban Development Board, 2003).

Table 7. An analysis of income structure of the targeted community in two villages (plantation sites) in Bidya-Raimonogol zone

MONTHLY INCOME (RS)	RAMCHANDRAKHALI	JYOTISHPUR
500-1000	11.68	22.06
1001-1500	19.31	36.51
1501-2000	21.09	20.18
2001-2500	18.12	9.41
2501-3000	15.18	7.35
3001-3500	2.59	1.47
3501-4000	7.79	1.47
4501-5000	2.59	1.47
7501-8000	1.29	0.08
8000 and above	0.36	0

People are very poor with more than 41% living below poverty line. Scarcity of drinking water, saline ambience has made life more difficult. People are often found to be engaged in unsustainable livelihood practices like illegal fishing (without permit), crab collecting, firewood collection, venturing into forest for honey collection illegally. They risk their life and fall easy prey to tiger and crocodile .Women and children are particularly vulnerable towards Post Larvae (PL) shrimp collection The collection of PL shrimp by dragging nets along the mudflats just after the high tide recedes causes major health hazards , crocodile victims and also encourages illiteracy among the school children which is an opportunistic source of income for poor people .It also uproots the mangroves naturally collected on the mudflats and thus inhibits the process of formation of green belts in natural course . Besides ,each time a net is dragged and the collection taken in a utensil , the PL shrimps are sieved and the rest of the water with seedlings of other fishes/invertebrates are thrown away to die on the mudflats thus causing a huge biodiversity loss. There are an estimated 1500 to 3000 million PL collected per annum. For each PL collected, the by-catch mortality was estimated to be 8 finfish seeds, 30 crab seeds, 150 other prawns, 1 mollusc seeds.

Many migrate outwards to seek opportunities in cities in Kolkata and even outside states (which increased at an alarming rate after cyclone Aila, in May 2009).

5.7 Administration

The Sundarban Biosphere Reserve area is a multiple-use area where there are inhabited and deforested agricultural lands, industries, towns and protected areas. There are 19 community blocks which before 1883 were forests and are now completely deforested and converted to many production related activities, associated settlements and agriculture.

Out of 9630 sq km, 2585 sq km is Sundarban Tiger Reserve and 1680 sq km of South 24 Parganas Reserved forests falls within protected area management under Sunderban Biosphere Reserve (SBR), Department of Forests, and Government of West Bengal. The Forest Protection Committees (FPC) in Reserve forest areas and Eco Development Committees (EDC) for wildlife sanctuaries are formal bodies of Joint Forest Management committees in Sundarbans between local communities and Forest Department for protection of nature and natural resources within the protected area.

Sunderban Affairs Department with a separate ministry also functions for the development of socio-economic standards of Sundarbans, where Sunderban Development Board (SDB) is the major axis, with its office at Kolkata.

6. Threats and challenges to afforestation programmes

6.1 Fragile ecosystem: factors of climate change

The increase in salinity has significantly influenced the mangrove vegetation pattern, where we find gradual replacement of *Heritiera fomes* (Sundari tree) on the western parts by saline dominant *Avicennia* species. But again specific preferential adaptation of *Excoecaria agallocha* in the high saline central sector has been discussed and documented (Mitra et al, 2010).

6.2 Lack of documentation and monitoring mechanism

If we consider the several projects on Mangroves regeneration by Government and Non-Government Agencies over last twenty years, we find there is lack of proper scientific approach to methodologies adopted and also documentation of best practices or lessons learnt. They have been sporadic, fragmented and localized with a goal of "plantation" rather than restoration of the ecosystem, hence it missed the larger vision. Thus it resulted in practices of undertaking plantation activity in areas, without intense community participation

and this, followed with poor monitoring mechanism and sustained vision of regeneration of forest, failed to produce the required result inspite of the large efforts.

Even in the Management plan of Sunderbans Forest department 2001, there is no intense afforestation programme in the non-forest areas, as with limited funds and human resources they are more focused on conservation activities in the protected area. "*Plantation of fresh water as well as mangrove plants are done in some of the degraded area. (...) Artificial planting had since then been discontinued within the protected area and natural mangroves had covered the areas. Artificial regeneration had however, been taken up on mudflats, streams banks and charlands in adjacent areas outside Reserved forests though at a small scale and has been continuing"* (Government of West Bengal, 2010).

6.3 Anthropogenic contributors

6.3.1 Shrinking of livelihoods and opportunities

Figure 2a. Fisherman ©hellio-vaningen 2b. Woman in a rice field ©hellio-vaningen

The Government has taken intense programme on generation of income through self-help groups and it appears from researches in post-aila period that the dependence on unsustainable use of ecosystems resources has increased .The general condition of life has not improved rather it appears to be more critical with shrinking agricultural options esp post-aila period when the soil was under saline cover and the regular paddy yields decreased , scarcity of freshwater resources adding on to the woes of people. The fish catch has also remarkably reduced and changed with commercial catch decreasing (Mitra et al, 2009). Post-Aila period man-animal conflict increased as there were reported incidents of tiger attacks on human- killing and injuring many, because more and more number of fishermen ventured illegally into core areas for an easy catch. Fish catch has declined considerably in the rivers outside the forests. This again brings forth, the importance of mangroves as breeding nurseries of fishes and finfishes.

Besides in post-Aila, there was a significant migration to other parts of the states and even other states of India in search of menial labour works.

The need of the hour: ***Scaling of afforestation of mangroves and restoration of ecosystem in Sundarbans, engaging community and linking to sustainable business models***

6.3.2 Evolution of the sustainable model

NEWS first tried to manage a small plantation (estimated 20 ha) in Dulki opposite Sajnekhali Wildlife Sanctuary in 2006 under UNDP project with the EDC, during implementation of developing alternative sources of income among poor community in the village. It was very successful and then in two phases NEWS implemented "mangrove plantation programme with community participation" in Amlamethi, Mathurakhand and Sonagaon village for an area of 80 (estimated) ha and 60 (estimated) ha with financial support from British High Commission and ABN –AMRO Bank resp in the period 2007-2009.Nurseries were maintained by villagers, training were imparted, intense campaigns were raised. It really showed a new path of community model afforestation programme. Simultaneously livelihood promotional activities were undertaken in the adjacent villages to create a sustainable 'care and protection' initiative for the mangroves .However , a sizeable portion of the plantation was lost when relief operations took place immediately after cyclone Aila and the two year old plants got trampled and ruined. However in Mathurakhand adjacent mudflats, the plantation has grown into thick forest.

7. Technical approach

Keeping in mind the fragility of this vibrant ecosystem and the threats and challenges, this initiative from Livelihoods, with NEWS as the implementing partner, addresses all the gaps and issues that we faced during our early programmes and develops a scientific approach towards a sustainable model of restoration of mangrove and allied ecosystem in Sunderbans.

7.1 Selection of sites

Science in practice: The accretion and erosion patterns along with a bathymetric figure of the rivers were considered and primary selection of plots were done. It was then analysed with landsat images of 1990 to check for existing vegetation. It meant qualifying the requisite CDM standards for large scale methodology for registration as a carbon project in UNFCCC. The socio-economic condition of the communities living adjacent to charlands or mudflats were also

considered as this will mean an immediate boosting of the economy at the primary household level by engaging them in nurseries, providing training, making jute bags, taking part in plantation etc. The existing modes of Self-Help groups were taken into consideration for organizing them especially women.

The sites were on 'charlands' i.e. islands that emerged in the siltation process and also narrow but continuous patches along the mudflats that acted as 'bio-shield stretches'.

Figure 3a. Replanting ©hellio-vaningen 3b. Watering plantations ©hellio-vaningen

7.2 Species selection and plantation techniques

The Important Values Index (IVI) indicates the structural importance of a species within a stand of mixed species. It is calculated by summing up of the relative percentages of basal area, density and frequency, each weighed equally for each species, relatively to the dimensions for the entire stand.

Therefore, **Important Value of a species = relative density + relative dominance + relative frequency IVI** study undertaken in BALLY ISLAND OF Bidya raimongol zone.

Table 8. Important values index for different species

SPECIES	IVI
Avicennia marina	129.5
Avicennia alba	128.8
Avicennia officinalis	116.6

Important Value Index parameters were calculated on the basis of surveys of the existing vegetation on the selected mudflats and the predominant species were valued. Besides the project being in a multi species scenario, other species were also selected as per the slope of the mudflats.

The propagule collection is never easy. From mid-February the seedlings of *Rhizophora* sp first starts coming followed by *Excoecaria* sp in Late June , *Avicennia Marina* in June-July , *Bruguiera sp* in July-August , *Aegiceras sp* in July-August , *Avicennia Alba* from August till October , *Sonneretia sp* in September. Although the pattern varies with the monsoonal onset but the arrival of seedlings more or less has the following course. The phenology pattern is also part of the monitoring process.

Table 9

SAPLINGS PLAN : NURSERY 2011-2012			
ZONE	SITE	SAPLING	JUTE BAG
Bidya Raimongol	jyotishpur	110000	100000
Bidya Raimongol	Balli	140000	
Bidya Raimongol	Pearatolla	100000	
Matla	Nikarighata	100000	
Matla	Kanthalberia	100000	
Matla	Purandar	105000	100000
Sagar	Patibonia	600000	200000
Sagar	Rudranagar	500000	200000
Sagar	Ramkar Char	500000	200000
Sagar	Muriganga II	200000	
Sagar	Muriganga I	100000	
Saptamukhani-Thakuran	Sridharnagar	200000	
Saptamukhani-Thakuran	Sitarampur	200000	
Saptamukhani-Thakuran	Upendranagar	150000	100000
	TOTAL	3105000	900000

The *avicennia sp* is quite common and for all other species , the seeds that drifted along with the tidal waters into the village sides were collected by the community and plantation took place by direct seed rowing (*avicennia* and in some cases *bruguiera*) . For the other species, they are maintained through nurseries. However *avicennia* is also maintained in nurseries as the mortality for direct seeds plantation happened to be almost 48-52% .In case of plantation through nursery raised saplings, the mortality rate was calculated to be 75-80%.

The cost of nursery raised saplings is higher. For a cost-effective model, the plantation was done in the ratio of 30% saplings and 70 % direct seed plantation.

It is beyond doubt that if jute bags are used in nurseries, it is a more eco-friendly viable option. The jute bag degrades naturally and mixes with the mud, also adds nutrients and strengthens the adhesion capacities, if the sapling is placed in

the pits with the jute bags. It also helps reduce the threading away of fragile roots during transplantation time from 'pots to pits'. In polypack pots the polythene has to be torn off very carefully and there is always chances of damage of the roots, which are crucial for the proper growth in the initial stage. A simple table chart of root-shoot ratio shows that the mangroves especially avicennia sends clusters of roots, appreciable larger than the shoot in the first three months to stabilize themselves in the tidal wave energy system. So, jute bags: polypackets ratio is 25: 75 among the nurseries.

7.3 Plantation Establishment Techniques

After identifying the planting site and species, the socio and biophysical attributes, it was necessary to determine what needs to be done to prepare the site , as it often needed some preparation prior to planting. This may include clearing the areas of fern or other weeds (brush), removing standing dead wood that will shade out the area and removing debris. Also evaluating the planting block size, a sharp eye is kept out for areas where people or boats commonly transit. This information contributes to developing a sketch map of the area.

7.4 Planting organization, area and spacing

Several organizational ideas can be used in planting.

7.4.1 Inverted V shape

An inverted V shape spacing with the point of the V facing the sea deflect wave impact. Spacing should be less than 0.5 meter. Planting may be done in triangle formation with one of the corners of the triangle pointing seaward. Spacing in between triangles is less than 1 meter and cluster planting may also be done. It is done to act as a wave break. To maximize survival, spacing is made much closer (25x25 centimeters). After 2-3 years, when the clusters are fully established, the gaps can be created for proper growth through a wise management. Even temporary inverted V-shaped bamboo structures were put up to dissipate the wave energy.

This is tried in Rudranagar area of Sagar, where the wind-wave energy from the South-western part of Sagar pounced heavily on the Western part of the island and plantation by other agencies failed several times due to lack of proper technical approach.

Santi Ranjan Mondal, the Upo-Pradhan of the Ramkar Panchayat Samiti of the Sagar Island iterates: "I have seen that for last four years social forestry tried plantation several times here but they failed. It is NEWS who could sustain the plantation for more than a year."

7.4.2 Strip Planting

The same principle applied in strip planting. Strips (10 or 20x100 or 150 meters) are established at very close spacing to withstand strong waves. Once established, the open areas between strips and shoreline may now be planted at a wider spacing, like in most of the planted sites of Bidya-raimongol, Saptamukhani-Thakuran and Matla.

In some areas where the upper shoreline has become stiff and unsuitable for plantation, the strip plantation is done with *avicennia* species in lower shoreline and silt thus trapped in the upper shoreline made it ripe for plantation in the coming year.

7.4.3 Seedling density or spacing

Channels of size 1 ft wide & 1 ft deep and 5 ft apart parallel to river flow is dug in the month of July for collection of silt to enable the seeds/plants to get new alluvium , after one and a half month of which the mudflats became ideal for plantation of seedlings.

The areas being island chars and lowlying, channel dug management is not considered. In the initial stage plantation is directed to obtain a plantation density of 4000 per ha. Considering the mortality, this spacing will produce a plantation of density 2500-3000 plants per ha, an ideal for optimizing carbon sequestration rate.

A common practice responsible for high mortality rates in mangrove planting is the sowing of propagules more than half their length in the soil. This is done because people believed that waves would dislodge the propagules, if planted too shallow. Propagules show lenticels that exchange air. Burying propagules too deep will render the lenticels useless, carrying a slow death to plants. Generally propagules are sown one third of their length in firm substrate and one half of the length in soft substrate.

7.5 Map

The boundary of the entire plantation site was mapped by walking with the geo-positioning satellite (gps) around the plantation area. It was then interpreted in a google earth map and kml files generated. It is a tedious task to delineate the boundaries in difficult muddy terrain, but it is crucial for the area management for a CDM project. This technique of plantation area management is used in mass scale for the first time in Sunderbans and will definitely set a role model to create transparency and avoid duplication and overlapping of plantation sites. This map forms the backbone of the project plan as any referencing with respect to monitoring can be done with this plan map.

7.6 Care and Maintenance of Plantation

Like any new borne, the first 2 years after the establishment are probably the most instance phase of care of plantation. Generally, from the 3rd through the 4th year the level of the care is somewhat less, when disease spread should be checked.

A typical monitoring structure
Zone: Saptamukhi-Thakuran
Name of the Species: *Avicennia alba*
Site: Sitarampur
Sonneratia griffithi
Area –134 ha

Table 10

SL. NO.	QUADRATE LOCATION	NO. OF PLANTS/ 100 SQ. MT.	HEIGHT OF THE PLANT (IN CM)	REMARKS
1	21040'59.26"N, 88022'52.34"E	44	12	Proximal Zone
2	21040'62.50"N, 88022'54.46"E	43	14	,,
3	21040'62.14"N, 88022'55.24"E	42	15	,,
4	21040'63.55"N, 88022'56.60"E	42	16	,,
5	21040'64.10"N, 88022'56.87"E	41	15	,,
6	21040'62.3"N, 88022'68.6"E	43	14	,,
7	21040'66.0"N, 88022'69.6"E	42	14	,,
8	21040'67.8"N, 88022'71.1"E	62	16	,,
9	21040'63.4"N, 88022'69.8"E	41	15	,,
10	21040'64.2"N, 88022'69.9"E	42	15	,,
11	21040'64.6"N, 88022'69.2"E	43	14	Distal Zone
12	21040'64.8"N, 88022'69.3"E	44	13	,,
13	21040'65.2"N, 88022'69.4"E	42	12	,,
14	21040'65.9"N, 88022'69.5"E	43	15	,,
15	21040'66.3"N, 88022'70.0"E	55	16	,,
16	21040'66.6"N, 88022'70.4"E	57	17	,,
17	21040'67.1"N, 88022'70.60"E	60	17	,,
18	2104067.3"N, 88022'70.8"E	60	18	,,
19	21040'67.5"N, 88022'70.85"E	61	17	,,
20	21040'67.7"N, 88022'71.0"E	62	18	,,
TOTAL		969	303	

Average number of plant/100 sq.mt: 48.45 Average number of plants/1ha (10,000 sq. km.) = 4845
Average height of the plant (in cm): 15.15 cm Age of the plants – 5 months

The 6th through the 15th years sees a period of relatively low maintenance.

The 16th through 19th are typically on lower maintenance. By the 20th year possibly the growth is over.

7.7 Removal of branches and other pests, uprooting and replacements of sick or dead plants

Regular visits especially at low tides and intense guarding of the area with community mobilization is an integral part of the maintenance process. Checks should be made so that if a large number of green algae floats into the area, regular visit will be able to remove it before it can do much damage. Other debris that might adversely affect the seedlings include pieces of driftwood, fishing nets and other heavy naturals or excess silt deposition that can knock over the seedlings or damage them.

7.7.1 Common threats

1. Encrusting organizes like barnacles - The shells must be removed by hand once the organism is carefully scrapped off and simple throwing in water will dispose them off as they cannot attach again.
2. Insects and moth larvae eating leaves or damaging roots - These organisms are much easier to remove than barnacles. It should be plucked from the leaves, trunks and branches of the seedlings, placed in a bag and removed from shore for disposal, simply throwing it in the water may allow them to reach another tree.
3. Dead or dying plants - Dead or dying trees should be quickly removed from the area. If seedlings are dying in large numbers, it is important to determine why?
4. Plants entangled in green algae or other debris- to be removed immediately manually.

7.7.2 Natural threats

Hailstorms can damage the axil part of a 2-3 year growing tree and eventually the plant dies. Excessive siltation covers up the lenticels of newly born plants which fail to breathe and die. The southwest winds in the spring time many a times take away lot of deposited silt and the *avicennia* on the lower shoreline suffers.

Table 11. Community participation: a glimpse

WOMEN IN NURSERIES -2010 TO 2012			
ZONE	SITE	No of Self-help groups worked in nurseries	Total no of women
Bidya Raimongol	BALI	16 GROUPS	180
Bidya Raimongol	AMLAMETHI (WEST)	17 GROUP	248
Bidya Raimongol	AMLAMETHI (EAST)	16 GROUPS	440
Bidya Raimongol	RAMCHANDRAKHALI	18 GROUPS	200
Matla	KATHALBERIA	11 GROUPS	165
Matla	NIKARIGHATA	20 GROUPS	200
Matla	JOTISHPUR	35 GROUP	350
Matla	PURANDER AND BHARATGARH	30 GROUPS	300
Matla	KAIKHALI	13 groups	150
Matla	GORANKATHI	16 GROUPS	200
Matla	MERIGANJ 2	7 GROUPS	100
Saptamukhani-Thakuran	SITARAMPUR	35 GROUPS	420
Sagar	SAGAR	57 GROUPS	684
Saptamukhani-Thakuran	UPENDRANAGAR AND SRIDHARNAGAR	16 GROUPS	240
			3877

7.7.3 Anthropogenic threats

Prawn seed collection, grazing of cows, goats and irregular fishing and boating activity destroys the newly-sprouted plants. Support to the distressed community with regards to livelihood options reduces the vulnerability of the prawn seed collectors who are discouraged to go for this income option. Supply of fodder grasses that are easily and quickly grown in small plots in homestead , utility of stall feeding of cows and campaigns among local people , fishing folk about the importance of mangrove regeneration are carried out .This enables community participation and mobilization which are key for the success of the project.

Thus, to our experience the plantation process of mangroves in Sunderbans in the first two to three years is never a steady graph and continuous mending, re-planting is required to stabilize it.

In the process the community especially the women group is not only economically benefited but they learnt the typicality of mangroves, their adaptive nature and also the technicality of their rearing and maintenance. Besides it also gives them a sense of pride bearing the onus of a socially important work.

7.7.4 Partnerships at the highest level

Partnerships at key level were maintained with Institute of Environmental Studies and Wetland Management (IESWM), Kolkata a unit of Department of Environment, Govt of West Bengal and nodal actor of the Integrated Coastal Zone Management (ICZM) project of Govt of India. The site selection, CDM eligibility and bathymetric data were analysed by their Senior Geologist cum Remote sensing specialist. All the trainings of area delineation at community level were provided by Unique-Landuse, a forestry support initiative.

Panchayats are the institutions of the Government at local levels who are integrated with the project at local decision-making stage. In the process, they are also accustomed with the scientific approach of mangrove afforestation programmes. Local Panchayats involved in the project are 43 till 2012 plantation.

Sunderban Biosphere Reserve and Wildlife Wing under Department of Forests, Government of West Bengal are in close association and updated about the project implementation.

The Joint Director, Botanical Survey of India – the lead centre for Sunderbans for Government of India is advisor to the project on species selection, establishing site plantation techniques, building monitoring parameters.

Lack of proper data availability, even of the Department of Forests, Government of West Bengal shows the lacunae in monitoring of mangroves planted, year after year. The monitoring mechanism over ten to twenty years of time are itself going to produce good scientific data that can act as base papers for further research activities . Livelihoods, who earns the carbon credits are the investors for the project. If the project chooses CDM standards, then carbon credits should correspond to 500,000 tonnes of CO^2 .If the project generates additional carbon credits, 50% of these additional carbon credits shall be transferred to Livelihoods, and the remaining 50% shall be transferred to the community. Carbon finance, in its folded design encompasses a sustainable business model for meeting biodiversity needs especially in afforestation sectors.

Table 12

AGENCY	YEAR	AREA	PLANTATION BUDGET	
TSRD	2007-08	541	676 MAN DAYS	http://www.tsrd.org/dnd.php?dndfile=pdf/AnnualReport.pdf
TSRD	2010-11	495		http://www.tsrd.org/dnd.php?dndfile=pdf/annualreport10-11.pdf
*SDB/ SOCIAL FORESTRY	2007-08		18000000	http://www.sadepartmentwb.org/Annual_Plan07-08_SocialForestry.htm
NEWS	2009-11	1400	12569161	Annual Report
*These plantation include both forest & non forest land				TSRD – Tagore Society for Rural Development is the biggest agency working in social development sector in Sundarbans

5. The Future

Figure 4. Women portraits ©hellio-vaningen

To extend this business model further into forest and wetland conservation projects, the REDD+ is a good mechanism that gives enough scope not only to restore degraded lands but also prevent further degradation of forested lands. However the investors should believe in the "cap and trade policy" for reducing greenhouse gas emissions for our planet to exist, thrive and grow.

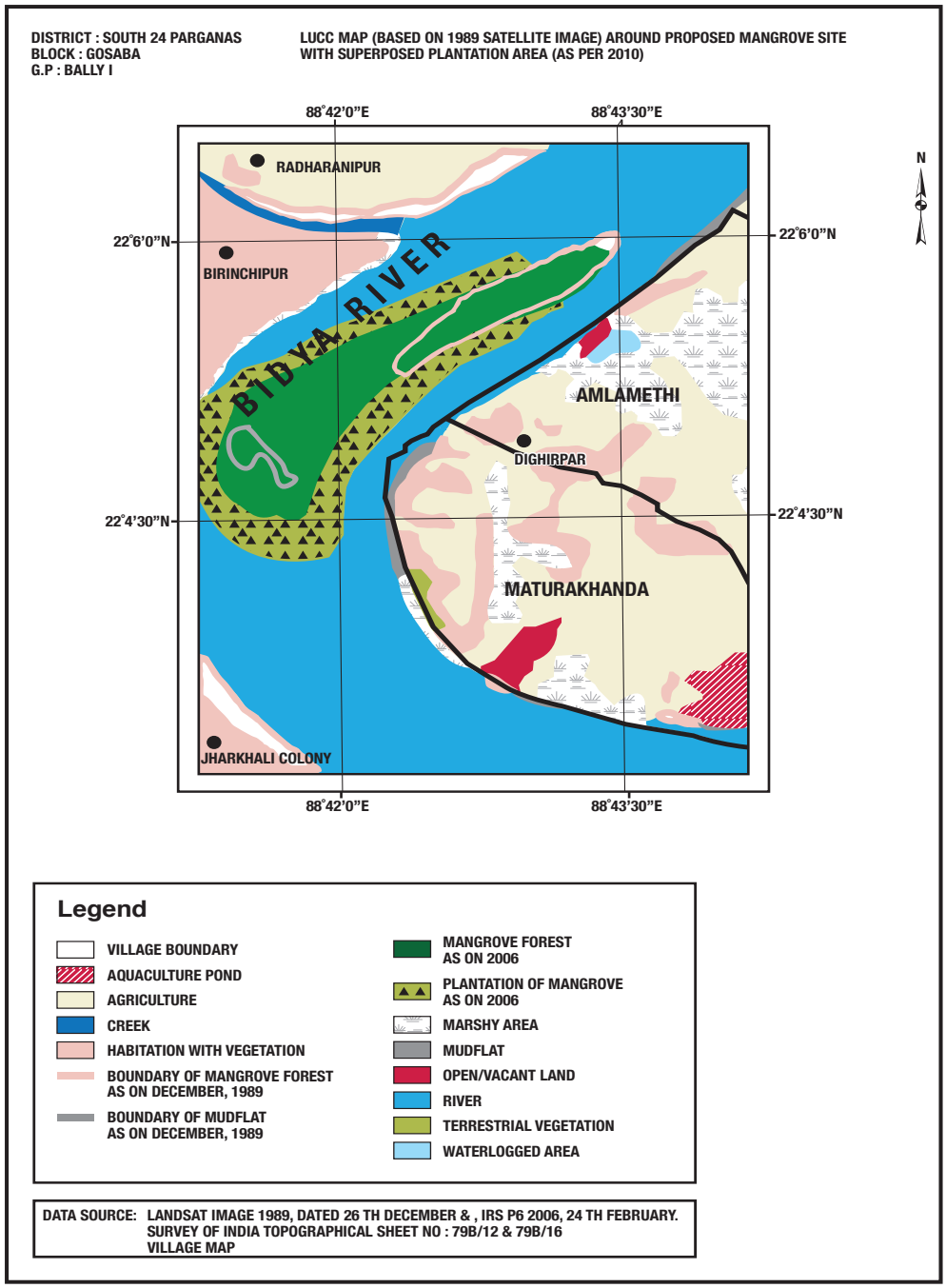

Figure 5. CDM eligibility maps used in the initial stage for Bali charland in Bidya-Raimongol zone

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