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Abstract of Project proposal

Title: Protection of Tsunami Affected Coastal Areas by Establishing Bioshields through people's participation

Objectives

1. To establish bioshields along coastal areas belonging to private land owners at Ganeshamangalam and Munakkakadavu beach with single and multi-species through people's participation

2. To evaluate the performance of bioshields

3. To estimate carbon sequestration potential of single and multispecies bio-shields

Investigators

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Duration: September 2007 to June 2010

Budget: Rs. **1,07,64,350/-**

Funded by: Tsunami Rehabilitation Programme, Disaster Management Division, Government of Kerala

Abstract

The occurrence of a tsunami on 26th December 2004 which affected the coastal areas of Kerala was the first of its kind that affected the property and life of people. Different projects for rehabilitation of the affected people and mitigation measures to reduce the ill effects of tsunami were launched in coastal areas by the Disaster Management Division, Government of Kerala. One of the project under mitigation measures was the establishment of bioshield with suitable species. It was undertaken by Kerala State Council for Science, Technology and Environment (KSCSTE) and Kerala Forest Research Institute implemented the project.

A bio-shield consisting of 30 Km length of varying width was established in the coastal areas of Thrissur District. Ten Panchayaths starting from Kadappuram to Eriyad participated in the programme. Mainly seedlings of *Casuarina equisetifolia* which is known as one of the suitable species in coastal areas were used for planting. An experimental plot with 14 species was planted for screening the suitability of other broad leaved species for bio-shield. Of the 14 species planted five species that recorded higher survival rate (above 50%) were *Terminalia catappa* (80), *Dendrocalamus strictus* (100), *Bambusa vulgaris* (80), *Samadera indica* (68) and *Terminalia tomentosa* (52). Four species were not able to survive (*Artocarpus hirsutus*, *Swietenia mahogany*, *Terminalia bellerica* and *Syzyygium jambos).* The project was implemented in association with the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) of the Panchayaths. KFRI provided seedlings, soil for filling the pits, stakes, nursery implements, sources for water and technical know-how while the Panchayaths undertook planting, maintenance and watering.

The major threats during the establishment phase of the bioshield can be grouped into two categories – biotic and natural. The biotic factors (man made reasons)included damages due to the construction of sea wall, removal of planted seedlings by the land owners etc. while the natural factors were inundation with salt water, waterlogging, deposit/removal of sand from the planted areas etc. A shift in the planting season from July-August to September October reduced the frequency of inundation with salt water and waterlogging. Awareness programmes organized in the Panchayaths and involvement of Panchayaths in the programme reduced the damages due to human interference. Nothing could be done with natural calamities like sand erosion, damage to sea wall, etc.

The soil samples were analysed from two Panchayaths. Electrical conductivity, salinity and total dissolved salt were highest in samples collected adjacent and decreased with distance from sea. This indicates that congenial conditions for growth of plants are at a distance from sea. However the EC is relatively higher when compared with normal conditions. Hence only salt tolerant species could be grown. Since the plantations are less than two years old, limited analysis of plant samples could not provide any meaning ful information regarding carbon sequestration potential of the species used in this study.

A long term study is required in the coastal areas of Kerala to know the impact of different mitigation measures taken such as construction of sea wall, establishment of bioshield with single/multiple species and a combination of sea wall and bio-shield.

Introduction

Tsunamis (harbor waves) are defined as a series of waves of extremely long wavelength and long period generated in a body of water by an impulsive disturbance such as underwater earthquake, submarine landslide, volcanic activity etc. and that vertically displace the water (Clague et al, 2003). When tsunami reaches a coast, it may appear as a rapidly rising or falling tide or a series of breaking waves. When tsunami reaches the shore, part of the tsunami wave is reflected offshore, but most of it slows, increases in height runs up towards the land with tremendous energy and causes massive destruction of the coast and in the hinterlands (Tanaka, 2009).

The Tsunami, which struck on the Indian Ocean on 26th December 2004, was first experience in terms of the loss of human life and damage to property in coastal areas of Kerala State. It affected the coastal belt of Thiruvananthapuram, Kollam, Alappuzha, Eranakulam and Thrissur Districts. Scientific investigations have been carried out by different agencies for understanding the impact of Tsunami on various aspects such as marine ecosystem, fisheries, water quality, soil status and vegetation including mangroves etc. The information has been collated and synthesized by Kerala State Council for Science Technology and Environment (KSCSTE, 2006). Though it is difficult to predict the occurrence of tsunami, post tsunami studies are helpful in predicting future tsunami impacts in coastal areas and initiate necessary mitigation measures.

The occurrence of tsunami has evoked a serious concern among public especially the residents of coastal areas, people's representatives from coastal zone, scientists, policy makers and media for protection of coastal areas. Different mitigation measures have been initiated immediately with the support of Central and State Governments. In general, tsunami mitigation techniques are categorized into two - artificial methods (hard solutions like construction of sea wall) and natural methods (soft solutions utilizing a natural buffer zone of coastal vegetation (Plate 1), sand dunes or coral reefs (Tanaka, 2009). Since the costs for artificial methods are very high and full protection is not guaranteed, focus is also made on the effect of soft solutions like coastal vegetation on reducing the hazards and to maintain the vegetation as a natural disaster buffer zone. Coastal vegetation is mainly of two types – mangroves and non-mangroves. Observations on damage during recent tsunami in coastal areas of Tamil Nadu (Pichavaram) indicated that mangrove wetlands and shelter belt plantations such as *Casuarinas* and palm trees and other thick coastal vegetation has a positive effect in terms of loss of lives and properties in the villages which are behind these areas. This may be due to the friction created by these trees in rows reduced the force of waves (Selvam et al, 2005).

Mangroves are woody trees and shrubs that grow normally in estuarine (places where river and seawater mixes). Mangrove wetlands consisting of small tidal creeks, channels and water bodies are characteristic features of

the tropical coastal areas. Along with mitigating effects of cyclones and tsunami, mangroves also provide suitable environment for hatching fishes, crabs, mollusks etc, increase their productivity with enhanced inorganic and inorganic nutrients and provide a habitat for migratory birds.

Non-mangrove bio-shield along the coastal zone is popularly known as shelterbelts (bioshield) which are strips of vegetation composed of trees and shrubs grown along the coasts to protect coastal areas from high velocity of winds, salt sprays and natural hazards like cyclones and tsunami. Shelter belts have positive effect on animals, crops and physical structures. About 15 species (1. *Anacardium occidentale, 2. Azadirachta indica, 3 Bambusa bambos,4. Bixa orellina, 5. Borassus flabellifer, 6. Cassia fistula, 7. Casuarina equisetifolia, 8. Clerodendron serratum, 9. Cocos nucifera, 10. Hibiscus tiliaceus, 11.Pongamia pinnata, 12.Salvadora persica,13. Sapindus emarginatus, 14. Thespesia populnoides* and 15. *Vitex negundo*) have been suggested for establishment of shelterbelt (Selvam et al, 2005).

With a view of providing relief to the affected people of coastal areas of Kerala State, The Disaster Management Department, Government of Kerala, has launched several short and long-term projects. The short-term projects mainly consist of building construction for rehabilitation, sanitation, water supply measures, improvement of livelihood, etc. The long-term projects mainly focus on mitigation measures such as sea wall construction and establishment of shelterbelt. KSCSTE has been entrusted with the responsibility of establishment of shelterbelt (bio-shield), plantations in coastal areas of Thrissur District. The project entitled "**Protection of Tsunami Affected Coastal Areas by establishing Bio-shield through people's participation"** which was implemented by the Kerala Forest Research Institute, Peechi had the following objectives.

1. To establish bio-shields along coastal areas belonging to private land owners with single and multi-species through people's participation.

2. To evaluate the performance of bio-shields.

3. To estimate carbon sequestration potential of single and multi-species bio-shields.

A shelter belt of 30 Km length with 10 to 20 rows (as per the availability of land between sea and houses) has been planned through the coastal belt of 10 Panchayaths. Awareness programmes were organized to increase the knowledge of public about tsunami and the need to protect coastal vegetation. During first year the project was implemented by KFRI and from second year onwards it was done in association with the Mahatma Gandhi Rural Employment Guarantee Scheme (MGNREGS) of Block and Grama Panchayaths.

Plate 1. 1. Building damaged due to waves 2. A part of the damaged sea wall 3. A view of the mangrove vegetation 4. Shelter belt with *Casuarina equisetifolia*

Materials and Methods

Species, sources of planting material and nursery sites

Planting materials of seven species were raised in six different nursery sites during 2008-2010. Of these, five species were raised from seeds/fruits. The weight of seeds/fruits/kg and pre-treatment are given in Table 1.

Table 1. Name of species for which seeds/fruits were used for seedling production, number of seeds/fruits per kg and pre-treatments.

No	Name of species	No of seeds/fruits/kg and pretreatment
1	*C. equisetifolia*	Seeds/750000 [OS]
2	*S. macrophylla*	Seeds/1600-2300 [DW]
3	*C. inophyllum*	Fruits/137-212 [RS]
4	*T. bellirica*	Fruits/97-176 [GS]
5	*T. arjuna*	Fruits/176-375 [OS]
6	*A. marmelos*	Seeds/4800-7200 [OS]

OS – Overnight soaking; DW – Dewinged;
RS – Remove seed coat before sowing;
GS – Germinated seeds collected from the forest floor.

Planting materials of two bamboo species were raised by vegetative propagation techniques. The source of seeds/cuttings, nursery locations and year of production are given in Table 2.

Table 2. The sources of seeds/cuttings, location of nursery and year of production.

Sl No.	Name of Species	Sources of Seed/Cutting	Nursery Site
Through seeds			
1	*Casuarina equisetifolia J.R. &G.Forst.* (Kattadi, Choolamaram)	Four sources KFRI seed centre; Plantation of KFD Valappad; SPA of IFGTB Puduchery; SPA of IFGTB SSO, Pondichery Univ Campus, Puduchery	Chendrappinni [1] Kandassankadavu [1] Peringottukara [2 & 3] Kadappuram [2 & 3] Mathilakam [2 & 3] Engandiyoor [3]
2	*Swietenia macrophylla King* (Mahogany)	Seed centre, KFRI, Peechi, Thrissur	Chendrappinni [1] Kandassankadavu [1] Peringottukara [2]
3	*Calophyllum inophyllum L.* (Punna)	Local	Peringottukara [2] Kadappuram [2]

4	*Terminalia bellerica (Gaertn.) Roxb.* (Thanni)	KFRI Campus, Peechi	Peringottukara[2]
5	*Aegle marmelos (L.) Corr* (Koovalam)	Vilayannur, Palakkad	Peringottukara [2]
Vegetative propagation			
6	*Bambusa striata Lodd.ex lindl* (yellow bamboo Manjamula)	Two sources KFRI-FRC Velupadam; Homestead, Chittilappilly. Thrissur	Chendrappinni [1] FRC Velupadam [1]
7	*Bambusa vulgaris Schrad.ex J.C.Wendl.* (Green-Pachamula)	KFRI-FRC Velupadam	FRC Velupadam [1]

1 – during the financial year 2008-09; 2 – in 2009-10; 3 – in 2010-11

Nursery technology

***Casuarina equisetifolia*:** The nursery beds were prepared with equal portion of sand, soil and cowdung. Shade was provided with coconut leaves/nursery nets for one week. The nursery beds were mulched with hay till the seeds germinated (Plate 2). After about one month the germinated seedlings were transplanted to polybags (22.5 x 17.5 cm) with a mixture of soil, sand and cowdung (3:1:1) as potting medium (Plate 2). Watering was done twice daily with rose can for mother beds and with hose pipe after transplanting to polybags. Weeding was carried out as per requirement in both mother beds and in polybags. A mild dose of fertilizer was applied one month after potting in liquid form through rose can (urea – 1kg; groundnut cake – 5kg; cowdung – 10 kg diluted with 200ml of water). Some of the seedlings which were infested with Cuscuta sps. were removed

Swietenia macrophylla: Seeds were sown horizontally to a depth of 2 cm in germination in nursery beds containing sand soil cowdung mixture. The seedlings were transferred to polythene bags of 22.5 x 17.5 cm filled with potting mixture containing soil sand cowdung (3:1:1) when they attained 15 cm height. The seedlings were ready for planting 3 months after poly-potting.

Calophyllum inophyllum: The seed coats were removed and the seeds were dibbled in vermiculite or river sand maintained in germination trays. Germinated seeds were pricked out and planted into polythene bags of 22.5 x 17.5 cm filled with potting mixture.

Terminalia bellerica: Germinated seeds were collected from the forest floor of the KFRI main campus at Peechi. The seedlings were planted in polythene

Plate 2. *Casuarina* nursery at Peringottukara. 1. Mother-bed: seeds sown and covered with hay 2. Germinated seeds after one month. 3 & 4 Stages of polypotting. 5. Polypotted seedlings 6. Seedlings one month after poly-potting.

bags of 22.5 x 17.5 cm filled with potting mixture. Six-month-old seedlings were ready for planting.

Aegle marmelos: Fresh seeds were sown in plastic trays filled with vermiculite. The germinated seeds were poly-potted in polythene bags of 20 x 10 cm size filled with potting mixture. The seedlings were ready for field planting after one year, as the growth was slow.

Bambusa striata* and *B. vulgaris*:* Planting stock of *Bambusa striata* (Yellow bamboo, Golden bamboo) and *B. vulgaris* (green variety) were produced by rooting culm and branch cuttings (KFRI, 1999). The mother clumps for collection of cuttings were selected from the healthy clumps growing in FRC campus, Velupadam and homesteads in Chittilappilly. Two-year-old culms (culm is one full bamboo from base to top) were extracted from mother clumps by cutting just above the first node. The leaves and side branches were trimmed without damaging the axillary buds. After shifting the culms to the nursery site, two-noded culm cuttings were prepared (Plate 4). The cuttings were treated with NAA 100 ppm (200 ml of the solution). The treated cuttings were planted horizontally in nursery beds. Profuse sprouting appeared first followed by natural thinning of sprouts retaining one to three dominant healthy sprouts. Slender roots developed within one month and rhizome development took place within three to six months.

Planting

Selection of planting locations: The coastal areas from Kadappuram to Eriyad Grama Panchayaths were examined during September to December 2007 and for the planting operations of first year two Panchayaths - Vadanapilly and Kadappuram with a length of 12 km were selected. During the second year all other Panchayaths in coastal areas of Thrissur District were examined and another 11 panchayaths were also included in the project to meet the target 30 km. Names of Panchayaths included along with coastal length as given from the Panchayath are provided in Table 3.

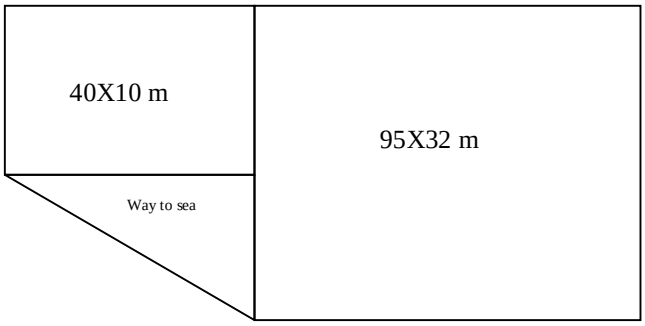
Table 3. Selected Panchayaths along with their coastal length

No.	Name of Panchayath	Coastal length (KM)	No.	Name of Panchayath	Coastal length (KM)
1	Vadanappilly	4.5	8	Edavilangu	2
2	Kadappuram	8	9	Eriyad	1
3	Nattika	3	10	Edathiruthi	0.9
4	Thalikulam	4	11	Perinjanam	1.5
5	Engandiyoor	2	12	Kaipamangalam	3
6	Mathilakam	4	13	Valapad	9
7	S. N. Puram	5	**Total**		**47.9**

Planting operations: The coastal area available between sea and the adjacent road (upto a maximum of 20 m width) was taken leaving about 10 m from the sea for planting *C. equisetifolia*. Spacing between plants and between rows was 1 x 1 m and the pit size was 30 x 30 x 30 cm. Planting was initiated during July – August in Vadanappilly, August - September in Kadappuram Panchayath, during 2008-09 and September to February in 2009-10 in all other Panchayaths. During the first year, all the expenses were met from the TRP funds for planting and from second year onwards the programme was implemented in association with the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) of respective Panchayaths. Technical know-how, planting materials, soil for filling the pits, nursery implements and stakes were provided by KFRI, while planting, protection and watering were done by the respective Panchayaths using MGNREGS. KFRI also helped by installing champ pipes and digging/deepening/cleaning the ponds in the locality for getting sufficient water during summer months.

Mixed bio-shield: An area with a length of 95 and 40 m and a width of 32 and 10 m was taken at Snehatheertam- Snehavanam at Thalikkulam Panchayath. Seedlings of 15 species viz., *Artocarpus hirsutus, Calophyllum inophyllum, Syzygium cumini, Terminalia catappa, Swietenia mahagoni, Dendrocalamus strictus, Bambusa vulgaris, Thespesia populnea, Glyricidia sepium, Terminalia bellirica, Saraca asoca, Samadera indica, Syzgium jambo, Cassia fistula and Casuarina equisetifolia* was established in December 2009 Survival and growth of the plants were recorded after six months.

Fig 1. A Plot diagram of the experimental plot of mixed bio-shield



Enumeration of planted area at Vadanappilly and Kadappuram Panchayaths: Enumeration was carried out in the planted area at Vadanappally and Kadappuram panchayaths to assess the percentage of survival and factors affecting establishment of bio-shield during March-April 2009 (about 6 months after planting). The area was marked in graph sheets and divided into different blocks (20 m x No. of rows planted between sea and road). The base point was *Azhimukham* at Kadappuram Panchayath. The block numbers were marked with paint on the coconut tree/sea wall stone/electric Post. The beginning of the blocks was from north, the right

Plate 3. 1. Moth found on *Casuarina* seedlings 2&3 Seedling affected by semi parasite *Cuscuta* sp.

Plate 4. 1 & 2. Cuttings of bamboo used for propagation. 3. Nursery after two months 4. Seedlings of Teak 5. Mahogany 6. *Terminalia*

hand side was sea and left side was private land facing Panchayath Road. Survival of the bamboo planted along with casuarina was also observed during enumeration. While taking observations, surviving casuarina seedlings were marked as 'X' in graph sheet, damaged or dry plants as 'O', surviving bamboo plants as B, coconut trees inside the block as 'C' and electric posts as '□'. There were 76 blocks in Vadanappilly Panchayath and 74 Blocks in Kadappuram Panchayath. The data was tabulated as area in m^2, number of surviving plants/planted, number seedlings damaged-natural/damaged, number of bamboo survived/planted per each block and average was taken.

Soil sampling and analysis: The physio-chemical properties of the experimental plot with C. equisefolia at Vadanappally and Kadappuram panchayath were studied. Soil samples at a distance of 200 x 2 m were collected for 2.6 km at Kadappuram and 4 km distance at Vadanappally Panchayaths. Initially samples at a distance of 600 x 2 m were taken for analysis (73 samples were analyzed from both panchayaths). Since there was not much difference in parameters analyzed, samples at 200 m distance was not taken for analysis. The details of sample numbers taken for analysis are given in Table 4. Conductivity, salinity, total dissolved salts (TDS) and pH were determined by using Electrical Conductivity Meter and pH meter.

Table 4. Details of soil samples analyzed from Kadappuram and Vadanappilly panchayaths.

Kadappuram

Distance in meter/sample no					
0	200	800	1400	2000	2600
2	K_0A	K_3 A	K_6A	K_9 A	K_{12} A
4	K_0B	K_3 B	K_6 B	K_9 B	K_{12} B
6	K_0C	K_3 C	K_6C	K_9C	K_{12}C
8	K_0D	K_3 D	K_6 D	K_9 D	K_{12}D
10	K_0 E	K_3 E	K_6 E	K_9 E	K_{12} E
12	K_0F	K_3 F	K_6F	K_9F	K_{12}F
14	K_0G	K_3 G	K_6G	K_9G	K_{12}G
16	K_0H	K_3 H	K_6H	K_9H	K_{12}H
18	K_0I	K_3 I	K_6I	K_9I	K_{12}I
20	K_0J	K_3 J	K_6J	K_9J	K_4J
22	K_0K	K_3 K	K_6K	K_9K	K_{12}K
24	K_0L	K_3 L	K_6L	K_9L	K_{12}L
26	K_0M	K_3 M	K_6M	K_9M	
28	K_0N	K_3 N	K_6N	K_9N	
30	K_0O	K_3 O	K_6O		
32	K_0P				
Total 73 samples					

Vadanappally - Distance in meter/sample no

meter	200m	800m	1400m	2000m	2600m	3200m	4000m
2	V_0A	V_3 A	V_6A	V_9 A	V_{12} A	$V_{15}A$	$V_{18}A$
4	V_0B	V_3 B	V_6 B	V_9 B	V_{12} B	$V_{15}B$	$V_{18}B$
6	V_0C	V_3 C	V_6C	V_9C	$V_{12}C$	$V_{15}C$	$V_{18}C$
8	V_0D	V_3 D	V_6 D	V_9 D	$V_{12}D$	$V_{15}D$	$V_{18}D$
10	V_0 E	V_3 E	V_6 E	V_9 E	V_{12} E	$V_{15}E$	$V_{18}E$
12	V_0F	V_3 F	V_6F	V_9F	$V_{12}F$	$V_{15}F$	$V_{18}F$
14	V_0G	V_3 G	V_6G	V_9G	$V_{12}G$	$V_{15}G$	$V_{18}G$
16	V_0H	V_3 H	V_6H	V_9H	$V_{12}H$	$V_{15}H$	$V_{18}H$
18				V_9I	$V_{12}I$	$V_{15}I$	$V_{18}I$
20				V_9J	V_4J	$V_{15}J$	$V_{18}J$
22				V_9K	$V_{12}K$	$V_{15}K$	$V_{18}K$
24					$V_{12}L$	$V_{15}L$	
26						$V_{15}M$	
28						$V_{15}N$	
30						$V_{15}O$	
Total 73 samples							

Plant sampling and analysis: Three plants each of *Casuarina equisetifolia* were uprooted from Vadanappilly and Kadappuram Panchayaths and were separated into root, shoot and needles. The fresh weight of each part was taken separately and the samples were dried to constant weight at a temperature of 70^{o}C to record dry weight. For estimation of nitrogen and potassium, samples were powered and digested using hydrogen peroxide (10 ml) and sulphuric acid (10 ml). Nitrogen and potassium were analysed using standard methods. The biomass of the different plant parts like root, shoot and leaf were also determined.

Results

Awareness programmes

Interaction meeting with people: An awareness programme namely "Tsunami Rehabilitation Programme: Interaction with people" was organized at Kadijumma Memmorial School on 21st May 2008 (Plate 5). Sri. TN Prathapan MLA inaugurated the meeting while Sri. P. V. Raveendran Master, President, Vadanappilly Panchayath presided over the function. Dr. R. Gnanaharan, Director, KFRI welcomed the participants. Dr. M. Balagopalan, Principal Investigator of the project provided information about the objectives and the activities planned under the scheme. Smt. Aripha Ashraf, Vice President, Vadanappilly Grama Panchayath, Smt. Leena Ramanathan, Chairperson, Welfare Standing Committee, Block Panchayath, Thalikulam, Sri. C. B. Sunil Kumar, Chairman, Development (Vikasanam), Sri. K. C. Prasad, Chairman, Welfare (Shemakariyam), Vadanapilly Grama Panchayath, Smt. Remani Anilkumar, Member, Block Panchayath, Thalikulam, Sri. Sheik Hyder Hussain, DFO, Vazhachal, Kerala Forest Department and Sri. K. R. Sabhu, ACF, Social Forestry, Thrissur were the other dignitaries for felicitation. The meeting was concluded with the vote of thanks from Dr. K. K. Seethalakshmi, Scientist, KFRI. The meeting was attended by about 60 inhabitants of the coastal areas (Plate 5).

Stakeholder meetings: Eighteen stakeholder meetings of the staff, people's representatives and Kudumbasree members from the Panchayaths and officials from KFRI in each Panchayath were held (Table 6). The officials from KFRI gave the details of the programme and the support available through Tsunami Rehabilitation Programme. As per the outcome, KFRI agreed to provide the seedlings, stakes, suitable soil for filling the pits, selection of area suitable for planting, alignment, nursery implements, facility for watering and transfer of technical know-how about bio-shield. Panchayaths took the responsibility of pitting, planting and watering under MGNREGS programme.

Table 5 Details of stakeholder meetings

Sl No	Name of the Panchayath/Block	Dates of meeting
1	Thalikulam Block	May 29, October 14, November 5, 2009
2	Vadanappilly	February 2, 2010
3	Nattika	October 06, November 19, 2009
4	Thalikulam	October 25, 2009
5	Engandiyoor	June 5, 2010
6	Perinjanam	January 17, 2010
7	Mathilakam	May 18, 20, June 28, 2010
8	S. N. Puram	February 17, and May 28 2010

9	Edathiruthi	November 17, 2009
10	Perinjanam	January 17, 2010
11	Kadappuram	September 09,2009
12	Valappad	October 06,2009
	Total	17 meetings

Nursery establishment and Seedling production

Nurseries were established in Chendrappinii, Engadiyoour, FRC Velupadam Kadappuram, Mathilakam and Peringottukara for raising bamboo, *Casuarina equisetifolia* and other species. The details of the nurseries established, species, number of seedlings produced are given in Table 6. Seedlings of *Casuarina equisetifolia* was infested with a semi parasite Cuscuta and unidentified insect pest (Plate 3). The tip of plants infested with Cuscuta dried and the plants infested with the insect showed symptoms of wilting. Spraying with an insecticide reduced the incidence of insect pest and removal and destroying of the seedlings infested with cuscuta reduced the damages.

Table 6. Details of nursery sites, species and number of seedlings produced

Sl No.	Nursery Site	Name of Species	No of seedlings produced
1	Chendrappinni [1]	*Swietenia macrophyllum*	5000
2	Chendrappinni[1]	*Bambusa striata (yellow)*	2500
3	Engandiyoor [3]	*Casuarina equisetifolia.*	50000
4	FRC Velupadam[1]	*Bambusa striata (yellow)*	2500
5	FRC Velupadam[1]	*Bambusa vulgaris (Green)*	500
6	Kadappuram [2]	*Casuarina equisetifolia*	101196
7	Kadappuram[2]	*Calophyllum inophyllum*	1000
8	Kadappuram [3]	*Casuarina equisetifolia.*	20000
9	Mathilakam[2]	*Casuarina equisetifolia*	10000
10	Mathilakam[3]	*Casuarina equisetifolia*	35000
11	Peringottukara [2]	*Casuarina equisetifolia.*	70740
12	Peringottukara [2]	*Terminalia bellerica.*	2500
13	Peringottukara [2]	*Aegle marmelose*	200
14	Peringottukara [2]	*Calophyllum inophyllum*	1500
15	Peringottukara [3]	*Casuarina equisetifolia.*	10000

1 – 2008-09; 2- 2009-10; 3- 2010-11

Transport of seedlings

From the main nurseries the polypotted seedlings were transported to planting sites in trucks. The age of seedlings at the time of field planting varied from 4 to 6 months during first year and 6-8 months during second year.

Plate 5. 1. Awareness programme at Kadijumma Memmorial School, Vadanappilly Sri. P. V. Raveendran Master, President, Vadanappilly Grama Panchayath delivering the presidential address. 2. A view of the participants. 3. Inauguration of planting - Dr. E. P. Yesodharan, EVP, KSCSTE welcomes the participants 4. A view of the participants

Planting

Planting sites: The coastal area from Kadappuram to Azhikode was visited by the project team (Drs. M Balagopalan, K.K. Seethalakshmi, Sri. V.P. Raveendran, Mr. Sheik Hyder Hussain, ACF, Social Forestry Trichur). Two Panchayaths, Vadanapilly and Kadappuram were selected during the first year. To complete the target of 30 km another 8 panchayaths were added during second year (Fig 2).

Inauguration of planting: The planting programme was inaugurated on 4th August 2008 by Hon'ble Minister for Agriculture Shri. Mullakkara Retnakaran in the presence of an august gathering of people's representatives, panchayath officials, public, students, teachers and project team. Shri. T. N. Prathapan, MLA presided over the function. A book on *Vriksha paripalana reethikal* was released by Shri. K. V. Abdul Kader, MLA. The programme started with the Welcome address of Dr. E. P. Yesodharan, Executive Vice President, Kerala State Council for Science, Technology and Environment (KSCSTE). Dr. M. Balagopalan, Principal Investigator of the project gave a briefing about the bio-shield and the work planned during the project period in the panchayaths of coastal area (Appendix 2). Sri. Ambadi Venu, President, District Panchayath, Thrissur; Dr. V. K. Baby IAS, District Collector, Thrissur; Smt. Vasantha Maheswaran, President, Block Panchayath, Thalikulam; Shri. P. V. Ravindran Master, President, Grama Panchayath, Vadanappally; Shri K. V. Peethambaran, Chairman, Social Welfare Committee, District Panchayath, Thrissur; Smt. Arifa Ashraf, Vice President, Grama Panchayath, Vadanappally; Smt. Anitha Baburaj, Member, District Panchayath, Thrissur; Smt. Ramani Anilkumar, Block Panchayath, Thalikulam; Shri. C. B. Sunilkumar, Chairman, Development Committee, Grama Panchayath, Vadanappally; Shri. K. C. Prasad, Chairman, Welfare Committee, Grama Panchayath, Vadanappally and Sri. T. S. Kumaran, Ward Member, Grama Panchayath, Vadanappally were among the dignitaries who graced the occasion with felicitations. The programme concluded with the vote of thanks Dr. K. V. Sankaran, Director, KFRI. Planting of *Bambusa vulgaris* and *Casuarina equisetifolia* by the participants was organized during this occasion (Plates 5 & 6).

Planting: Planting was initiated in August 2008 and completed in May 2010. A strip of 30 km was planted mainly with *C. equisetifolia* seedlings in 10 Panchayaths. The width of the strip varied from 5 m to 25 m (rows) based on the availability. The details of planting length in each panchayath is given in Table 7 and Fig 2.

Table 7. List of Panchayaths along with the area planted for bio-shield

Sl. No	Name of Panchayath	Area planted (Km)	Sl No.	Name of Panchayath	Area planted (Km)
1	Vadanappilly	4.0	7	Kadappuram	7.0
2	Nattika	2.5	8	Edathiruthi	1.0
3	Thalikulam	3.5	9	Perinjanam	1.0
4	S.N. Puram	3.0	10	Valapad	5.0
5	Mathilakam	2.0			
6	Edavilangu	1.0	**Total**		**30**

Fig. 2. Coastal area of Thrissur district where bio-shield was established

Mixed Bio-shield

Of the 14 species planted in the experimental plot at Natika, five species that recorded higher survival rate (above 50%) were *T. catappa* (80) *D. strictus* (100) *B. vulgaris* (80) *S. indica* (68) and *T. tomentosa* (52). Four species were not able to survive (*A. hirsutus*, *S. mahogany*, *T. bellerica*, *S. jambos).* The details of species and number of seedlings planted are given in Table 8. This can be considered only as a preliminary screening. Experimental plots need to be established in different locations with large number of seedlings to

Plate 6. 1 & 2. Hon'ble Minister for Agriculture Sri. Mullakkara Retnakaran and 2.Sri. T. N. Prathapan, MLA during the planting of bio-shield 3. Dignitaries assembled during inauguration of planting at Vadanappally Panchayath 4. A view of the planting area and 5. planting operations with people's participation.

Plate 7. 1. A view of area aligned with bamboo stakes for planting 2. Planting process 3. Watering with participation of ladies under MGNREGS 4. Champ pipe installed by KFRI

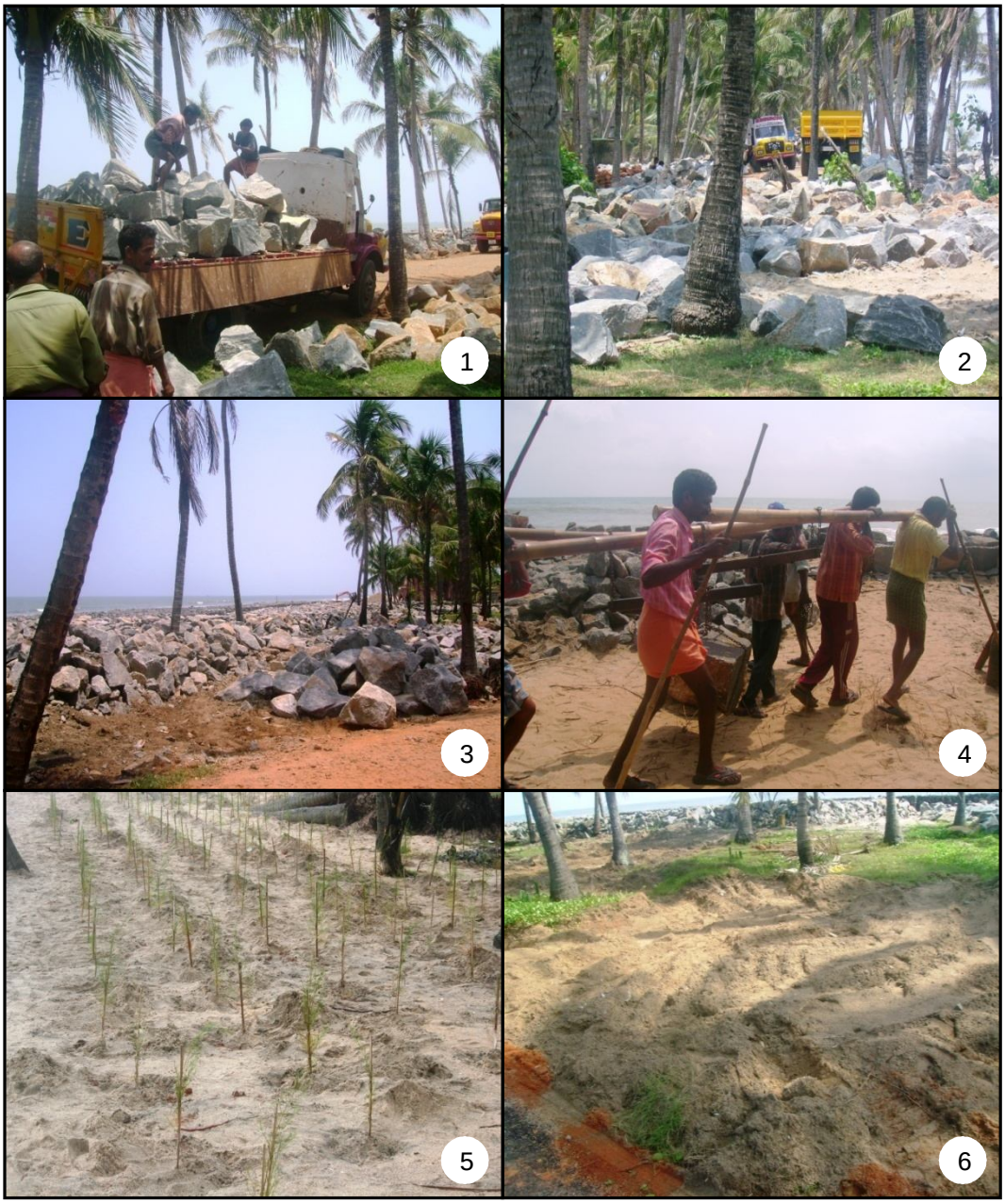


Plate 8. 1-4. Different stages of sea wall construction. 5 & 6 The planted area before and after sea wall construction.

draw a conclusion about different species that can be planted along with *Casuarina* and *Cocos nucifera.*

Table 8. Details of the different species planted in the experimental plot and percentage of survival

S. No.	Name of Species	Surviving/ Planted No.	Percentage of survival
1	*Artocarpus hirsutus*	0/10	0
2	*Calophyllum inophyllum*	4/10	40
3	*Syzygium cumini*	3/10	30
4	*Terminalia catappa*	8/10	80
5	*Swietenia mahagoni*	0/25	0
6	*Dendrocalamus strictus*	50/50	100
7	*Bambusa vulgaris*	20/25	80
8	*Thespesia populnea*	15/150	10
9	*Glyricidium sepium*	38/120	31.66
10	*Terminalia bellirica*	0/25	0
11	*Saraca asoka*	4/10	40
12	*Samadera indica*	17/25	68
13	*Syzygium jambos*	0/10	0
14	*Terminalia tomentosa*	13/25	52

Maintenance

The bio shield after planting was maintained by the respective panchayaths. Due to the association with MGNREGS there was no shortage for labor force. (Plate 7)

Enumeration

Six months after planting enumeration was carried out (during 2008-09 March-April) in planted areas of Vadanappally and Kadappuram Panchayath (Table 9). Of the total 22143 seedlings planted in Kadappuram 9109 plants survived resulting in a success rate of 41.1%. The percentage of damage recorded by natural reasons like rotting due to waterlogging, erosion of the sea shore, deposit of sand, etc was 31% and the damage due to biotic reasons like construction of sea wall, uprooting and breaking of planted seedlings by public, etc was 28%. At Vadanappally out 26187 plants 6336 survived showing a success rate of 24%. Damage due to natural reasons was 56 % and biotic 20%. One of the major reason for manual damage was construction of the sea wall in these area soon after planting (Plate 8). Only 250 bamboo plants survived out of 800 planted indicating that bamboo near the sea shore is not very promising. The leaves showed scorching due to salt breeze.

Table 9. Details of seedlings of *Casuarina* planted percentage of survival after six months.

Name of the Panchayath	Number of seedlings survived/planted	Percentage of survival	Causality (%)	
			Biotic	Natural
Vadanappally	6336/26187	24	20	56
Kadappuram	9109/22143	41	28	31

Soil analysis

Electrical conductivity, salinity and total dissolved salt were highest in samples collected adjacent to and decreased with distance from sea. This indicates that congenial conditions for growth of plants are at a distance from sea. However the EC is relatively higher when compared with normal conditions. Hence only salt tolerant species could be grown

In Vadanappally panchayath, the electrical conductivity values of the coastal soil decreased from the maximum value of 1376 µS/cm near the sea to minimum value of 23.2 µS/cm away from the sea. Salinity of the soil was found decreased, its value ranged from 0.6% to 0.2% along the sea level and its value decreased from 0.6% to 0.1% away from the sea. Values of total dissolved salts was high adjacent to the sea and lowest away from the sea. The maximum value of total dissolved salts was 679 Mg/L and the lowest value 6.72Mg/L. The pH of the Vadanappally range from 8.21 to 6.64. The high pH value 8.21 found near the sea and lowest value of pH 6.64 observed in maximum distance from the sea. In Kadappuram panchayath there was no much difference observed. The electrical conductivity value varied from 1093 µS/cm to 42.2 µS/cm, the salinity changed from 0.54% to 0.03%, total dissolved salt 514 Mg/L to 31.6 Mg/L and the pH varies from 8.3 to 7.14 (Figs. 3-6).

Plant analysis

Total biomass, nitrogen, potassium and moisture content of needles, shoot and root of one-year-old seedlings of *Casuarina equisetifolia* were analysed and the results are given in Table 10.

Table 10. Biomass, Nitrogen, Potassium and Moisture content of different plant parts of one-year -old *Casuarina equisetifolia* seedlings

Location	Plant part	**BM (Gms)**	**Nitrogen (%)**	**Potassium** (ppm)	**MC (%)**
Vadanappilly	Needles	89	3.07	155	13.59
	Shoot	109	1.03	83	12.10
	Root	49	1.27	69.5	9.26
	Total	**247**			
Kadappuram	Needles	83	3	98.5	16.16
	Shoot	81	2.84	112	41.73
	Root	38	1.92	63	11.63
	Total	**202**			

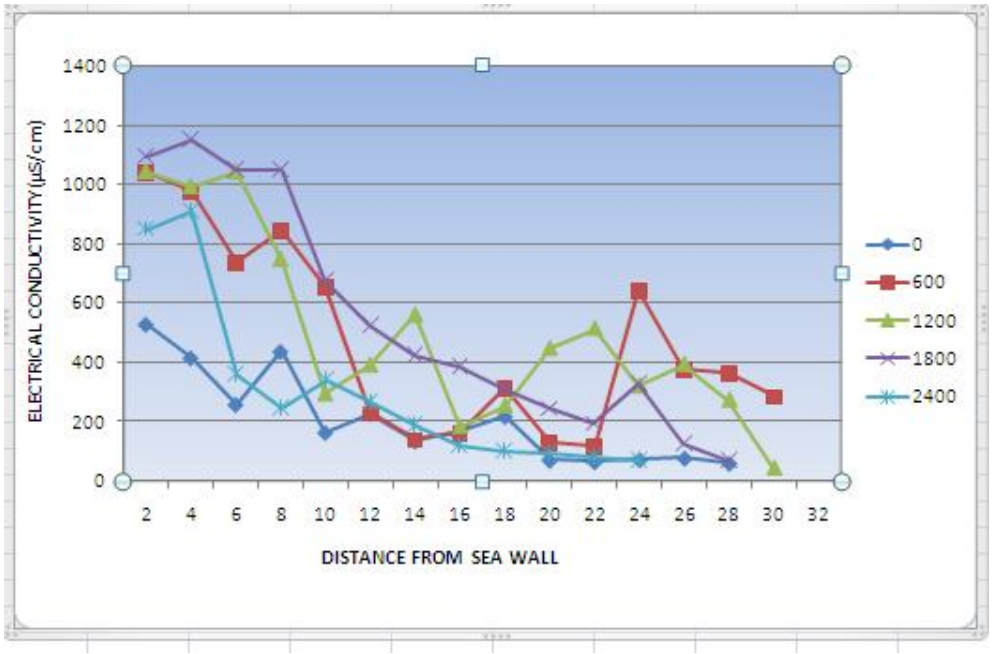
Establishment of bio-shield

The planted areas were inspected at monthly intervals and the performance of bio-shield was assessed. Seedlings plated in 2008-09 showed higher survival and healthy growth than seedlings planted in 2007-08. Most of the biotic reasons like removal of planted seedlings by the landowners and effect of sea wall construction were less during the second year. Watering and maintenance activities were carried out in time and received good attention from local people since it was the activity of respective Panchayaths.

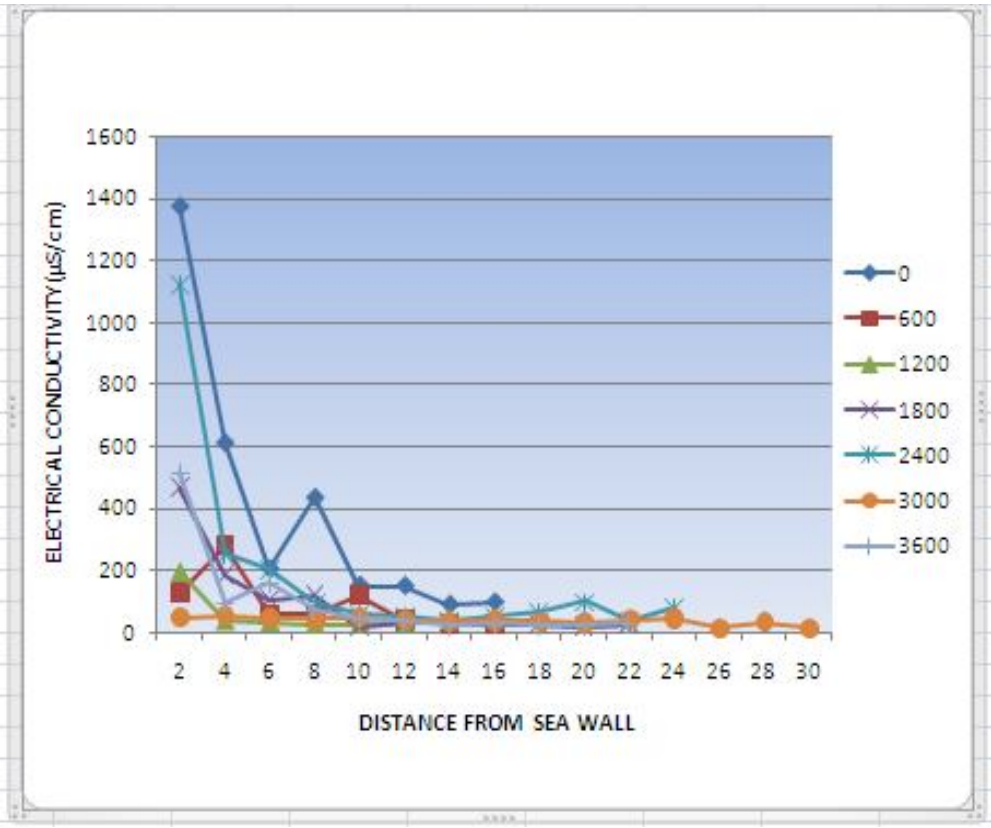
The major problem was erosion and sand deposition over the planted seedlings. Sea erosion was observed in two ways. The first type was caused by breaking of the shore area to a height of about 2-4 m and along the coast; the casuarina seedlings and coconut trees were washed away. Breaking of the seedlings due the pressure of waves was also observed (Plate 8). The second type of erosion happened when the waves rose above the level of sea wall. Along with the back flow of salt water, sand erosion occurred resulting the formation of a narrow canal (Plate 9). The weaker areas of the wall were damaged ultimately resulting in the damage of the sea wall.

Another problem was the deposition of sand to a height of 1-3 m above the planted areas resulting in the complete submersion of seedlings (Plate 9 & 10). In many places the sea carried away the sand and in some other places it was deposited. In both areas parts of the bio-shields were damaged. It was very critical during the first year after establishment of bio-shield.

Fig 3. Electrical conductivity in soils collected from Vadanappilly and Kadappuram Panchayaths

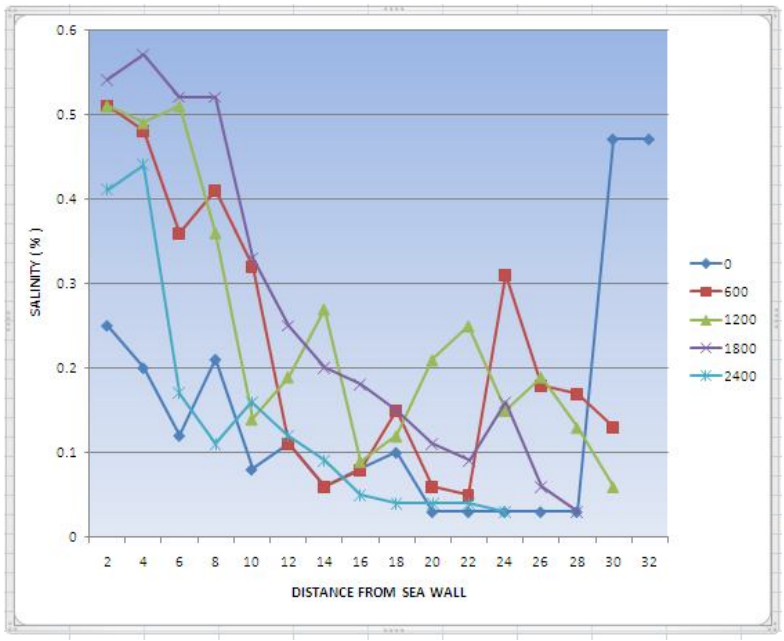


Kadappuram Panchayath

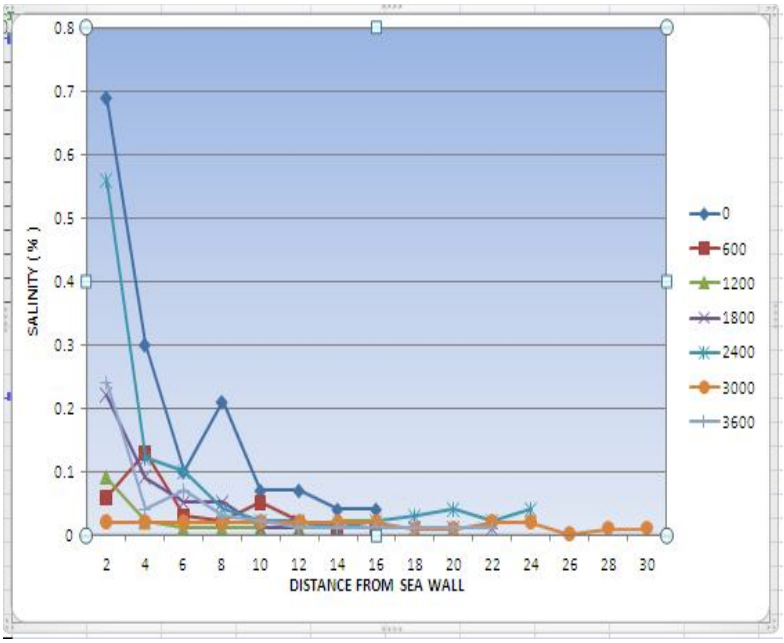


Vadanappilly Panchayath

Fig 4. Salinity in soils collected from Vadanappilly and Kadappuram Panchayaths

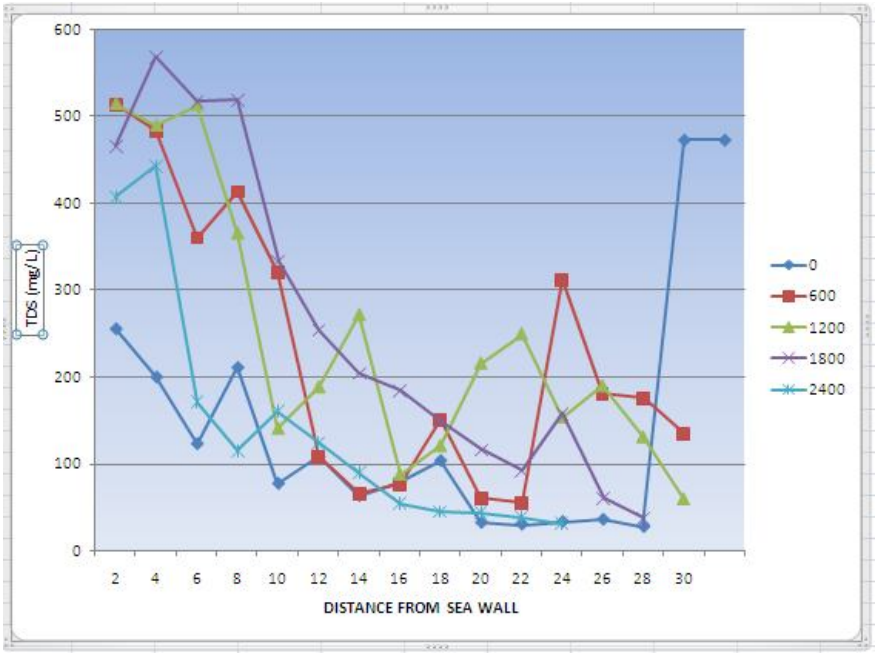


Kadappuram Panchayath

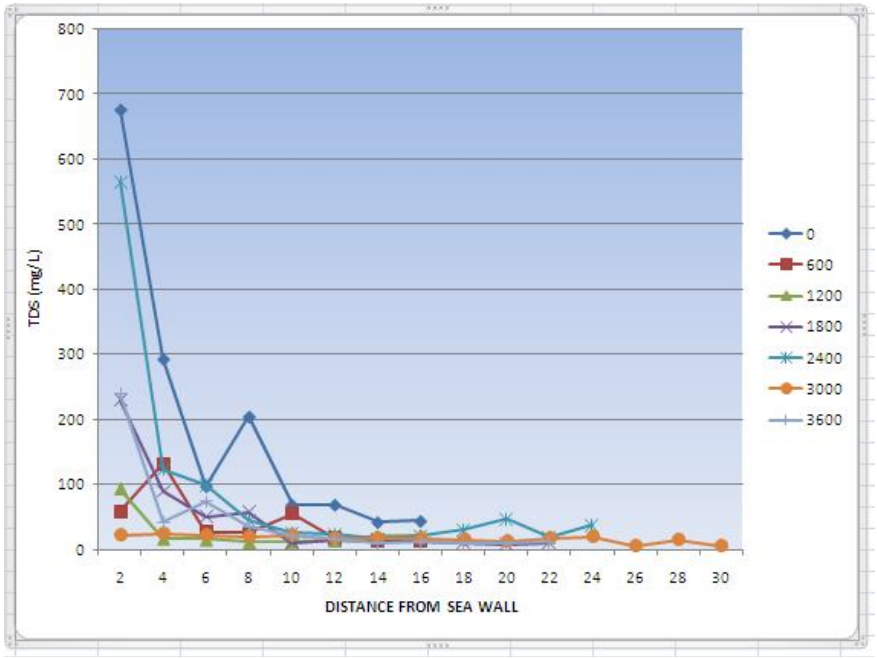


Vadanappilly Panchayath

Fig 5. Total dissolved salt in soils collected from Vadanappilly and Kadappuram Panchayaths

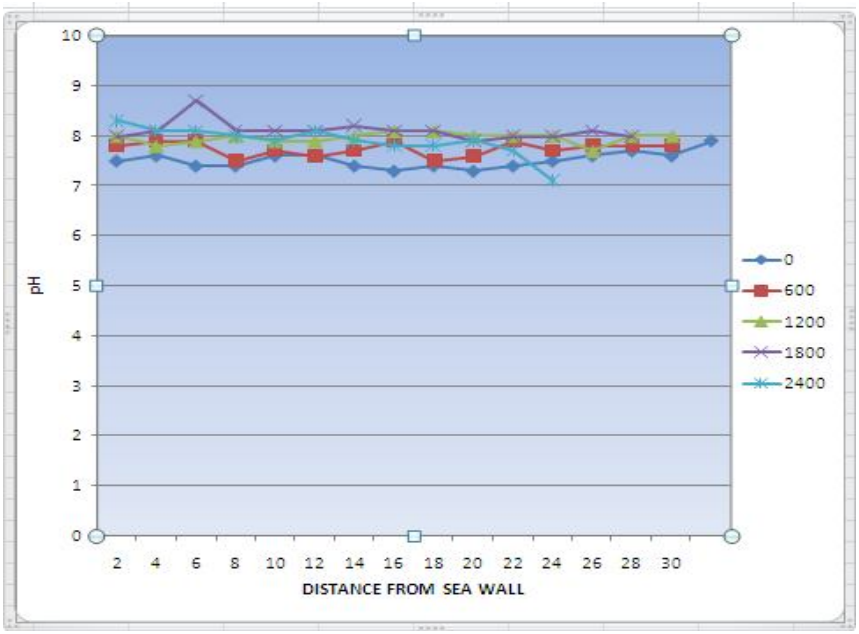


Kadappuram Panchayath

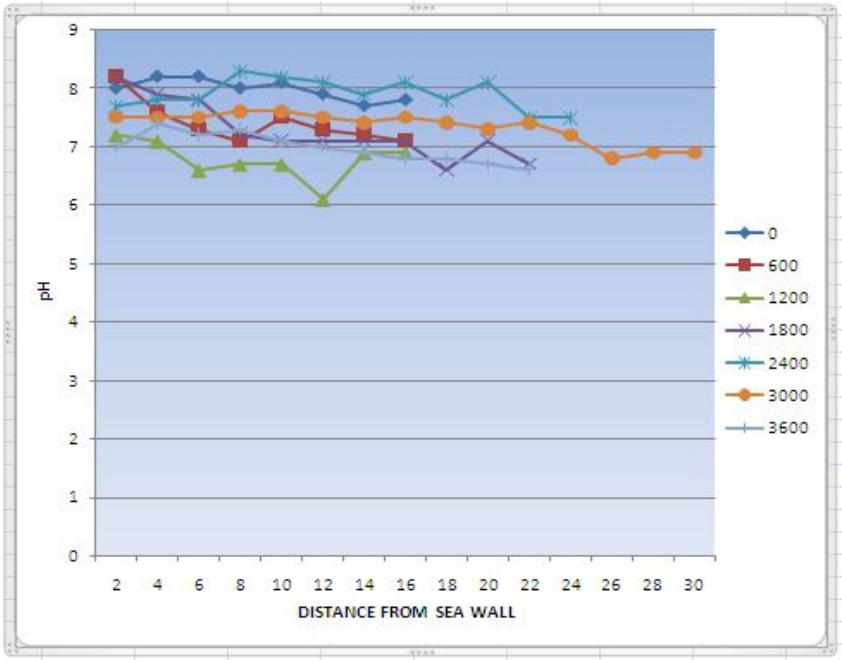


Vadanappilly Panchayath

Fig 6. pH in soils collected from Vadanappilly and Kadappuram Panchayaths



Kadappuram Panchayath



Vadanappilly Panchayath

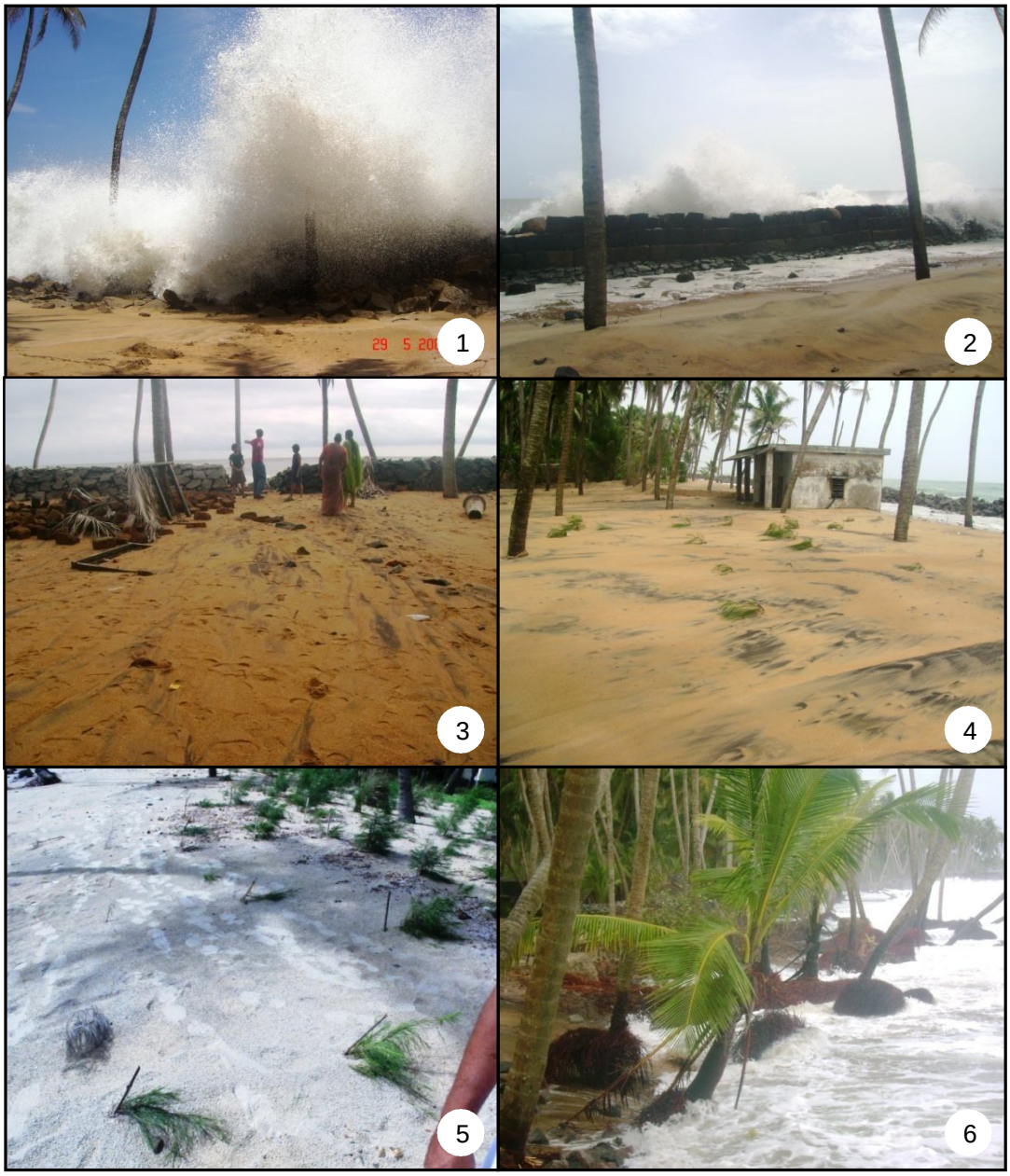


Plate 9. A view of the raising waves during high tides 2. Waves thrashing above the sea wall and flowing water behind the wall resulting in sand erosion 3. Sea water flows through the damaged area of sea wall. 4 & 5. Sand deposited on the shore above *Casuarina* seedlings. 6. A view of the damage to coconut trees due to high tides.

Plate 10. 1. Seedlings of *Casuarina* completely submerged under newly deposited sand. 2. Erosion of sea shore in planted areas of bio-shield. 3 & 4 Views of bending, breaking and uprooting of seedlings planted due to the force of waves.

Discussion

The project was implemented in a mission mode with a strict time target. Hence, within the time allotted, only the first stage of establishment of a bio-shield of 30 km extending up to 10 Panchayaths could be completed. There are gaps in between the shelterbelt due to the opening of the approach roads, places for landing of fishing boats and occasionally due to non-cooperation of the land owners. In most places, *C. equisetifolia* was used since it is known as the best salt tolerant tree species and capable of fixing nitrogen through root nodules. Preliminary screening using 14 species indicated that only five *T. catappa, D. strictus*, *B. vulgaris*, *S. indica*, and *T. tomentosa* showed positive results for establishment of bio-shield with more than 50% survival. Multi-location trials are required to find out suitable mixture of species for Kerala coast.

The awareness campaigns and stakeholder meetings contributed to educating the people about the need for establishment of coastal vegetation and the need to protect them for preventing the impact of strong winds, windblown sand, salt sprays and in reducing the energy of tsunami waves. Planting season has a good impact on the survival rate of seedlings. The seedlings planted in August during the first year suffered from frequent inundations with salt water and water-logging resulting in decay of roots. Change of planting season to September was beneficial for better establishment of seedlings.

The change in mode of implementation i. e, association with Panchayaths through MGNREGS invited the attention of officials and labourers alike. It provided opportunities for employment to local people especially women. The support from local authorities and inhabitants of coastal area was critical in success of the project. Another major problem during the first year was the disturbance due to sea wall construction. Dumping of large stones, movement of vehicles and people damaged the planted seedlings. Planting after the construction activities solved this issue to a great extent. In most of the areas where planting was done during second year, sea wall was constructed first and then the bio-shield was established. The experience clearly indicated that coordination between the implementing agencies of different projects at the same location is unavoidable.

The Panchayath officials, people's representatives and local people along with higher officials from KSCSTE, KFD and KFRI gave maximum support to the project. The inauguration meeting organized in each Panchayath during planting programme enhanced the interest of public and helped to clarify their doubts about the ownership of trees and impact of *Casuarina* etc (Plate 11)

The soil analysis along and away from the sea side clearly showed higher EC, salinity and total dissolved salts as expected. The variations in soil properties

did't reveal any impact on survival and growth of *Casuarina* seedlings. The high rainfall prevailing in Kerala and watering the seedlings with normal water is likely to be reduce the toxicity of salinity and provide congenial condition for the survival and growth of plants.

After the Indian Ocean Tsunami in December 2004, research was carried out in India and elsewhere to see the impact of coastal vegetation (Danielson et al 2005; Kathiresan and Rajendran 2005; 2006, Harada and Kawata, 2005, Tanaka et al, 2007) in reducing destruction of infrastructure and protect human life. The results from Tamil Nadu, Andhra Pradesh and Orissa coasts have indicated the positive effect of coastal vegetation in saving human life and property. It was pointed out that the deterioration and clearing of mangroves and other types of coastal vegetation along many coastal lines has increased their vulnerability to tsunami damage (Danielson et al 2005). During the tsunami in Papau New Guinea (1998) it was observed that *Casuarina* trees showed more resistance than palm trees (Dengler and Preuss 2003). In Sri Lanka and Thailand also the older *Casuarina equisetifolia* trees withstood Indian Ocean Tsunami but they were not able to provide good protection (Tanaka et al, 2007). Observations of Mascarenhas and Jayakumar (2008) also revealed that *Casuarina* plantations remained intact except for the frontal strips, when tsunami run-up levels ranged from 0.7 to 6.5m and the length of flooding area from the coast varied from 31 to 862m. Active forest management is required to produce variously aged stands of trees with a range and sizes and branches at all levels to enhance the potential for mitigation of natural hazards like tsunami (FAO 2007). A bio-shield with different species is suggested since the mitigation capacity of species like *Pinus* and *Casuarina* declines with age due to self thinning. A two layer forest of *Pandanus odoratissimus* and *C. equisetifolia* is recommended with other broad leaved trees behind (Tanaka et al, 2007). The undergrowth like *Ipomea pes-caprae* creepers also plays a role in reducing sand erosion.

Various efforts have already been taken in coastal areas of Kerala to reduce the impact of natural disasters like tsunami which includes strengthening mangroves, construction of sea wall, temporary measures like stacking of bags filled with sand, establishment of shelterbelts etc. A long term study is required about the impact of all these mitigation measures and arrive at the most suitable technique for combination of methods to protect coastal areas from further erosion and the people from losing their lives and property. However, the observations made elsewhere have shown the positive effect of coastal vegetation in reducing the wind effect and salt sprays.

Plate 11. 1-2 Sri. Mansur Ali, President, Kadappuram Grama Panchayath inaugurates the planting 3. Dr. E. P Yesodharan, EVP and the team from KSCSTE, and Forest Department along with Principal Investigator Dr. M. Balagopalan visiting the nurseries. 4. Dr. K. V. Sankaran, Director, Dr. C. Renuka, Registrar, Dr. K. K. Seethalaksmi, Principal investigator from KFRI during the field visit. 5 and 6. Different views of the established parts of bio-shield with one - year old seedlings of *C. equisetifolia*

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