The Ecological Restoration of Coastal Terrestrial Ecosystems in Southern Sri Lanka

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Abstract

This paper examines six different post tsunami ecological restoration projects conducted along the southern coast of Sri Lanka in 2006 by various Sri Lankan organisations. Eighteen months after the devastating 2004 tsunami, Sri Lanka's southern coastal zone has seen the replanting of an array of coastal vegetation ranging from *Rhizophora apiculata*, to *Borassus flabellifer* to *Cocos nucifera*. Local, national and inter-agency partnerships have been established as well as the formulation of local driven collaborative environmental restoration projects involving local communities Centred on the principles of ecological restoration, projects ranged from small and large scale mangrove replanting and sand dune stabilisation, to the re-establishment of home gardens. In addition to re-establishing nature's protective defences and acting as a natural barrier against possible future natural hazards, efforts are being made to realign the balance of damaged ecosystems by planting a selection of plants, which if utilised and managed sustainably can provide a wealth of socio- economic opportunities to coastal communities.

Keywords: Community, Restoration, Sri Lanka, Sustainable, Tsunami

1. Introduction

The past 250 years have seen in excess of 60 tsunamis in the Indian Ocean with nine of these tsunamis affecting Sri Lanka (excluding the 26th December 2004 tsunami) [4], [11]. Four of these tsunamis occurred in 1762, 1847, 1882 and 1946 in the Bay of Bengal impacting the eastern coast of Sri Lanka, three were related to earthquakes near the Nicobar Islands, India and two were triggered off the coast of Pakistan in 1819 and 1945 [11]. On the 26th of December 2004 at 00:59 GMT a 9.0 magnitude earthquake struck off the coast of Sumatra, Indonesia triggering a series of tsunami waves directly impacting coastal areas of Indonesia, Sri Lanka, Bangladesh, India, Thailand, the Maldives, Kenya, Malaysia and Mauritius resulting in the deaths of over 200,000. The worst natural disaster to have befallen Sri Lanka since historical times, the tsunami claimed over 35,000 lives, displacing over a million people and destroying homes, hospitals, roads and railways and other infrastructure [24].

As a result of the tsunami waves, the Sri Lankan coast suffered devastating ecological damage to more than two thirds of its coastline, with damage varying greatly and inconsistently from place to place [18]. Reasons for this included the differences in on-shore and off-shore coastal geomorphology, the presence/absence of off-shore coral reefs, the presence, maturity and width

of mangrove belts and the location of human settlements [12], [26]. Depending on local land forms, the physical area of the tsunami impact varied from high-tide level to 1km inland [10]. The disaster was unusual in the sense that the total destruction of some areas was found metres from unharmed areas [23], [24]. Areas with estuaries and natural and artificial lagoons acted as channels for the entry of seawater, facilitating damage and leading to the intrusion of saltwater far inland; in numerous cases, several kilometres inland, leaving the land salinated damaging home gardens, agricultural crops and coastal vegetation such as *Cocos nucifera* and *Borassus flabellifer* in the process [13], [22], [23]. The tsunami struck ecosystems, previously strained by unsustainable practices including habitat destruction, over fishing, and the detrimental destruction of coastal wetlands and mangroves for prawn culture. Together these activities have threatened the state of biological diversity and the livelihoods of local communities [17], [12]. Other affected ecosystems include coastal sand dunes, lagoons, maritime grasslands, as well as environmentally sensitive areas including national parks, and special area management sites (table 1).

Coastal ecosystems have evolved over hundreds, and even thousands of years, adapting and evolving with natural catastrophes and disasters. The sheer magnitude of the 2004 tsunami had the potential to disrupt the natural stability of these ecosystems, yet the impact of the tsunami lasted less than thirty minutes, and initial environmental assessments concluded that the damage to Sri Lanka's coastal ecosystems was disproportionately less despite the severity of impact on human life and infrastructure, with no irreparable damage occurring to terrestrial ecosystems [9], [18], [24].

Table 1: "Ecological impacts of the tsunami on coastal terrestrial ecosystems in Southern Sri Lanka" (Sources- Atapattu & Tharme 2005, Fernando et al.2006, IUCN 2005, MENR 2005, UNEP-MENR 2005)

Vegetation	Impacts
Mangroves	Various degrees of degradation and loss. Frontline and mangrove strips less than 10m devastated, broader stretches less affected. Sponge effect of mangrove swamps lessened damage. Large healthy mangroves seen toppled as far inland as 700m metres from the beach. Deeper mangroves left intact. Dense mangroves converted tsunami waves into a flood.
Sand dunes	Large, vegetated dunes absorbed wave energy and acted as a barrier stopping tsunami intrusion. Where dunes were disturbed, impact of waves was disastrous e.g. - a hotel resort, for the purpose of better scenic views, removed some of the dunes seaward of its hotel, the hotel was destroyed.
Pandanus tectorius and *Borassus flabellifer*	Seashore *Pandanus* cover reduced by up to 75%. Inland *Borassus flabellifer* less affected. Difficult to establish protective function as many settlements with interspersed palms suffered severe damage to houses.
Lagoons and Estuaries	Absorbed tsunami energy, but in doing so lost banks were scoured and lost seasonal sand barriers. However have recovered quickly. Various shifts in salinity concentration, Kalametiya lagoon transformed from a closed system separated from sea by sand bar to

	an open system- part of sand bar breached and now removed. Tsunami waters plugged estuaries.
Coastal waters	Sedimentation/turbidity of costal waters leading to algal blooms.
Casuarina plantations	Acted as an effective barrier in buffering destructive tsunami waves, although vulnerable to damage. Had little protection value on their own, although in places helped to stabilise sand dunes.
Beaches	Ecological impacts were severe where the beach was narrow and low in height. Scoured and eroded losing width and height from tsunami back-wash. Large amount of debris deposited on beaches.
Home gardens	Salt water intrusion destroyed production capacity due to high saline conditions. Up to 10 cm of topsoil was lost Approximately 27,710 home garden units were washed away or affected.
Other vegetation	Intrusion of seawater affected coconut plantations and agricultural crops (especially paddy). Salt water intrusion affected function and biodiversity in broader soil ecosystems. Sand casting occurred on productive lands.

The southern Sri Lankan coastline is characterised by sand dune systems vegetated with indigenous and alien trees (for example Casuarina), shrubs, creepers, occasional mangrove swamps and forests, *Cocos nucifera*, *Borassus flabellifer* and cashew plantations [1], [7]. Together, all these ecosystems provide coastal communities with a host of valuable services and goods including a resource of food and livelihoods, erosion control and sediment trapping, climate modification (micro and macro), habitats for wildlife and endangered species, biogeochemical cycling (nutrients, carbon sequestration), fuels and water (quality and quantity) and pollination [8], [19]. When the tsunami waves struck these services and goods were severely disrupted and in some cases, totally destroyed (Shanmugaratnam 2005).The geomorphological effects and physical characteristics relating to the impacts of the tsunami and the destruction caused to the built environment and society have been well documented [10], [12], [22], [23], yet few studies have analysed the effect of the tsunami on natural terrestrial ecosystems [10]. Post tsunami environmental issues chiefly consisted of waste management issues such as the clearing and removal of solid waste, focusing primarily on the immediate relief effort that was required, biodiversity and coastal ecosystem issues were not given due consideration [6], [18], [22]. Although at the time this was seen as an understandable focus and urgent priority, the most pressing issue to be addressed, eighteen months after the tsunami relates to the post tsunami restoration and rehabilitation of coastal ecosystems [1]. This paper reports research which evaluates this with regard to one key research question: What post tsunami activities are being conducted in southern Sri Lanka to restore coastal terrestrial ecosystems?

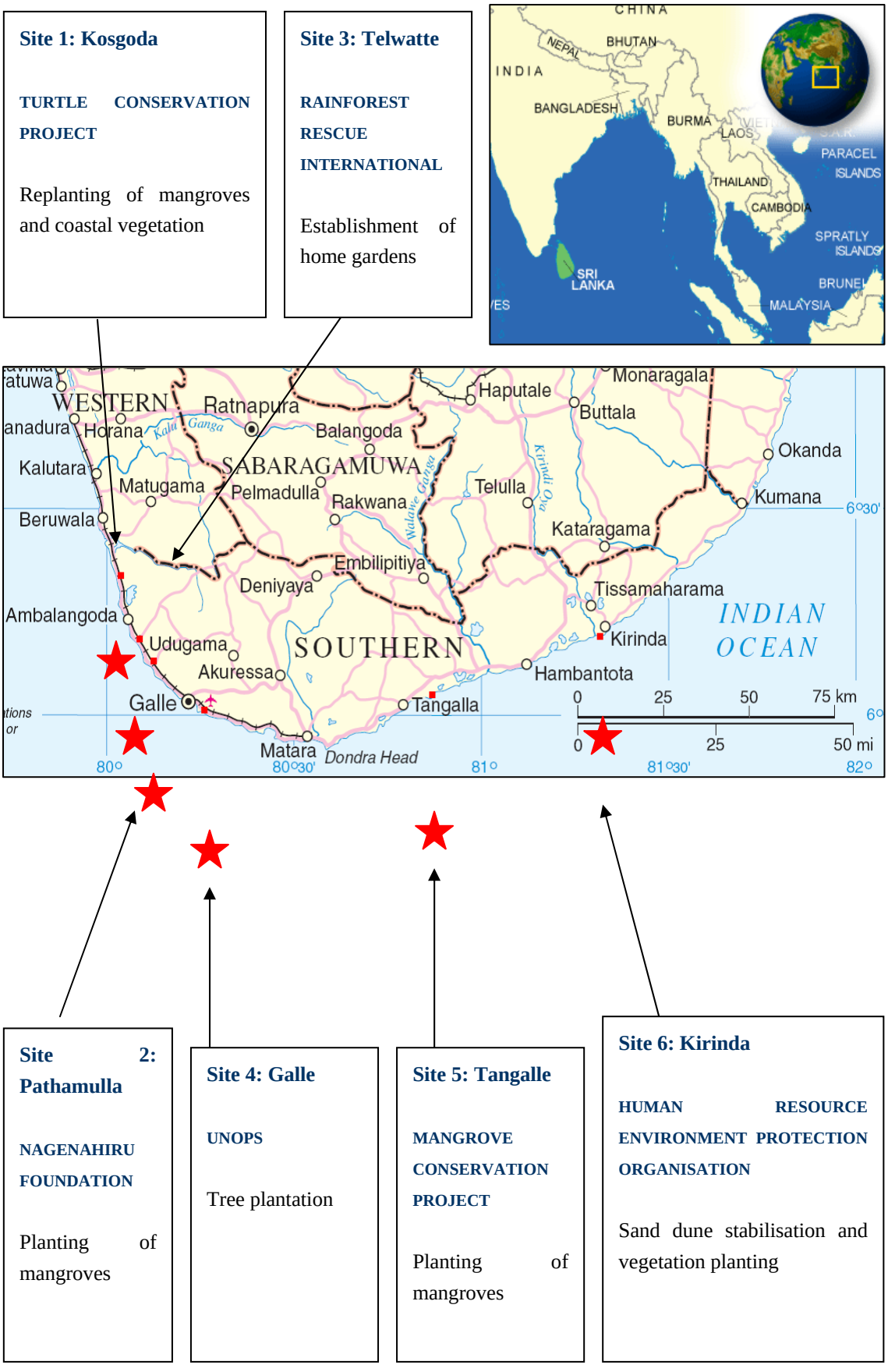
2. Methods

Research was conducted from April to June 2006 with the southern coast of Sri Lanka chosen as the focus of the research. Due to the physical impact of the tsunami waves being greatest on the East coast of Sri Lanka, numerous projects involving the rehabilitation of coastal greenbelts were established there in the aftermath of the tsunami. However due to increased violence and

rising tensions between the Liberation Tigers of Tamil Eelam and the Sri Lankan government, it was deemed too risky to travels to these areas and so firsthand evaluation of these schemes was not possible. Therefore the southern coast was chosen as the basis for the fieldwork, with six projects being identified along the South and South-Western coast (table 2).

It was contented that by analysing six projects, a reasonable cross section of environmental restoration projects in Southern Sri Lanka would be reflected.

Table 2: A map of Southern Sri Lanka showcasing the project locations



Research was conducted using qualitative methods, namely in-depth, face-to-face semi structured interviews and visual observation. Interviews were used to ascertain participants' role and views regarding the ecosystem projects. Participants ranged from local residents and business owners to government officials and NGO representatives. In total twenty people were interviewed- one representative each from the IUCN and the CCD, twelve local residents (two residents; one female and one male from each project), and one representative from each of the six organisations in charge of implementing the environmental restoration projects. Guided by project representatives and local residents, visual field observations were undertaken to assess firsthand the state of the restoration process. Observations were supported by photographical documentation of fieldwork sites and hand written notes with secondary data incorporated into the research in the form of maps, journal papers, environmental assessments and policy documents.

3. Results

The Sri Lankan government together with the assistance and support of the local and international community has launched a major restoration and rehabilitation programme in a bid to bring the country to a point of recovery from the devastating effects of the tsunami. As a result, broader strategic efforts are being made by government departments, NGOs, INGOs, and Community Based Organisations (CBOs) in restoring and rehabilitating the vegetation along coastal areas affected by the tsunami [20].

3.1 The Coastal Reservation Green Belt (CRGB) Project

The Coastal Reservation Green Belt (CRGB) project was founded as a direct result of the tsunami and centres around the establishment of a 100m green belt around the island. The project's overall objective is to rehabilitate ecosystems damaged in the tsunami by greening and restoring the coastal reservation [21], [25]. The CRGB strategy has been adopted in the hope that it will protect the shoreline from coastal erosion, curtail the impacts of natural hazards including cyclones, hurricanes, and tsunami to the environment, development, infrastructure and coastal communities and support and sustain coastal community livelihoods by planting commercially viable plant species. The Coast Conservation Department (CCD) is overseeing the CRGB helping to initiate many short and long term projects designed to rehabilitate, protect and conserve Sri Lanka's coastal belt [21]. All post tsunami coastal rehabilitation projects/schemes in the country are part of the CRBG project and require the permission of the CCD. This island wide initiative, estimated to cost approximately £6.7 million pounds is implemented by the Central Environment Authority (CEA), Urban Development Authority (UDA), Coconut Development Board (CDB), Forest Department (FD) and Horticultural Department (HD) [16]. This figure covers plant materials, maintenance of nurseries, awareness and educational programmes, staff training, site selection and surveys and project administration costs. As of July 2006, under the scheme, more than 25,000 plants have been planted along the Southern coast. Details of the six projects analysed in 2006 are summarised below;

Project 1: Kosgoda lagoon and beach, Turtle Conservation Project: *Mangrove and shoreline ecosystem project*

Location: GPS- N° 06 20’41.8, E° 080 01’20.4

Project partners and funding: Implemented and funded by the Turtle Conservation Project (TCP). The exact cost of project is not known but has been estimated at Rs.500, 000 rupees (£2186). After the tsunami, the organisation took an active interest in coast conservation for the sake of the turtles and the turtle breeding grounds.

Impact of tsunami: The beach was hit by six metre waves which surged 1.5km inland. 63 turtle eggs and three TCP workers were lost to the tsunami. Waves reached a height of 6 metres and penetrated 1km inland. The total destruction of *Pandanus tectorius*, *Cocos nucifera* and various species of mangroves were reported.

Project and details and objectives:

- Well rooted plants and trees including mangroves have been planted in damaged areas on the barrier beach to prevent coastal erosion in the future and to act as a protective barrier. The TCP has also established several coastal plant nurseries which maintain over 1,000 mangrove plant species.
- The project aims to re-establish the ecological destruction caused by the tsunami, leading to the preservation of the turtle breeding grounds.

Vegetation planted: *Terminalia catappa, Pandanus tectorius, Cocos nucifera, Calophyllum calaba, Barringtonia asiatica, Rhizophora apiculata, Rhizophora mucronata, Bruguiera sexangula, Bruguiera cylindrica*

Project 2: Pathamulla**:** ***Nagenahiru foundation*****:** *Mangrove Restoration and Educational Programme*

Location: GPS- N° 06 10’53.8, E° 080 05’52.8

Project partners and funding: Implemented by the Nageniharu Foundation and funded under the “EU Post Tsunami Project” by the European Commission and the Global Nature Fund, Germany.

Impact of tsunami: The project area is situated 500m from the coast beside the Maduganga River, Pathamulla. Approximately 1200 people reside in the area. Extensive damage was caused to houses as tsunami water travelled along the river to the village damaging land and buildings. 20 deaths were reported in the area.

Project details and objectives:

A nursery was established to house 5000 seedlings. 3000 mangrove seedlings have been distributed for planting in selected areas with the remaining 2000 seedlings still present at the nursery.

- As of July 2006, a mangrove educational centre is being constructed for demonstrational workshops and training sessions.
- Project organisers anticipate that the planting of mangroves will provide natural protection against the flooding of the Maduganga River and natural hazard events.

Vegetation planted: *Rhizophora apiculata, Bruguiera gymmorhiza and Excoecaria agallocha mangroves.*

Project 3: Telwatta: Rainforest Rescue International: *Establishment of home gardens*

Location: N 06 10’14.4, E 080 05’31.3

Project partners and funding: Implemented by Rainforest Rescue International (RRI) and Funded by Swiss Solidarity, the project is estimated to cost in the region of Rs 2 million rupees (£8746).

Impact of tsunami: Waves reached a height of 1.3m, penetrating 500m inland. The majority of trees in the vicinity died with only *Cocos nucifera* remaining intact. 150 people perished. An increase of salinity in the soil as a result of seawater destroyed people’s home gardens. Located 300m from the coast, home gardens in the village were left devastated and suddenly people had no way to sustain themselves or earn an income.

Project details and objectives:

- To re-establish and introduce home garden production in affected areas. Various fruits and vegetables were cultivated, and used to satisfy nutritional needs, with surplus stock later sold at local markets or roadside stalls.
- The RRI have established seven nurseries producing 100,000 plants. Plants are stockpiled to supplement subsequent requirements of the affected communities. As of July 2006, 2500 home garden plants of 10 different species have been distributed to local communities (table 4).
- To preserve Sri Lankan agricultural traditions, provide supplemental nutrition and assist communities in enhancing the availability of food improving income security.

Vegetation planted: *Moringa olifera, Carica papaya, Mangofera indica, Artocarpus heterophyllus, capsicum annum, Murraya koengii, Artocarpus altilis, Bassela alba, Abelmoschus esculentus, and Cinnamomum verum*

Project 4: Galle: UN Office for Project Services: *Tree plantation*

Location: N 06°02’58.5, E 080°11’04.2

Project partners and Funding: Funded by the UN Office for the Co-ordination of Humanitarian Affairs (UNOCHA), implemented by the UN Office for Project Services (UNOPS) and supported by the CCD. The cost of the project is Rs.750, 000 rupees (£3280).

Impact of tsunami: A 10km stretch of coastline took the full force of the tsunami waves. Pre-tsunami vegetation consisted of 150-200 *Cocos Nucifera* trees. Initially the soil was made infertile by the intrusion of salt water and therefore the CEA supplied organic manure to help with the tree planting process. 1500 persons perished.

Project details and objectives:

- 10km of coastline has been earmarked for vegetation planting. *Pandanus tectorius* and *Cocos nucifera* sapling have been planted 1m apart along a 10km stretch.

The project aims to form a protective vegetation barrier against future natural hazards as well as preventing sea breeze and wind problems to landward dwellers.

Vegetation planted: *Pandanus Tectorius, Cocos Nucifera*

Project 5: Tangalle: Mangrove conservation project: Mangrove planting

Location: N° 06 03’47.3, E° 080 52’53.1

Project partners and funding: Implemented by the Mangrove Conservation Project, Bandaramulla. Funded by German Technical Co-operation and supported by GITEC. Rs.2 million rupees (£8746) were allocated for the entire project. Rs. 1.2 million rupees (£5248) have already been spent on the establishment of a mangrove nursery, and maintenance of plants.

Impact of tsunami: 37 families were living in the area when the tsunami struck. A few *Rhizophora* mangroves were destroyed, with 7 perishing in areas where no mangroves were present with homes and hotels destroyed.

Project details and objectives:

- A mangrove nursery was first established with planting of seedlings along a 50m stretch, 100m from the coast situated next to an inland lake.
- A baseline survey of mangrove species in the area was conducted before the tsunami leading to the identification of existing mangroves native to the area. 6500 *Rhizophora apiculata*, *Rhizophora mucronata*, *Bruguiera gymmorhiza* and *Excoecaria agallocha* mangrove species have been planted. The project is expected to last 5-10 years.

Vegetation planted: *Rhizophora Apiculata and Mucronata, Bruguiera Gymmorhiza, Excoecaria Agallocha*

Project 6: Kirinda: Human Resource Environment Protection Organisation: *Sand dune stabilisation and vegetation planting*

Location: N° 06 12’06.6, E° 081 19’06.0

Project partners and funding: Implemented by the Human Resource Environment Protection Organisation (HREPO) and funded by the UNDP at a cost of Rs.600, 000 rupees £2624). World Food Organisation also provided Rs.600 rupees (£2.62) worth of dried food products for distribution amongst the local community.

Impact of tsunami: Before the tsunami the sand dunes were intact and not degraded. *Borassus flabellifer* were planted in the area to act as a buffer to the coastal winds, and it was reported that the presence of the trees had a slight effect dissipating the tsunami waves. Waves reached a height of 8m penetrating 1km inland. Approximately 150 families were affected, with 14 persons perishing. Over 46 houses were destroyed. The presence of the dunes (roughly 6m high) obstructed tsunami waves protecting the village from serious damage. Consequently the dunes were damaged and in need of restoration. It was reported that neighbouring villages which did not have sand dunes, rather coastline buildings, suffered a far worse fate.

Project details and objectives:

- Destroyed, damaged dunes left communities vulnerable to future hazards. The project aims to stabilise and restore the dunes by planting gentle, sea-shore vegetation in order to encourage the rehabilitation process along a 10km stretch of coastline.
- It is hoped that the services provided by the dunes (e.g. wind erosion control, regeneration of interior agro biodiversity, aesthetically pleasing for eco-tourism opportunities) will be restored leading to the introduction of eco-friendly employment opportunities in the southern coastal region

Vegetation planted: *Spinifex littoreus and Ipomoea pescaprea*

Project objectives

The main objectives of the six projects evaluated are fourfold: to re-establish the ecological destruction caused by tsunami waves to affected flora and fauna, to realign the balance of damaged ecosystems and to restore the services provided by affected ecosystems, to help communities build a sustainable future by introducing eco-friendly employment opportunities by planting a selection of plants which can be harvested for local handicraft and lastly to form a protective barrier against coastal erosion, wind storms, and future natural hazard events.

Vegetation planted

In total, twenty seven different varieties of plant and tree species were planted (table 3 and 4).

Table 3: Review of the plant/trees species planted

Coastal Vegetation			
Scientific name	English	Sinhala	Tamil
Cocos nucifera	Coconut palm	Pal	Tennai
Rhizophora apiculata Rhizophora mucronata	Red mangrove	Kadol	Kandal
Excoecaria agallocha	--	Talakiriya	--
Bruguiera sexangula Bruguiera cylindrica	--	--	--
Pandanus tectorius	Pandanus	Mudukeyiya	
Ipomoea pescaprea	Bermuda grass		Muhubu bim thamburu
Casuarina equisetifolia	Casuarina	Kassa	
Borassus flabellifer	Palmyrah palm	Tal	Panai
Spinifex littoreus			Maha ravana revula
Barringtonia asiatica Barringtonia racemosa		Diya Mudilla	
Terminalia catappa	Indian Almond	Kottamba	
Calophyllum calaba		Guru Kina	
Thespesia populnea		Suriya	
Sonneratia caseolaris	--	Kirala	Kinnai

Table 4: Review of tree and plant species planted for the home garden project

Scientific name	Sinhalese name	English name	Tamil name
Tree species			
Moringa olifera	Murunga	Drumstick	
Carica papaya	Papol/Gas labu	Papaya	
Mangofera indica	Amba	Mango	Manga
Artocarpus heterophyllus	Kos	Jackfruit	
Plant species			
Capsicum annum		Capsicum	
Murraya koengii	Karapincha	Curry leaves	
Artocarpus altilis	Del	Bread fruit	
Bassela alba	Nivithi	Spinach	
Abelmoschus esculentus		Okra	
Cinnamomum verum		Cinnamon/Ceylon cinnamon	

Establishment of Plant Nurseries

For all three mangrove projects, temporary mangrove nurseries were established prior to the commencement of plantation in order to produce native seed stock and propagation materials. This was due to the general lack of sufficient numbers of suitable plant species, to the sheer amount of mangrove saplings required for the restoration effort and for growing the plants until they reached a suitable size for planting. New, good quality plant genetic material such as

mangrove propagules were supplied (in some cases) voluntary by the CEA, the Palmyrah Development Board, and two NGOs- *"The Green Movement"* and *"Ruk Rakaganno"*. The propagules were planted in small, black plastic bags containing soil and kept in the nursery until they reached four-leaf stages. Propagation was necessary to ensure that newly planted vegetation acclimatised to the maximum effort. The time taken to reach this stage varied from three to nine months dependent on conditions of growth. Seedlings, grown from the seed were approximately 11 months old when distributed to local communities. A temporary plant nursery was also established for the home garden project. Vegetation is a critical factor in the formation and stabilisation of sand dunes and so *Spinifex littoreus* and *Ipomoea pescaprea* seedlings were planted in bare areas on the sand dunes to stabilise the dunes [5]. The area was then cordon off to protect the vegetation from being disturbed or destroyed by local inhabitants or animals. Naturally 3 of the 6 projects analysed were concerned solely with the planting and restoration of mangroves; this was to be expected when taking into consideration the highly publicised view of the role mangroves play in dissipating the energy of the tsunami waves [8], [15], and [16]. Mangroves were planted to replace those destroyed in the tsunami as well as to boost the existing mangrove population with the intention of providing a greater range of protection to human settlements from future natural hazards. Young [27] highlights the danger of unnecessary mangrove planting in unsuitable areas in Sri Lanka's coastal zone. This concern was put forward to project officers who made assurances that the mangrove restoration areas in each of the three projects were suitable, as mangroves species planted were native to the area; *"we analysed the remaining mangrove in the area, and so planted the same species"* (Nageniharu Foundation representative).

Environmental assessments and traditional ecological knowledge

In all six projects, local communities were fully involved in initial environmental assessments, surveys and site selections including the planning and planting stages**.** Basic post tsunami environmental assessments were conducted by project co-ordinators and staff members of the named charities/organisations in conjunction with local residents. Accurate data including satellite imagery and aerial before and after photos were either not kept, available, or were disparate for the six projects concerned. Consequently identifying the impacts of the tsunami on the natural environment became a tedious task. To compensate for the lack of scientific data available, traditional ecological knowledge possessed by the local population was identified and utilised in environmental assessments of the project sites. The use of indigenous environmental knowledge by scientists and researchers has been well documented [2], [3]. Berkes [2] highlights, "*traditional ecological knowledge is as old as ancient hunter-gatherer cultures*". That statement is especially true in Sri Lanka, where local ecological and environmental knowledge of the ecosystems which the community inhabits are built upon and passed down from generation to generation. Arguably the local community, especially the indigenous population possessed firsthand knowledge of the natural environment which in turn acted as a useful and practical guide as to what steps should be taken regarding the restoration of the ecosystems found there. Discussions with project co-ordinators and participants indicated that this local knowledge and information has been valued and utilised well; "*we had some guidance*

from several government departments but we also used the knowledge of local people, if anything they know more about the area than anyone else" (RRI representative).

Although there are several environmental restoration projects in the East and South East of the country, there is not an abundance of environmental restoration projects as originally hoped for in the South and South-Western coasts, and it is only fair to say that the process of environmental rehabilitation is slow. It seems that it is only now, some 18 months after the tsunami that the environment is being given due consideration. When questioned why environmental restoration projects have taken so long to initiate, representatives replied that it simply a case of funding for projects being delayed. Projects co-ordinators also stated the need to be certain when planting or replacing new and damaged species; *"basically it was a case of receiving the funds, but we needed to be certain of how we were to approach the restoration of the mangroves, we needed to be certain of the species of the area before we proceeded otherwise it would have been a disaster to the nature of the area"* (Mangrove Conservation Project representative). One project co-ordinator shared Katz [14] view that damaged/destroyed vegetation should be left to recover naturally without human intervention. However it was evident that this view was not shared by other representatives: *"some things can take decades to recover, however I believe that we, humans should start the restoration process ourselves"* (TCP representative). Three of the six organisations did not initially deal with the natural environment but after the tsunami, they included environmental projects in their manifesto recognising the urgent need for post tsunami environmental restoration work.

Economic benefits

Communities were subsequently assured of financial benefits, through employment on cash for work basis as plant nursery entrepreneurs, landscape contractors and green belt managers (including long-term maintenance). A system of regular maintenance and management of the vegetation planted was established. This involved local residents monitoring the plantations, removing dead vegetation, weeds etc, ensuring that the vegetation was not being trampled upon or removed and keeping the plants and vegetation free from pests and diseases. There was a noticeable discrepancy in the incentives and rewards awarded in each project ranging from Rs100 to Rs1250 rupees (approximately £0.50p-£6.00) a week for maintenance. The home garden scheme has encouraged communities to be more self reliant by introducing low cost organic farming to the project area. In turn, communities have enhanced their availability of food as well as providing communities with an economic, sustainable livelihood. In addition to all the home garden crops which provide a regular, accessible and vital source of food and nutrition, *Pandanus tectorius* and *Cocos nucifera* vegetation, featured most prominently for both its protection factor against various natural hazards and its intrinsic economic value. For example the woven leaves of the *Pandanus tectorius* can be used to make indigenous local handicrafts such as handbags which appeal to foreign tourists. Project co-ordinators envision that the restoration of these ecosystems, the very resource base that provides these opportunities, will benefit local communities through the generation of economic opportunities.

4. Discussion and conclusion

It is evident that considerable efforts are being made to restore coastal terrestrial ecosystems in southern Sri Lanka. Although half of the projects evaluated were solely concerned with the replanting of mangroves, this is just one small step of many that the country is taking towards restoring the coast to its former state, providing moderate protection against any possible future natural disasters and rehabilitating ecosystems which provide a life support for coastal communities. Capacity building at local levels is seen as a key factor for securing the sustainability of Sri Lanka's coastal ecosystems. Local, national and inter-agency partnerships involving all stakeholders have been established and the formulation of local driven, collaborative environmental restoration projects have boded well for the progression of restoration projects. Nevertheless there needs to be a greater emphasis placed on the importance of restoring affected ecosystems to the pre-tsunami state of production activity including restoring the ecosystems to a functioning state where they could provide services and goods again to local residents. Efforts are being made to realign the balance of damaged ecosystems by planting a selection of plants, which if utilised and managed sustainably can provide a wealth of economic benefits to coastal communities. Good management practices have ensured that the maintenance of vegetation planted is both meticulous and consistent and it is imperative that these efforts are continually monitored and sustained for the restoration process to achieve its desired effect.

References

[1] Atapattu S & Tharme R (2005) *"Tsunami Impacts on Coastal Ecosystems of Southern Sri Lanka"* (available online) www.siwi.org/downloads/_WF%20Articles/WF_05-1_Tsunami.pdf [accessed 12th January 2006]

[2] Berkes F (1999) *"Sacred Ecology: Traditional Ecological Knowledge and Resource Management"* Taylor & Francis, Philadelphia

[3] Briggs J (2005) *"The use of indigenous knowledge in development: problems and challenges"* in Progress in Development Studies, Vol. 5, pp. 99-114

[4] Carayannis-Pararas G (2005) *"Tsunamis of the Indian Ocean"* (available online) http://www.drgeorgepc.com/Tsunami2004IndianOcean.html Accessed 28th July 2006

[5] Carter R.W.G (1998) *"Coastal Environments"* Academic Press Ltd, London

[6] Chiew H (2005) *"Change in Coastal Ecosystems after the Tragedy"* (available online) http://www.ecologyasia.com/news-archives/2005/jan-05/star_050118_1.htm [accessed 22nd June 2006]

[7] Cooray P.G (1984) *"The Geology of Sri Lanka (Ceylon)"* National Museums of Sri Lanka Publications, Colombo

[8] Danielsen F, Sorensen M.K, Olwig M.F, Selvam V, Parish F, Burgess N.D, Hiraishi T, Karunagaran V.M, Rasmussen M.S, Hansen L.B, Quarto A & Suryadiputra N (2005) *"The Asian Tsunami: A protective role for coastal vegetation"* in Science, 310, pp. 643

[9] FAO (2005) *"Sri Lanka: Post-Tsunami Consolidated Assessment"* FAO, Thailand

[10] Fernando, P., Wikramanayake E.D & Pastorini J (2006) *"Impacts of terrestrial ecosystems of Yala National Park"* in Current Science, Vol. 90, No.11, pp. 1531-1534

[11] Gunasekera (2005) "*Forewarned is forearmed: future tsunami threats to Sri Lanka" Asian Disaster Management News*", Vol. 11 No.1, pp. 8, Asian Disaster Preparedness Centre, Thailand

[12] IUCN (2005) *"A report on the terrestrial assessment of tsunami impacts on the coastal environment in Rekawa, Ussangoda and Kalametiya (RUK) area of Southern Sri Lanka"* IUCN, Colombo

[13] IUCN (2005b) *"After the Tsunami: Restoring Terrestrial Coastal Ecosystems"* Information Paper No.10, IUCN, Colombo

[14] Katz (1996) *"The Problem of Ecological Restoration"* in Environmental Ethics, Vol. 18, p222-224

[15] Kathiresan K & Rajendran N (2005) "*Coastal Mangrove Forests Mitigated Tsunami"* in Estuarine, Coastal and Shelf Science, Vol. 65, No.3, pp. 601-606

[16] Kinver M (2005) "*Mangroves Save Lives*" (available online) http://news.bbc.co.uk/1/hi/sci/tech/4547032.stm [accessed 10th January 2006]

[17] Kiringoda T (2005) *"Living with tsunami: Can we go to the sea beach again?"* in Journal of Sri Lanka Institute of Architects, Vol. 106, No.1, pp. 20-25

[18] MENR (2005) *"Rapid Assessment of Damage to Natural Ecosystems in the Coastal and Associated Terrestrial Environments"* Battaramulla, Sri Lanka

[19] Olsen S, Sadacharan D, Samarakoon J.I, White A.T, Wickremeratne H.J.M & Wijeratne M.S (Eds) (1992) *"Coastal 2000: Recommendations for a Resource Management Strategy for Sri Lanka's Coastal Region Volume II"* CCD, Colombo

[20] Sunday Observer (2005) *"Sri Lanka Setting up Natural Coastline Barriers"* 12th June, Sri Lanka

[21] UDA (2006) *"A Basic Guide to Design and Planning of Coastal Green Belts in Sri Lanka"*, UDA: Environment and Landscape, Battaramulla, Sri Lanka

[22] UNDAC (2005) *"Rapid Environmental Assessment in the Democratic Socialist Republic of Sri Lanka"* Joint UNEP/OCHA Environment Unit, Switzerland

[23] UNEP- MENR (2005) *"Sri Lanka: Post-Tsunami Environmental Assessment"* MENR, Battaramulla

[24] USGS (2004) *"The Magnitude 9.0 Sumatra-Andaman Islands Earthquake FAQ" (available online)* http://earthquake.usgs.gov/eqcenter/eqinthenews/2004/usslav/neic_slav_faq.html [accessed 10th January 2006]

[25] Wickramasinghe, A (2005) *"Tsunami: Building the Nation through Reciprocity While Reconstructing the Affected Areas in Sri Lanka"* in Local Environment, Vol. 10, No.5 pp. 543-549

[26] Yamada S, Gunatilake R.P, Roytman T.M, Gunatilake S, Fernando T & Fernando L (2006) *"The Sri Lanka Tsunami Experience"* in Disaster Management and Response, Vol. 4, No. 2, pp. 38-48

[27] Young E (2006) *"Is replanting coasts the way to protect against tsunamis?"* in New Scientist, No.2547, 15th April