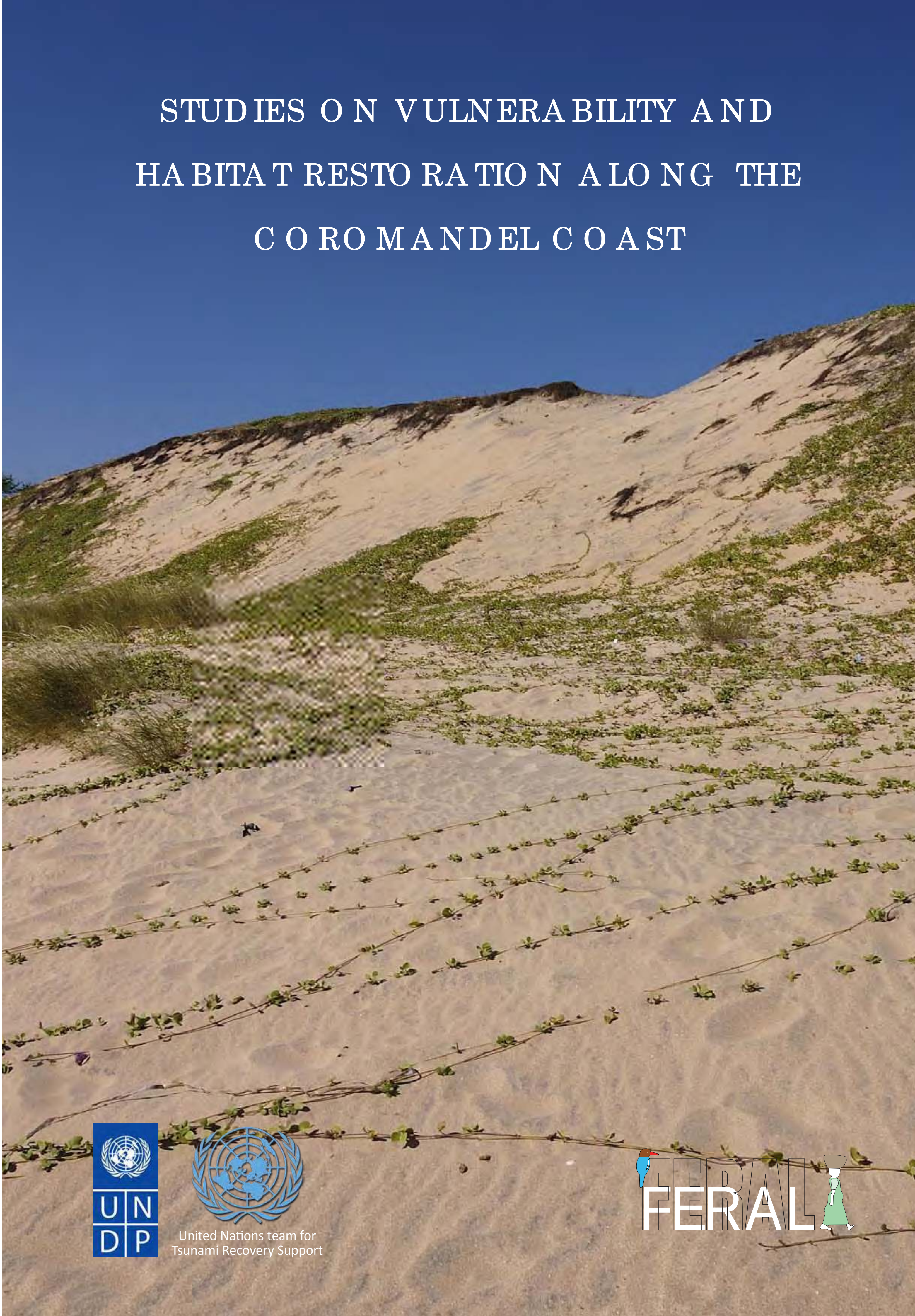
STUDIES ON VULNERABILITY AND HABITAT RESTORATION ALONG THE COROMANDEL COAST



UNDP

United Nations team for Tsunami Recovery Support

FERAL

A Post-Tsunami Environment Impact Report

Studies on Vulnerability and Habitat Restoration along the Coromandel Coast

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United Nations Team for Tsunami Recovery Support

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Finally, we acknowledge and thank the FERAL field staff who gave their best to this project and made it possible to achieve the results presented in this report. Continuous inputs from Dr.Rauf Ali and Dr.Neil Pelkey helped steer the various activities and supported the analysis and presentation made in this report.

Contents

Executive Summary

The coastal environment and its long-term sustainability, a key component in the UN Recovery framework, are the main points of focus in the UNDP-Post Tsunami Initiative (PTEI). The restoration, management and conservation of these habitats has direct relevance to post-tsunami reconstruction and ongoing policy discourse on coastal zone management and planning, coastal defences, bio-shields and environment.

This document consolidates the learning of one of the four components of the UNDP-PTEI Phase II. The primary goal of the component was to build protocols for restoration of coastal habitats based on a combination of literature reviews and field experience. The component was implemented by the Foundation for Ecological Research, Advocacy and Learning (FERAL) who joined the initiative in December 2006. The objectives of the project were :

1. To conduct studies on coastal vulnerability at a spatial level.
2. A spatial analysis of land use change and social change on the Coromandel coast of India over the last three decades.
3. To identify sites for pilot restoration using and extending PTEI Phase I results; coastal sand dunes, mangroves and tropical dry evergreen forest habitats were covered.
4. To mobilise local stakeholders and build local capacities at selected restoration sites.
5. To mobilise institutional support and financial sustainability of the work through linkages with local and district authorities and
6. to set up pilot demonstrations sites for restoration of native coastal habitats.

While the first two objectives covered the entire Coromandel coast, the restoration related activities were limited to patches of degraded native habitat lying within 50 km of the coast which extends from the South of Pulicat Lake to Point Calimere in Nagapattinam.

This is among the first efforts to collate and analyse information in a spatial framework that encompasses long term changes in coastal land use and consequent impacts on the vulnerability of communities and native habitats. This is also among the few attempts to document and build comprehensive restoration strategies for these habitats and involves partnerships with local communities, institutions and other agencies in the region. Our learning emphasise the need for multidisciplinary approaches. The ability to use participatory tools and community organisation in conjunction with remote sensing, GIS, specialised nursery techniques and ecological assessments was a major strength of the project.

Outcomes of the UNDP-PTEI project are expected to feed directly into restoration and conservation efforts for these unique but fragmented and highly threatened habitats both at a local community level as well as at the level of policy makers and government.

This document presents the findings of studies conducted on the impacts of the tsunami and vulnerabilities of communities and habitats along the Coromandel coast. It also presents strategies that were evolved and tested for the restoration of coastal habitats. Among the salient achievements of the project were:

1. Documentation of the impact of the tsunami on coastal communities and ecosystems, including the collation of available literature and publicly accessible datasets (included in the DVD-ROM appended to this document.
2. Documentation of land-use changes that have occurred on the East coast of India over the past three decades and their implications for coastal vulnerabilities.
3. A critical look at the role of bio-shields in mitigating the tsunami and weather related disturbance events, which includes a review and critique of available literature.
4. Identification of representative habitats along the Coromandel coast using imageries and following up with extensive field visits and ecological assessments of their status.
5. Sites selected for restoration satisfied a number of criteria including willingness of local communities to participate and contribute to their restoration and continued protection.
6. Restoration techniques were both low cost and low on maintenance.
7. Planting native species of vegetation in suitable and protected locations.
8. Community mobilisation involved a series of awareness generation activities followed by negotiations and micro level planning of restoration activities.
9. Formation of eco-restoration committees which comprised of representatives from various groups in the village including the elected Panchayat, representatives of women self help groups, traditional Panchayats and temple authorities in the case of sacred groves.
10. Administrative arrangements between the implementers and various organisations were designed to ensure there was transparency and accountability at all stages of implementation.
11. Collation of relevant data and documents pertaining to the topics listed above in a DVD-ROM to facilitate further work.

Coastal Vulnerability and Impacts of the Tsunami

Post 2004 tsunami, there was a great deal of interest in understanding coastal vulnerability and the impacts of the tsunami. While a few studies were carried out immediately after the tsunami, this study is one of the first attempts to develop a coastal vulnerability index to explain the observed impacts and to categories the coast into different vulnerability classes to future events.

We first examine how much of the damage incurred as a result of the tsunami can be explained by an index of coastal vulnerability based on various physical parameter. We develop a Coastal Vulnerability Index (CVI) for the coastal stretch for the southern states of India which incorporates topography, bathymetry, tidal range, wave height and geomorphology.

Results indicate that nearly 40% of the coast line is under high and very high risk to stochastic events like the tsunami and storms surges. The most vulnerable areas are characterised by shallow coastal slope, low tidal range and waves with high energy, while the least vulnerable zones are characterised by higher coastal slopes and smaller waves. Our analysis shows that the largest stretch of relatively less vulnerable zones are found in the southern most part of India between Kollam and Ramanathapuram. While relatively large stretches between Cochin and Kollam, Thuthukudi and Sirkazhi, Ulvapadu and Nagayalanka are highly vulnerable. On comparing the observed impacts to human lives and property the vulnerability index shows a positive correlation and does explain the observed impacts.

We also compared the index which we developed to identify coastal ecosystems that are under risk and results indicate that coastal littoral forests, sand dunes and back waters are amongst the most vulnerable ecosystems. This index was compared to an earlier study of impacts to ecosystems and find an over all agreement of 40% between our categorisation of the coast into vulnerability zones and impacts to ecosystems. While the study highlights the significant role physical variables play in determining coastal vulnerability we also recognise the need to incorporate spatial data on coastal settlements, which is currently not available, to further strengthen the vulnerability index and prioritise the collection of the same in future initiatives.

In the second study we look at how changing landuse patterns are likely to affect coastal vulnerability and also economic vulnerability of human communities along the coast. To assess the key land use changes occurring in this human dominated landscape of the Coromandel Coast we make use of a diverse array of datasets from published government records to remotely sensed data. The study also assesses the implications of changing climatic patterns on land-use patterns and the future consequence of increasingly stochastic weather on coastal vulnerability.

The key findings from the study are major landuse change over the last three decades with an increase in areas under non-agricultural use or urbanisation, decrease in area under cultivation and increase in other fallow lands along the Coromandel Coast. Using a series of night light images we also show the growth and sprawl of urban areas around existing towns and cities like Chennai, Pondicherry - Cuddalore and Karaikal – Nagapattinam. Given the limitation of two date image classification techniques we use a time series of images for the period 1985-1996 to high light areas undergoing changes in vegetation bio mass and results indicate the greatest loss in Nagapattinam district. Other than these trends we also looked at modifications of coastal estuaries and back water systems along the Coromandel Coast over the last decade. Of the 45 sites that we examined along a stretch of 450 Km., 40 % of the sites showed new or increased areas under salt pans or aquaculture ponds over the last decade and bulk of these changes are observed in the coastal stretch between Sirkazhi and Nagapattinam.

While these land use changes are observed we also assessed changes in human communities along these coastal districts with respect to demography and economic variables from the primary census abstracts. The key changes observed are increase in human populations along the coast but a reduction in decadal growth rates. The changes in economic variables are reduction in the workers in the agricultural sector and increase in marginal workers or people with less than 6 months of employment. In conjunction with the observed landuse changes the demographic and economic parameters highlight that more people are now residing in urban areas in high vulnerable zones and reduction in area under cultivation is forcing to seek employment in other sectors and also increasing employment rates, thus such land use changes do have implication on economic vulnerability of coastal communities.

The key implications of these land use changes with respect to changes in climatic patterns due to even minor deviations from the normal pattern of rains and with the possible and impending global warming and climate change scenarios are issues of further decline in agricultural productivity which is a potential problem that needs to be addressed at the earliest. Also with increasing urbanisation the loss of life and infrastructure due to vagaries and changes in climate is likely to increase. The rapid urbanisation with poor planning and civil infrastructure in place is quite common in urbanised areas all of which have witnessed severe inundation in the recent past during heavy monsoons.

In the last study that looks at impacts of the tsunami, we assess the role of coastal bioshields in protecting coastal stretches in large scale events like the tsunami. This has been one of the most widely debated and publicised topics. We reviewed a total of 13 relevant scientific publications and find less than half supporting the mitigation hypothesis that coastal vegetation played during the Indian Ocean tsunami. We also highlight the analytical and statistical flaws in the studies that support the mitigation hypothesis. We address this issue by developing a statistically robust frame work to understand the role of physical features, in explaining the observed inundation distance during the tsunami. We use a model selection approach using Akaike's Information Criteria (AIC) scores as this approach allows several competing models to explain the observed effects and also provides a frame work of evaluating the competing models.

Our results clearly show that coastal vegetation was not the most important factor that explained the observed run up distances and it was the topographic relief that played a major role. Results also highlight that univariate models are not the best models that explain the observed inundation distances and in fact the best model incorporated topographic relief, bathymetric slopes, coastal vegetation and near shore bathymetry. The results clearly dismiss the role of coastal vegetation in protecting coasts from large weather related disturbance events and s vegetation might not protect people from disaster like the tsunami, the efforts to restore degraded coastal habitats should continue for ecological reasons and not on the false premise of coastal protection.

Restoration Protocols

Why conserve coastal habitats?

The coastal zone contains many of the Earth's most complex, diverse and productive ecological systems. It functions as a protective buffer and filter between the land and the sea. Coastal ecosystems are under threat due activities such as increased human settlement, industrial pollution, development of roads, vehicles, buildings, coastal defence , water catchment, agriculture, mining and tourism etc. The ecosystems in the coastal zones are important for biological and economic productivity, storm protection and erosion control. Reefs, mangroves, wetlands, coastal sand dunes and tidelands are vital breeding, nursery and feeding areas for the majority of known marine species. Worldwide, over two thirds of all marine fisheries species depend on coastal systems.

Coastal habitats are among the most threatened ecosystems in the world. This is due to a combination of factors including high population densities and consequent anthropogenic pressure on space, the dynamic nature of the ecosystems and dependence on materials and flows from other systems and last but not least, climate change and its likely impact on sea levels. Coastal habitats play a crucial role in maintaining ecological goods and services and reducing local vulnerabilities. Their local and regional value, in terms of environmental and economic services and cultural importance is both tangible and demonstrable. For instance, coastal sand dunes and sand formations are integral to the lives of fishing communities who use them for boat landing, parking and repair, for mending of nets and sales and auction of fish catch. Mangroves directly contribute to the lives of backwater fishers by positively impacting fisheries and shrimp. Tropical dry evergreen forests are known to harbour over 450 species of plants many of which have known medicinal value which traditional healers continue to utilise to this date. Sacred groves, which are among the last remnants of these forests, are an integral part of the local culture and sites for annual religious fairs.

The topic of restoration ecology brings in to the frame a number of related concepts, many of which have been defined and used interchangeably over time. We define ecological restoration as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. Subsequent to the identification of study area, the measurement of ecological and environmental parameters at potential restoration sites is an important part of any restoration programme. This enables us to establish the needs for restoration and for setting restoration goals.

Results

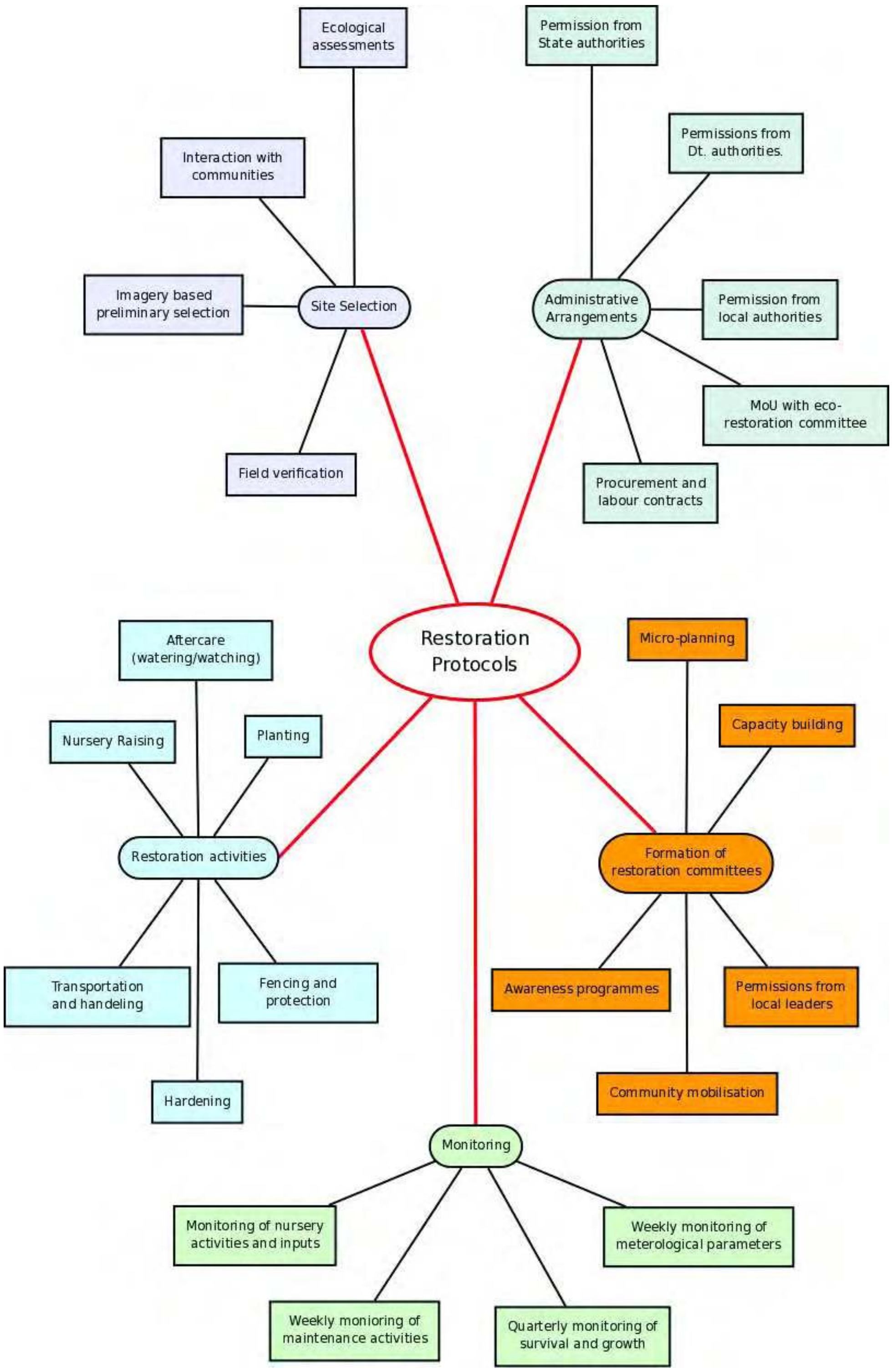
The primary objective of testing and demonstrating replicable protocols for restoring coastal habitats was achieved by this project. This document is a compilation of field observations, analysis and literature on the subject with specific focus on each of the three habitat types, namely, tropical dry evergreen forests, coastal sand dunes and mangroves systems. In all of the above we have built upon work done by other individuals and agencies, with a mind to simplify the methods and techniques so they are cost effective and replicable. The activities followed by the project had a similar sequence irrespective of habitat type. This strategy drew upon earlier projects, both internally implemented and those implemented by other organisations. It needs to be noted that the socio-economic context of Tamil Nadu is in many ways unique and therefore governed the approaches used. However, many of the lessons learnt are clearly applicable to other regions of India and South/South-East Asia.

There were two areas which were beyond the scope of this project, but which remain crucial to ensuring the survival of coastal habitats.

1. The survival of coastal sand dunes and backwater systems is contingent on flows of sand, nutrients and water from other areas. A construction of a sea-wall or dam upstream can and continues to spell the end of many coastal sand dunes and mangroves. To alter development strategies in a way that they are more sensitive to downstream impacts will determine the status of many coastal, and inland habitats.

2. The present pressure for convertion of these habitats to other uses is immense and comes from both local as well as external sources, which local institutions are unable to withstand. The nearly complete conversion of coastal backwaters to shrimp cultivation and shrinkage of areas under tropical dry evergreen forests is evidence to these pressures. Evolving an administrative setup which respects the rights of local communities while preventing habitat modifications is the need of the hour. In its absence, we are likely to see further degradation if not disappearance of the majority of these native patches.

The protocols that were evolved during the course of the project have been summarised in the diagram presented below.


Restoration Protocols
Site Selection
Ecological assessments
Interaction with communities
Imagery based preliminary selection
Field verification
Administrative Arrangements
Permission from State authorities
Permissions from Dt. authorities.
Permission from local authorities
MoU with eco-restoration committee
Procurement and labour contracts
Restoration activities
Aftercare (watering/watching)
Nursery Raising
Planting
Transportation and handeling
Fencing and protection
Hardening
Formation of restoration committees
Micro-planning
Capacity building
Awareness programmes
Permissions from local leaders
Community mobilisation
Monitoring
Monitoring of nursery activities and inputs
Weekly monioring of maintenance activities
Quarterly monitoring of survival and growth
Weekly monitoring of meterological parameters

Part I

Project Achievements

Chapter 1 Introduction and Background to the Project

Abraham V. A. and R. S. Bhalla

Contents

The December 2004 earthquake and tsunami that swept through the Indian Ocean region had unprecedented consequences for human populations and natural systems along the coasts and islands of the region. The coastline of India was seriously impacted and led to large-scale destruction of not only housing and infrastructure but also affected the fragile coastal ecosystems and resulted in the loss of thousands of lives, assets, livestock and crops. The initial response by the state governments, along with national and international agencies, focused on rebuilding better shelters of the communities living along the coast and to restore their livelihoods.

Questions on the environmental impacts of this catastrophe are now being addressed. Importantly it is becoming increasingly clear that plans that address the long-term interests of coastal communities and that of the coastal environment (Integrated Coastal Zone Management Plans - ICZMP) should be based on a participatory approach and strong research and scientific principles. There is also an urgent need to focus more closely on the mid to long-term consequences of rehabilitation efforts on the natural resilience of social and ecological systems along the coast.

Past studies to address the above issues have been severely constrained, as there is very limited baseline information on the status of ecosystems and its services pre-tsunami and on the status of human communities that are dependent on these ecosystems for their livelihoods. There is also a limited capacity among the various stakeholders to understand and undertake various environmental initiatives for a more holistic and integrated coastal area planning as well as to incorporate environmental sustainability concerns in various livelihood activities.

Therefore, coastal environment and their long-term sustainability is a key component in the UN Recovery Framework. UNDP as the agency for the initiative on the coastal environment has adopted a two phase approach to the programme; Phase 1 was more a means of understanding the many issues that affect the coast line and to establish at a preliminary level the ecological and socio-economic impacts of the tsunami. This phase further studied the impacts of the tsunami on coastal populations and the ecosystems they use, in the context of rapid coastal development, increasing resource needs, and changing legislative mechanisms. This was the phase that also detailed out the various medium and long-term interventions that were needed (phase 2) along the tsunami affected coastline of mainland India, that would ensure the long-term sustainability of the coastal environment.

The overall outcome expected of the post-tsunami environment initiative is; *environmental and ecological effects of the tsunami identified and capacities of government agencies, civil society and local communities built for holistic and integrated coastal area planning. Environmental sustainability concerns incorporated in livelihood activities and environmental risk reduction and restoration strategies developed.*

1.1 Project Scope & Partners

The overall geographic scope of the study is the tsunami affected states of mainland India (states of Kerala, Tamil Nadu, Andhra Pradesh and the Union Territory of Pondicherry).

Phase II of the Post-tsunami Environmental Initiative includes five major components, namely (1) Land use and hydrology (2) Socio ecological studies (3) Policy analysis (4) Capacity building and networking, and (5) Pilot restoration initiatives.

The partners involved in the implementation of the programme in Phase 2 are Nature Conservation Foundation, Mysore (NCF), Ashoka Trust for Research in Ecology and Environment, Bangalore (ATREE), Citizen consumer and Civic Action Group, Chennai (CAG) and Foundation for Ecological Research, Advocacy and Learning (FERAL).

1.2 Objectives Related to the FERAL Component

Spatial analysis and remote sensing are two components of the UNDP led coastal environment initiative programme that were implemented by FERAL. Both the components have direct relevance to post-tsunami reconstruction and ongoing policy discourse on coastal zone management and planning, coastal defences, bio-shields and environment. The objectives and brief description are provided below;

To conduct a broad scale assessment of the environmental impacts of the tsunami using GIS and remote sensing.

The spatial analysis component extended and further detailed the work done in Phase I of the project. An analysis of coastal land-use changes across the entire tsunami affected region was undertaken using freely available satellite imageries. High resolution satellite imagery was purchased to extend the existing spatial database along the Coromandel coast. This data was used for field based investigations in two principal areas. A quantitative explanation of factors that determined run-up and inundation by the tsunami which provided important information on the role of barriers such as dunes and coastal vegetation or bio-shields. The second investigation dealt with vulnerability analysis which incorporated both the social as well as environmental and ecological parameters.

To build strategies for restoration of mangroves and other native coastal habitats through pilot demonstration sites.

The pilot restoration undertaken during the project attempted to demonstrate strategies to revive coastal vegetation and habitats within the socio-economic and environmental realities of coastal regions. The component involved planting along six sites along the Coromandel coast, each with a unique set of social, political, environmental and management conditions. The sites were located along backwaters, coastal sand dunes and extend landward to remnant patches of tropical dry evergreen forests.

1.3 Stakeholder Networks for Restoration of Coastal Habitats

The success of the project we envisaged was by forming crucial networks with the state forest department (Principal Chief Conservator of Forests), local forest officials (District Forest Officers), NGOs and the community. Necessary permissions to undertake research and collect mangrove propagules from designated forest areas were obtained through facilitation from UNDP and throughout the project period, the forest department were kept informed through timely reports on various research and implementation activities.

Since, all the restoration activities were implemented on community areas (common property) available in villages along the Coromandel Coast, it was imperative to develop a good rapport with the Panchayat level institutions to ensure sustainability. This we achieved through frequent micro-planning meetings with the Panchayat heads, village leaders (traditional leaders) and SHG group members and by making them participate actively in the restoration activities.

Advocacy, through participation and presentation of the project activities in stakeholder workshops, both at a regional and national-level was an important activity throughout the project period. Project presentations were made at the UNDP-PTEI partner's workshops in Chennai and also at donor organisations like International Development and Research Centre (IDRC, Canada) at New Delhi. Meetings and workshops were held at local-level as well (Nagapattinam and Pondicherry), where the project activities were presented to village leaders and forest department officials. These activities were covered in the local news papers also.

A conscious strategy adopted by the project has been to maximise the exposure of community and government representatives to the project areas and to share experiences with these representatives. As part of this process, a field visit was organised for the Wildlife Warden of Guindy National Park who is proposing to take up restoration of parts of the park and wanted to see the strategies and techniques

Figure 1.1: Prelimnary surveys involved discussions with various stakeholders and visits to each of the sites. These visits helped us understand the social dynamics governing the administration of potential restoration sites and gave us a first hand impression of their ecological status.

adopted at by the PTEI project. The warden was accompanied by Dr.N.M.Ishwar the Project Officer - Energy & Environment of the UNDP-UNTRS office.

Field visits were taken to the Vadagram TDEF site, near Marakannam. This was followed by a visit to the Botanical Gardens of Auroville which provides technical support for nursery raising for the project. Mr. Paul Blanchflower and Mr. Santo from Auroville were the resource persons for the Botanical Gardens trip while various persons from the FERAL team participated in the field visit and subsequent discussions. A final visit to the mother nursery was made and a commitment to supply saplings to the forest department was given. This was followed up by the selection of saplings of various species by the Ranger from Guindy National park and the transfer of two thousand saplings to the park for transplanting.

1.4 Site Selection for Restoration

A detailed site selection protocol was planned to short list sites along the Coromandel Coast for restoration. Preliminary site selection surveys, addressing logistical (presence of a restoration patch), administrative (land ownership, control, etc.), social (willingness of community to participate, presence of SHG groups) and physical attributes of the sites (size of patch, distance from coast, etc.) were completed in 75 Tropical Dry Evergreen Forest (TDEF), 40 sand dune and 46 mangrove sites along the Coromandel Coast. This is covered in detail in a subsequent section of this report.

Of these, 3 TDEF, 2 sand dune and 4 mangrove sites were finally short-listed for restoration. However, one of the TDEF site, S. Pudhur, was dropped from the restoration activity after discussion with the community leaders due to interference from the local cricket team. In these sites detailed ecological assessments and participatory methods for social data were collected, which are mentioned in the subsequent sections of the report.

Figure 1.2: Micro-planning sessions, such as this one, formed the core of the community mobilisation and participatory planning done prior to physical activities. The resulting plans were the basis of a formal MoU between the restoration committees and FERAL and guided the activities taken up at each site.

1.5 Restoration Plans and Micro-planning

Based on the detailed ecological and social assessments, detailed restoration plans for each of the selected sites were developed following a methodology presented subsequently. The restoration plans were presented on maps with details on the exact number and type of species proposed for the village, protection for the site (fencing) and selection of SHG members from the village for active participation during the planting. The restoration plans and the micro-planning sessions laid the platform for planting and awareness activities. All the activities were carried out only after requisite permissions were taken in writing from the Panchayat heads. In all the selected sites for TDEF and sand dunes (4 villages) and 6 sites for mangrove restoration plans and micro-planning session were completed. Of these implementation took place in two sites.

1.6 Awareness Activities

Street plays

Services of a professional theatre group called Yatra from Auroville was used to conduct street plays at 5 TDEF, 5 sand dune and 5 mangrove villages (target according to the LFA was 10 villages) along the Coromandel Coast. The script of the street play was modified to suit each of the habitat type and the message sent across was that of the importance of maintaining these coastal habitats and in particular the community's role in protection of these habitats. The street plays attracted large crowds in all the villages where it was staged and the impact was instantaneous in most villages, the village Panchayat heads immediately after the street play expressed their interest in being part of the restoration activities. Video CDs of the street plays were made by Yatra and these were submitted to UNDP after the completion of all the street plays.

Figure 1.3: Street plays were probably the most effective of the awareness activities taken up by this project. The ability of this medium to reach out to the entire village and its flexibility which allowed us to make slide presentations during the play was utilised effectively.

Eco-monitoring Workshops

Eco-monitoring workshops were conducted in schools near the project sites. Awareness activities including campaign by school children at their villages on protection of coastal habitats. Students were trained in maintaining simple meteorological stations that were set up at the sites and were subsequently handed over the responsibility of maintaining a daily record of temperature, relative humidity and rainfall.

Posters and pamphlets: Posters and pamphlets on restoration and protection of TDEF, sand dunes and mangroves have been developed. These were translated to Tamil for distribution to the villages along the Coromandel Coast.

During the temple festivals, presentation and posters were exhibited to create awareness on protection of TDEF areas within the village (figure 1.5 showing an announcement during the temple festival at Vadagram). The presentations and posters included useful information on TDEF and the restoration activities activity undertaken as part of the UNDP-PTEI project.

1.7 Mother Nursery

A mother nursery was developed at the FERAL field office in Morattandi village. The nursery, consisting of three parts was developed on land that was leased for the activity. Several TDEF, sand dune and mangrove species are being raised in the nursery. All the activities in the mother nursery were carried out by SHG women from Morattandi. At the inception phase of the project, Shakti, a group from Auroville was envisaged as a resource organisation for providing technical assistance in raising the saplings at the nursery. However, as costs for this service was way beyond the proposed budget, it was decided to utilise the services of Auroville Botanical Gardens (ABG), a group which has worked closely with Shakti to be used for technical assistance and training in the mother nursery. Administratively, the nursery was monitored through registers that were regularly updated for number and species of

Figure 1.4: Eco-monitoring workshops were a mix of awareness generation, education and monitoring of environmental parameters at the restoration sites. Slide-shows about the project and the importance of coastal habitats were followed by hands on training sessions on using meteorological stations and a visit to the restoration sites. Processions such as this one (at South Pogainallur, a sand dune site) were made during site visits and further enhanced the awareness about the project in the participating villages.

Figure 1.5: Traditional drum beaters announcing the temple festival at Vadagram which was held inside the temple grove. The poster, showing watering of saplings, was one among many displayed at the grove and urged the community to protect the saplings. A slide show about the project was held in the evening and was well attended.

Figure 1.6: The mother nursery, established at the FERAL campus with the help of the Auroville Botanical Gardens, was the source of saplings for the entire project. The nursery was run by members of local self help groups supported by FERAL. These members were trained in a range of techniques from germination of TDEF and mangrove seeds to preparation and packing of saplings for transportation.

saplings raised, survival details (once a month), labour log book and purchase of soil and manure. A short nursery report was prepared on the methodologies adopted for raising and maintaining saplings at the mother nursery, which is enclosed with this report as Annexure A.2.

1.8 Formation of Eco-restoration Committees, Setting Up On-site Nurseries and Planting

Before the actual planting could begin, eco-restoration committees, consisting of a village animator, watchmen and two or three SHG women guided by the Panchayat head were formed. Subsequently, on-site nurseries (figure 1.7) were established to harden the saplings before planting. The eco-restoration committees were given training off-site training at Auroville Botanical Garden and on-site training by FERAL staff and SHG women from the mother nursery. The actual planting in the selected TDEF and sand dune sites began after the first North-east monsoon rains in October 2007. Planting in one selected mangrove site was initiated in the month of June 2008.

1.9 Maintenance and Monitoring

The village eco-restoration committees were given the responsibility of watching, watering and regular maintenance of saplings planted in the sites. Water for the sites were accessed by drilling auger wells or ponds near by and providing the committees with water pump for water the saplings on the site. Additionally, in the TDEF sites, fencing to protect plants from grazing was taken up.

Monitoring activity (figure 1.9 showing monitoring at Vadagram) was initiated to assess survival of saplings through a monitoring protocol, which is submitted as a separate report. At Karikulacheri, a sand dune site, one monitoring activity was completed after which it was handed over officially to

Figure 1.7: This site nursery at Kothattai housed the saplings for about three months. Local women were trained in the maintenance of the saplings and were involved in the day to day running of the nursery. The nursery was primarily used for hardening the plants prior to planting. It also served as an awareness tool and was constantly visited by villagers who were curious about the activities of the project and choice of species for the plantations.

Figure 1.8: Auger wells were dug at two of the sites to help tide over the hot, dry summer of the region. These inexpensive wells were fitted with a kerosene pump which was used to lift water for watering. The frequency of watering varied according to soil moisture and was as frequent as twice a week in the peak of summer. This investment proved to be highly effective and contributed to the high survival rates at the sites.

Figure 1.9: Monitoring of survival and growth was an important component of this project. The methodology followed for monitoring was based on a standard sampling design. Here we see measurements of girth, height and signs of grazing in a quadrat at Vadagram sacred grove (left) and a school student taking down meteorological measurements from a station set up at the school premises (right).

the Pondicherry forest department for maintenance and upkeep of saplings. Weather stations were established in schools at three sites, Vadagram, Kothattai and South Pogainallur. School children and the eco-restoration committees were trained to take readings in the weather stations regularly. Readings from these stations were part of the monitoring strategy wherein environmental parameters were tracked along with survival and growth.

1.10 Training and Workshops

Trainings on various topics addressing coastal habitat restoration were an integral part of the project. The various programmes held included training on nursery raising techniques for SHG women at Auroville Botanical Garden, Participatory Geographical Information Systems (PGIS) at Pondicherry University, training on environmental statistics and eco-monitoring training workshops with schools. The eco-monitoring workshop at schools was used as a platform for both training the school children on monitoring meteorological parameters and also as an awareness activity. These workshops were held in schools in all the TDEF and sand dune sites.

One of the other outreach activities conducted was an experience sharing workshop with the communities from TDEF and sand dune restoration sites. Three such workshops were held, one in Nagapattinam on Sand Dunes and a second in Pondicherry on TDEF and a final one on project completion at Pondicherry for all habitat types, in which community representatives, SHG members, Panchayat members and traditional leaders participated. The workshop at Nagapattinam was inaugurated by the District Forest Officer who addressed the participants and actively participated in the proceedings. Details of the first two workshop have been provided in Annexure A.1.

1.11 Logical Framework Analysis

The table below is a summary of project achievements against the targets set in the initial phase of the project. The LFA was revised in light of field realities. There were two major changes to the targets

Figure 1.10: Workshop on participatory GIS, held in collaboration with the Pondicherry University. A number of organisations and students from various departments participated in this event. The workshop included training on field techniques for participatory GIS and an introduction to open source GIS packages for vector and raster GIS. The monitoring workshop in schools (at right) included a presentation about the relevance of local habitats and was followed by a demonstration of various tools used for monitoring meteorological parameters.

which were:

1. An increase in the total area and number of saplings planted in TDEF and CSD sites and a corresponding decrease in areas and saplings planted under mangroves. This was done largely due to the delay in sourcing planting materials for mangroves and the inability to get permissions to work in areas of Puducherry and Parangipettai. The inability to take up planting at one of the sites due to blockage of the eastuary mouth also contributed to this. A detailed discussion on this has been presented in section 1.12.

2. An increase in the total number of villages covered during the various awareness programmes. There were many last minute withdrawals of villages, often within days of initiating the planting activities. This forced us to re-initiate the awareness effort in other potential sites.

Expected Outputs	Activities/ Methodologies	
Deliverables	Suggested Indicators	Achievements
OUTPUT 1: Post-tsunami coastal vulnerability studies at a spatial level completed	Identification of additional inundation points behind specific vegetation; Collection of training sites for the above vegetation types for supervised classification of satellite imagery; Installation of wind gauges at locations at varying distances from the coast and varying amounts of bio-shields before them; Regular collection of data and analysis after at least one cyclonic event.	
CD/DVD-ROMs of GIS database for open-access distribution to stakeholders and coastal area planners. 1. A report on the impact of the tsunami on coastal ecosystems and human communities. 2. A report on the roles of coastal bioshields and their putative role in protecting coasts from large weather-related disturbance events.	1. Spatial maps/databases made available to the government, NGOs and other stakeholders in usable forms. 2. Reports made available to policy makers for incorporating into management strategies.	1. DVD ROM interface completed. 2. Impact report completed.
OUTPUT 2: A spatial analysis of land use change and social change on the Coromandel coast of India over the last three decades completed.	Collection of additional ground control points for imageries; Geo-referencing of the images so we have three mosaics – 30 years ago, immediately post tsunami and one year or more after the tsunami; Identification of features on imageries and collection of ground points/training sites	
1. CD/DVD-ROMs of the database 2. Report on land use change on the east coast of India over the last four decades	1. Baseline data from spatial analysis made available for planning. 2. Lessons from the analysis made available for feeding into coastal management plans.	1. DVD ROM interface completed. 2. Completed.
OUTPUT 3. Sites identified for pilot restoration using and extending phase I results	Preliminary site selection on basis of phase-I results and additional satellite images; Meeting with government officials; Field visits and initial contact with communities, their representative and other stakeholders; Broad ecological assessments.	

Expected Outputs	Activities/ Methodologies	
Deliverables	Suggested Indicators	Achievements
1. Imagery based site selection for restoration completed using phase 1 results. 2. Required permissions obtained from government officials and local leaders for restoration. 3. Interested communities and other stakeholders identified. 4. Preliminary ecological assessments completed. 5. Final list of sites short-listed.	10 sites identified for pilot restoration projects.	1. Site selection completed (78 TDEF, 44 mangrove and 46 coastal sand dune sites surveyed). 2. Permissions obtained where possible. 3. Stakeholders identified. 4. Ecological assessments completed. 5. Sites shortlisted
OUTPUT 4: The local stakeholders are mobilised and their capacity built at selected restoration sites.	Street play, production of posters and pamphlets in English and Tamil, poster exhibition, public discussion, micro-planning workshop, training programmes, weekly meetings, quarterly training of trainers.	
1. Roadshow covering 10 Panchayats in selected areas. 2. Posters and pamphlets on restoration activities (4 each). 3. One micro plan/year for every eco-restoration committee. 4. Stakeholders (minimum of 3 individuals per site) trained in nursery raising. 5. Minimum of one SHGs (around 15 individuals/SHG) incorporated into programme or formed in each restoration site. 6. Site based resource persons (5 individuals/site who will act as animators) trained.	1. At least 10 Panchayats, 10 SHGs members and 3 individuals per site sensitised on eco-restoration and participate in the activities. 2. Increased awareness of local communities in coastal vegetation conservation	1. 15 villages covered by road show. Targets exceeded. 2. Posters & pamphlets published in both Tamil and English and distributed. 3. Microplans completed. 4. Stakeholders trained. 5. SHGs involved in all sites. 6. Animators trained.
OUTPUT 5: Institutional support and financial sustainability of project ensured through linkages with local and district authorities.	Bi-annual experience sharing workshop; Proposals for extending project activities prepared for government and non-government schemes; Annual workshop with community representatives, business (shrimp) representatives, district and state officials.	

Expected Outputs	Activities/ Methodologies	
Deliverables	Suggested Indicators	Achievements
1. Better coordination and understanding among local and government stakeholders. 2. Additional support and funds for extending project activities. 3. Collaborative management framework detailing linkages with local government bodies and departments towards long term sustenance of project activities.	1. 3 workshops organised with Govt and civil society representatives. 2. Proposals for extending project activities prepared. 3. District and other relevant institutions involved in dialogue for a collaborative framework.	1. 3 workshops conducted. 2. Draft proposal submitted to UNDP. 3. Local and state govt. involved where possible.
OUTPUT 6: Pilot demonstration sites for restoration of native coastal habitats established.	1. Collection of seeds and propagules. 2. Raising in bags or PVC pipes. 3. Hardening. 4. Transportation to planting site. 5. Raising of large mother nursery at FERAL (mangroves) and Shakti (TDEF). 6. Fencing with PVC/Chainlink. 7. Watering and watching. 8. Planting through local committees and hired labour. 9. Hiring backhoe or labourers locally. 10. De-silting and disposal/reuse of soil.	

Expected Outputs	Activities/ Methodologies	
Deliverables	Suggested Indicators	Achievements
1. Raising of TDEF and mangrove saplings in village based and mother nurseries 2. Fencing and maintenance of areas prone to grazing and desiccation. 3. 200,000 mangrove saplings planted covering approximately 20 ha. 4. 50,000 TDEF saplings planted covering approximately 10 ha. 5. About 10 ha of dunes stabilised. 6. 5km of drainage channels de-silted to a depth of running 1m at various sites.	1. 200,000 mangroves & 50,000 TDEF planted and maintained by SHGs and Panchayat. 2. 10 ha of dunes stabilised, 5km of drainage de-silted and maintained by SHGs and Panchayat. 3. Alternative restoration strategies demonstrated for feeding into government strategies and replication.	1. 90,000 TDEF and 200,000 mangrove saplings raised. 2. Fencing and gates put up on all sites as per micro-plans. 3. About 64,439 mangrove saplings and propagules planted over 14.42 ha. 4. 77,109 TDEF and coastal species planted covering 22.69 ha of TDEF and 10.2 ha of coastal sand dunes. 5. Prosopis (invasive exotic species) removed from 7.38 ha and drainage channels constructed for nearly 8,891m.

1.12 Challenges Faced and Lessons Learnt

A number of challenges had to be overcome to reach the present level of achievements for this project. These challenges are, by and large, a reflection of ground realities and therefore provide a valuable set of lessons for similar efforts at habitat restoration or community based natural resource management in general. Overcoming these challenges involved continuous adaptations to the original project strategy, re-allocation of resources and revisions to the original targets and outputs.

Sourcing Planting Material

Tropical Dry Evergreen Forest

There are few organisations along the Coromandel coast who have a stock of TDEF saplings and the expertise to successfully maintain a nursery of TDEF species. Many of these organisations are located in the international community of Auroville and are closely associated with the "green works" or re-forestation programmes run in the region. FERAL had negotiated support for setting up its mother nursery with one such group. However, when the project was finally initiated, the costs that had been agreed upon earlier had been increased four fold and we were forced to re-negotiate with another organisation, the Auroville Botanical Gardens. The latter not only supplied us with the desired number of saplings but continued to support the project through building capacities of FERAL in setting up and maintaining a nursery.

This however resulted in a delay in procurement of saplings for the TDEF plantations, and we were forced to plant saplings which were under six months of age. Fortunately, the summer of 2007 was comparatively mild and had intermittent showers throughout the year. The provision of adequate care during planting by including large amounts of compost and mulch and after care through watering and protection from grazing also contributed to the high survival rates.

Mangroves

Another serious problem faced by the project was the denial of permission to collect mangrove propagules and seeds from within protected areas. The Forest Department made this decision owing to the lack of planting material for its own use, however it took eight months for this to be conveyed to FERAL, leaving us with no option but to postpone the mangrove plantations by a year. The fallout of this decision was a re-working of the deliverables and the increase of area under TDEF and dunes and numbers of TDEF saplings planted with a corresponding decrease in numbers and areas under mangroves.

The lack of planting material was overcome by contacting the Kerala Agricultural University who supplied the required number of saplings and seeds. However these were very small in size and we were forced to transplant very young saplings in the first year resulting in extremely high moralities. Moralities were also high due to other environmental factors discussed subsequently.

Handling and Hardening

The manner in which saplings are removed from beds and transported, in bags or bare-root, the stress they are exposed to during transport and subsequent conditions during their hardening at the site nurseries can make a substantial difference to their survival. Minimising the stress on the plants is crucial during transportation. The organisation of transport, including the loading and loading of saplings and their conveyance to the site are an important part of this. We faced a number of logistic problems in the initial phases of this project leading to high mortality of plants during transportation to site. This was particularly pronounced in mangroves which were younger and transported “bare root”.

After determining that the major cause for mortality for the mangroves was the handling and transport, we adopted a number of measures to reduce stress for the plants. These included:

1. Careful removal of plants from the beds to minimise damage to the roots.

2. Removal of leaves from the plants prior to their removal from the beds and to reduce transpiration and consequent moisture loss.

3. Reduction of loading times by hiring smaller vehicles for transportation and shipping smaller quantities at a time.

For TDEF saplings which were transported in bags, we ensured the bags were handled carefully and packed so that there was minimal shifting and movement during the transportation.

Conflicts within the Villages

One of the problems that we were unable to deal with, largely due to the short timeframe of the project, was the conflicts which occurred within the communities. A number of sites had to be abandoned after a substantial effort had been expended in surveys and mobilisation. We faced different kind of internal conflicts which can broadly be categorised as follows:

1. Political rivalries. These occurred between elected or traditional leaders (Ommiper, Cheyyur).

2. Conflicts over resource control. Work in the Karikulacheri site had to be abandoned soon after planting had taken place for dune stabilisation. This was because of conflicts with the neighbouring village which did not permit after-care of the planted saplings. Permissions to work in the site were withdrawn by the concerned officer after these conflicts surfaced and the teams were not even allowed to take photographs of the site for monitoring.

3. Resource competition. Available land was often contested for access. Thus we were made to abandon work in S.Puddur and Tsunami Nagar just before the actual planting itself. In the former, a cricket team wanted to use the site earmarked for plantations as their cricket ground. In the latter, there was a conflict between use of the land for defecation and parking boats and the digging of channels for planting of mangroves.

4. Traditional or feudal control. This was encountered in Chidambaram where the ownership of the concerned site was contested by a traditional leader, even though it was clearly marked as revenue lands in the records.

Thus a substantial amount of work was un-done at the latter stages of the mobilisation. This set the project back both in terms of physical targets as well as time and effort.

Deliberate Disruption

One of the unfortunate but real facts of implementing projects of this nature is that often persons who have an element of control on potential sites demand “favours”. We were forced to abandon a number of sites, particularly those in Pondicherry and Parangipettai area, because favours were demanded in exchange of permissions to take up restoration activities. Awarding contracts for activities such as fencing also forced us to confront various vested interests. The clear financial and administrative guidelines of the project ensured work was done in an accountable and transparent manner. However this had a cost in itself as much of the effort made in mobilising communities, surveying sites and building detailed restoration plans came to nought and had an adverse impact on the project outcomes. In particular, we had to withdraw from five mangrove sites after the formation of restoration committees and completing the entire mobilisation and awareness generation. This had a direct impact on the area and numbers of saplings we were able to plant.

Corruption, in its various forms, is a difficult issue to tackle. It however needs to be noted that levels of corruption were higher in areas which had received tsunami related funding for relief and rehabilitation. The transparent structure followed for earmarking areas for restoration, involvement of a range of stakeholders in the restoration committees and well documented system of accounts and field activities were significant in successful restoration activities in various sites.

Environmental Factors

One of the most promising mangrove restoration sites in the project area was in the Kollathur village where mangrove restoration was attempted in the Ediyanthittu estuary. Owing to the blockage of the mouth of the estuary by a sand bar, tidal movements ceased and the water became increasingly saline and water levels dropped till large parts of the estuary were dry. There were algal blooms as the water began to recede during the end of summer (June-July). These algae smothered the saplings that had been planted in the site and the few surviving saplings died due to increasing salinity and dessication.

The situation was reversed with the onset of the monsoon. The sand bar prevented the fresh water from leaving the estuary and levels rose to one and a half meters above normal throughout the estuary, submerging the salt pans, fencing erected for the plantations and other saplings planted by other organisations on the opposite shore of the estuary. This status continued till the beginning of November 2008, when we finally decided to abandon the site for the year.

We hope that the expected runoff from the North East monsoon will be able to breach the sand bar and restore natural tidal flows into the estuary. Once this happens it will be possible to resume planting along the banks of the estuary.

Lessons Learnt

Perhaps the most important lessons learnt from the experiences of the past two years have been the need for perseverance in dealing with local communities and the necessity to mobilise and work towards a larger target than that specified in the project. It is clear from our experience that work in a high proportion (over 50%) of the sites will need to be abandoned at the last moment due to factors such as those listed above. Given this, it is important that project design recognises the risks and limitations and has the required amount of flexibility to accommodate last moment changes in strategies and

Figure 1.11: The water level at the estuary at the end of summer receded and algal blooms smothered the newly planted saplings (top left). The same place was flooded a few months later (top right), after the first monsoon shower (note that the photograph on top left was taken in side the fence and the second one outside it. Water levels rose to over a meter, yet the sand bar held (bottom left) and prevented the movement of tidal flows in and out of the estuary. Across the estuary is the Alambara fort (bottom right).

adoption of new sites and areas.

1.13 Organisation of the Report

This report draws from the past one and half years of the first phast of the PTEI project as well as other implementation projects that FERAL has been part of. It tries to distill our learning from these projects and presents the same in a non-scientific fashion in the executive summary and this chapter. Subsequent chapters dwell into the details of each aspect. We provide references and citation to available literature throughout the document. We have referred to literature on the subject where possible and a bibliography is provided for every chapter. The document is divided into two parts and ten major chapters, not including the executive summary, a brief summary of which follows:

1. Introduction

   The present section frames the report in terms of location and perspective and briefly describes its components.

2. Impacts
3. Restoration Protocols
   a) Administrative arrangements

      A brief discussion of administrative procedures that have been evolved in similar projects followed by our strategy and its pros and cons.
   b) Community involvement

      A review of the role of communities in restoration projects with a discussion on the constraints and field realities that moulded this projects strategy.
   c) Monitoring protocols

      Reasons to build sound monitoring protocols for such projects are reviewed with a description of what is being done under this project.
   d) Tropical dry evergreen forests

      A detailed analysis of TDEF, particularly along the Coromandel coast, drawing from the extensive knowledge base at our disposal[1]. This is followed by a status report on TDEF, planting strategies adopted and actual activities conducted during this project.
   e) Coastal sand dunes

      A review of CSD in India and particularly along the Coromandel coast. The challenges and threats to the ecosystem followed by the status and strategies followed by this project for their restoration.
   f) Mangroves

      A review of status of mangroves along the Coromandel coast. Challenges facing backwater systems in general and mangroves in particular and various strategies adopted for their restoration, both by other agencies and during this project.

[1]in particular Prof. N. Parthasarathy, Dept. of Ecology, Pondicherry University

Part II

Impacts of the Tsunami on Coastal Ecosystems and Communities

Chapter 2 Impact of the Tsunami on Coastal Ecosystems and Human Communities

Srinivas.V and Sunita Ram

Contents

2.1 Introduction

Background

The impacts of the December 2004 Indian Ocean tsunami has emphasised the importance of coastal zone vulnerability studies for better preparedness and disaster management in the event of such large scale natural disasters in the future. While a few studies have examined impacts along select areas of the Indian coastline after the tsunami, a comprehensive analysis of coastal vulnerability has not been conducted for the entire affected coastline (see Mukherjee et al., 2007b for details). An earlier study by Madhusudan et al. (2007) provides a comprehensive analysis of the impacts of the tsunami on coastal habitats, human lives and infrastructure. However it stops short by speculating the possible role of physical features that might have played an important role in influencing the observed impacts. This study picks up from where the earlier work stopped and here we examine how much of the damage incurred as a result of the tsunami can be explained by an index of coastal vulnerability, based on various physical parameter such as land form and bathymetry along the coast. This study also provides a baseline assessment of coastal vulnerability which is important given large-scale coastal modifications being proposed and implemented after the tsunami.

Coastal Vulnerability

The issue of coastal zone vulnerability has received much attention over the last two decades throughout the world with studies being initiated largely due to concerns of rising sea levels. Climate change models suggest an increase in global sea-level of between 15-95 cm by 2100 (Wigley and Raper, 1992). The recent assessment by the Intergovernmental Panel on Climate Change report a sea level rise of 18-59 cm by 2100 when compared to global sea levels for the period 1980-99 (IPCC et al., 2007). They also report that coasts are exposed to increasing risks in the form of coastal erosion due to climate change and sea level rise. Increased floods due to sea level rise are likely to affect millions of people and densely populated, low-lying areas of Africa and Asia are likely to be severely affected (IPCC et al., 2007). Driven by these estimates of sea level rise and given the fact that most coastal areas are densely populated there has been an increasing concern to identify and map areas that are vulnerable to such long term changes.

In the recent past the need to identify coastal vulnerability zones has further gained momentum and interest due to the increased damage caused by storms and tropical cyclones. A by Webster et al. (2005) shows a large increase in the number and proportion of hurricanes reaching categories 4 and 5 over the past 35 years. The largest increase occurred in the North Pacific, Indian, and South-West Pacific Oceans. On the other hand, the number of cyclones and cyclone days has decreased world over except in the North Atlantic during the past decade with a 20% decline in cyclone frequency over the last century reported for the Indian Ocean (Singh, 1999; Kumar, 2006). Although the increase in the periodicity of such severe storms and cyclone may not be to climate changes, the severity and impacts of such events are being witnessed world over (Hurricane Katrina in 2005 and Cyclone Nargis in 2008) and reemphasise the need for coastal vulnerability studies.

In the Indian context the need to carry out such studies has been recognised and gained impetus after the 2004 tsunami and have become more important with the proposed draft Coastal Management Zone (CMZ) notification by the Ministry of Environment and Forests (MoEF), (Ministry of Enviornment and Forest, 2008). Such assessments not only identify the most vulnerable settlements and communities but also pinpoints linked vulnerable industries which are likely to be affected by these extreme weather events. Results from such studies help in making more realistic predictions for future storm and sea level rises, and additionally have implications on insurance premiums, urban infrastructural design and emergency planning especially in regions where rapid urbanisation is occurring. However, there are very few studies that have assessed the coastal vulnerability of Indian coasts (Dwarakish et al., 2006; Hegde and Reju, 2007; United Nations Environment Program, 2006).

While the urgency for vulnerability mapping has been acknowledged there are no standard methods or guidelines that are being followed (Thieler and Hammar-Klose, 1999). The different approaches to estimating coastal vulnerability can broadly be classified into two categories namely, physical and socio-economic. The physical models classify coastal stretches into different vulnerability zones based on physical attributes of the coast (for example flood plain analysis). The socio-economic models assess coastal vulnerability based on factors concerning people, land use, or the economy (for example the Global Vulnerability Analysis, (United Nations Environment Program, 2006; Kumar, 2006)). A few studies have focused on developing techniques which incorporate both approaches (Cutter et al., 2000; Boruff et al., 2005). Models that rely only on physical parameters can further be categorised into two classes the static and dynamic models, with a few quasi dynamic models (http://www.pdc.org/atlas/html/atlas-viewer.jsp). Static models provide a snapshot of the predicted vulnerability scores whereas dynamic models incorporate real-time data to provide more realistic and accurate outcomes. Although the latter is more expensive and data intensive, they provide reasonable estimates for long term monitoring and baselines for planning. A number of approaches and different datasets have been used to make predictions, especially studies modeling the vulnerability of coasts to effects of global warming. Some approaches used earlier include, extrapolation of historical data (e.g., coastal erosion rates), static inundation modeling, application of a simple geometric model (e.g., the Bruun Rule), application of a sediment dynamics/budget model, or Monte Carlo (probabilistic) and simulation based on parametrised variables (see National Research Council (1990); Thieler and Hammar-Klose (1999)).

Each of these approaches, however, has its shortcomings or can be shown to be invalid for certain applications (National Research Council, 1990). Similarly, the types of input data required vary widely and for a given approach the required datasets might exist only at different resolutions, may be imprecise or may not exist at all (Nicholls, 1995; Thieler and Hammar-Klose, 1999), thus severely constraining the choices of approach that could be used. Although there is no clear stepwise methodology spelt out and given that a quantitative predictive approach is not available, the relative vulnerability of different coastal stretches can be quantified using basic physical information of the coast. Given this background, the objectives of this study were to adopt a simple and replicable approach in identifying vulnerable coastal areas in the tsunami affected states of Southern India, to see how well physical factors explain the loss of life and infrastructure during the 2004 tsunami and also, to develop an index which will address future issues related to sea level rise and storm surges.

Description of Study Area

The study area (Figure 2.1) used in an earlier assessment by Madhusudan et al. (2007) is retained here as it allows analysis of observed mortality and damage in the tsunami affected taluks in the states of Andhra Pradesh, Tamil Nadu, Pondicherry and parts of Kerala. The coastal zone in the study region is predominantly human landscapes and is known for their long history of human interference. The man-made habitats, besides human settlements are characterised by areas under agriculture, agricultural plantations, salt pans, shelter belts, and aquaculture farms. Interspersed are a few remaining patches of natural coastal habitats which comprise of sand dune systems, tropical dry evergreen forest (or littoral forest), natural scrubs and mangrove forests. The area is also dominated by various aquatic systems which include man-made tanks, canals, backwaters, sea grass beds and estuaries. (see Daniels et al., 2006 for details). The average human population density in these coastal taluks is around 1000/km^2 with a minimum of 121/km^2 (Chillakur, Andhra Pradesh) and a maximum of 22000/km^2 (Chennai, Tamil Nadu).

The study area is predominantly flat with gentle slopes, except for southern Kerala and northern Andhra Pradesh where relatively higher stretches of varied elevation are encountered. Although the study area is relatively a flat plain there is large amount of small scale local variations which are crucial while assessing the risk of inundation.

Rainfall along the Indian coast is highly varied. The West coast is wetter and receives bulk of its rain during the South-West monsoon whereas the relatively drier East coast receives most of its rainfall during the North-East monsoon. The minimum annual rainfall along the East coast is about 600mm whereas along the West coast it is 840mm. The annual averages also differ between the coasts (1020mm along the East coast and 2250mm along the West coast). Also, the East coast witnesses a higher number of cyclones than the West coast (figure 2.2). These cyclones contribute significantly towards the total rainfall received and also expose the coast to higher threats from storm surges. Both erratic rainfall and cyclonic storms along the coast contribute considerably to risks related to flooding. Earlier studies have also shown that there is considerable variation in wave heights which are associated with the monsoon system (Vijayarajan et al., 1976; Sundar et al., 1999; Shankar, 2000; Vethamony et al., 2000, 2006).

Impacts of the 2004 tsunami along the main land was as diverse as the coast itself - while the East coast suffered bulk of the damage and human mortality, the west coast was relatively less impacted. These impacts have been summarised in the earlier report by Madhusudan et al. (2007). The same authors and Daniels et al. (2006) also report the diverse nature of habitats affected by the tsunami.

2.2 Methods

In this study we make use of satellite imagery analysis backed up with ground truth data and other secondary GIS databases for deriving a composite index of vulnerability from major risk variables including coastal erosion, inundation and sea level rise. The datasets used for the different risk variables is detailed below. We further test how well the model performs in explaining the observed impacts of the 2004 tsunami.

Datasets

Erosion/Accretion

We used decadal mosaics of LandSat satellite images to assess the rates of soil erosion and accretion along the coast. The images corresponded to the post monsoon seasons for the time frame 1990-2000. The mosaiced images were subjected to standard procedures of geo-referencing and edge matching[2] before extracting coastal dune features. Given the lack of ground truth data for the two time periods, a supervised classification was not possible and would have proven unreliable if training site data from the current time frame was used to classify images. Also coastal dune systems were visually and spectrally easy to differentiate. These factors dictated the selection of unsupervised classification in both cases. Both images were classified, using an image processing software, into 16 categories using an unsupervised iso-clustering technique (Ball and Hall, 1965) thus allowing the use of similar techniques without any subjective judgement. The resulting images were reclassified into dune and non-dune categories to assess rates of change.

Geomorphology

We derived the geomorphology of the study area using a combination of landforms, soils and vegetation cover index (Normalized Difference Vegetation Index, NDVI). The coasts were classified into five categories 1) rocky and steep cliff coast; 2) medium cliffs and indented coasts; 3) alluvial plains; 4)

[2] The process where a spatial adjustment aligns features along the edge of one map extent to the corresponding features in an adjacent map extent.

Figure 2.1: Study area includes the coastal taluks of Andhra Pradesh, Tamil Nadu, Pondicherry and Kerala.

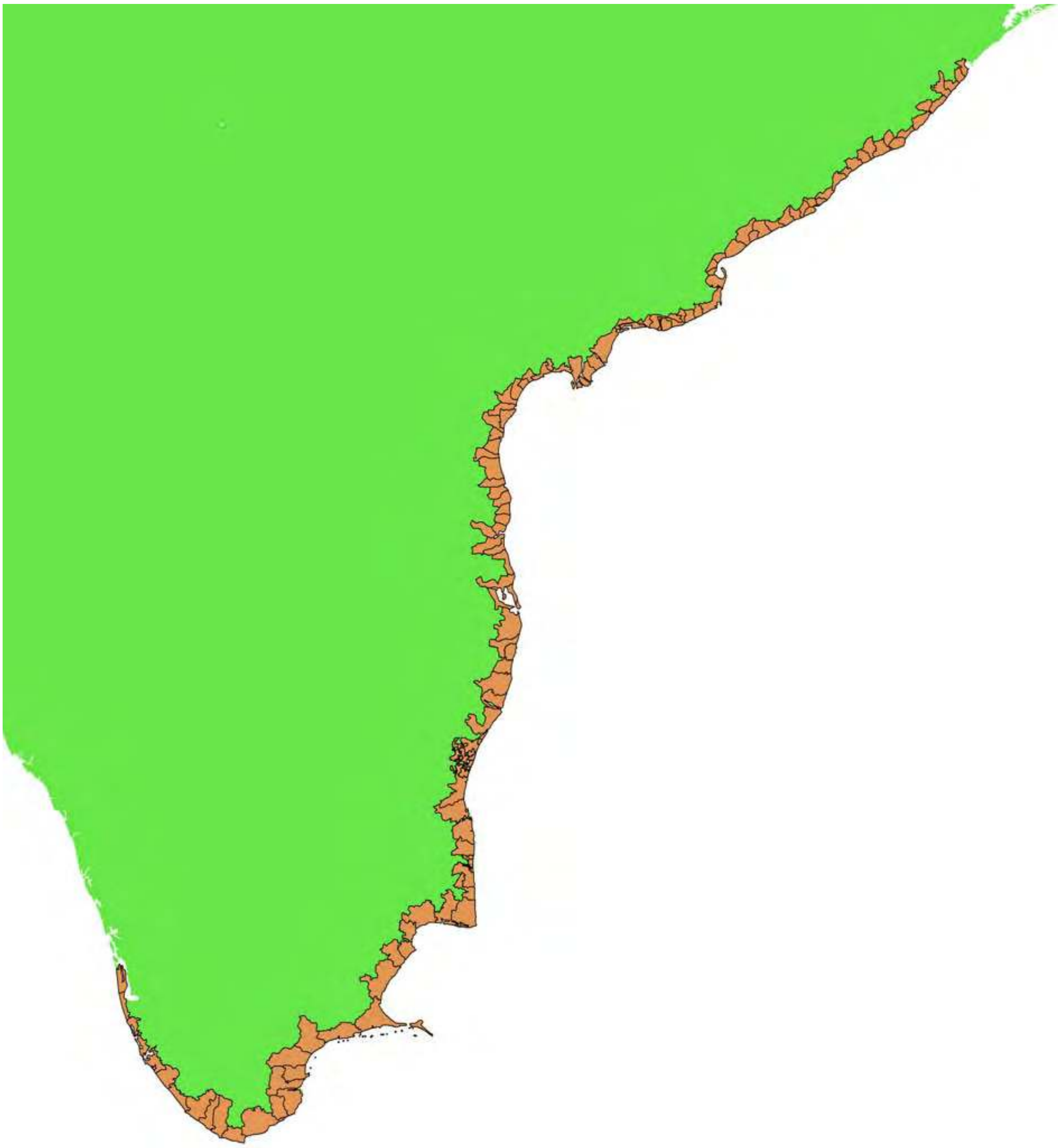


Figure 2.2: Number of potential cyclones observed for the period 1957-1997.

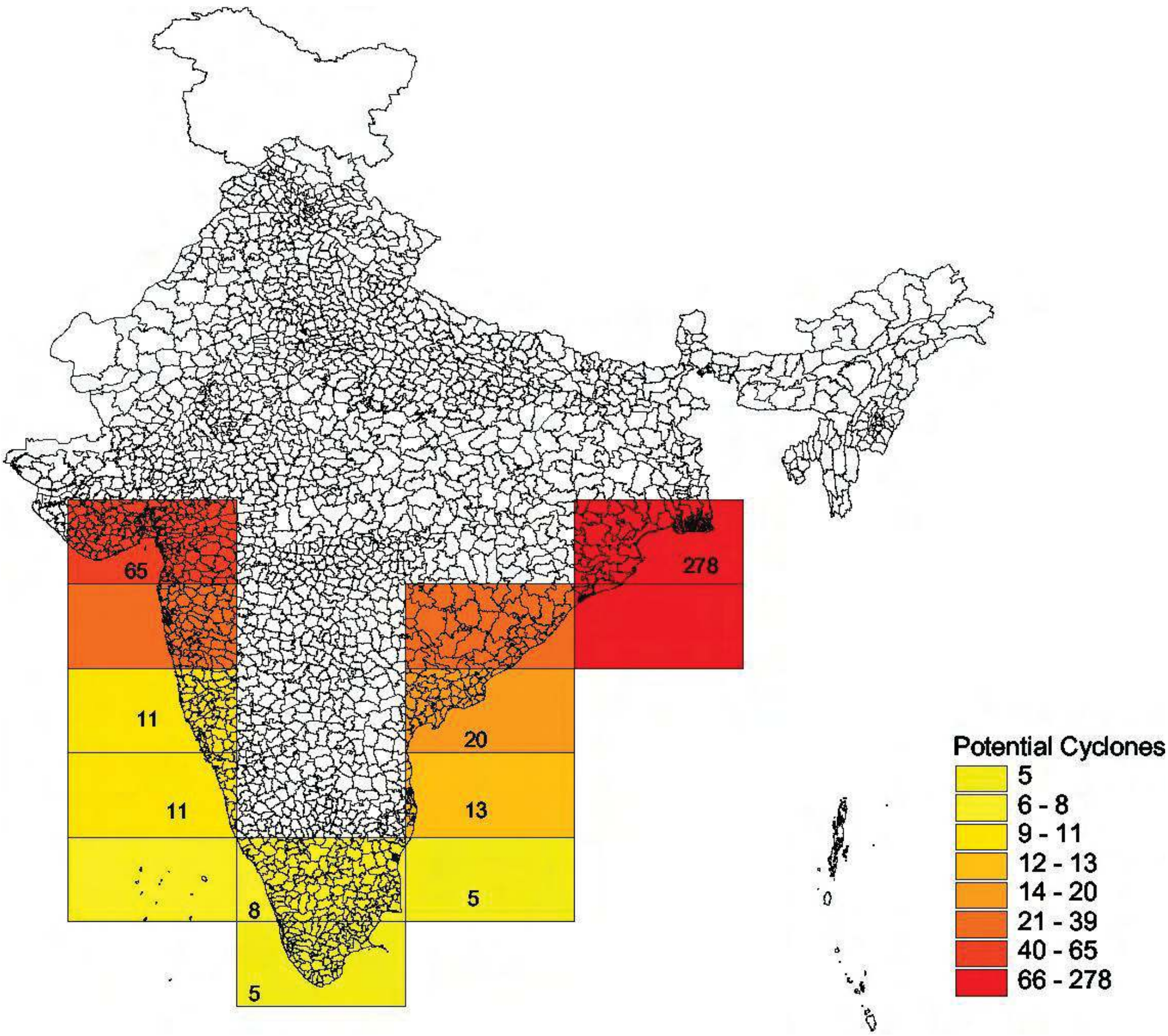


Table 2.1: Details of the six tide gauge stations along the East coast of India.

Station Name	No. of years of data	Spanning
Cochin	65	1939 - 2004
Tuticorin	26	1964 - 2002
Tangachchimadam	14	1969 - 1983
Nagapattinam	18	1971 - 1989
Madras	55	1916 - 2003
Vishakhapatnam	62	1937 - 2004

estuaries and backwaters; and 5) sandy beaches, mudflats, mangroves, deltas, coral reefs and salt marshes. The categories were further refined by a visual inspection of high resolution images.

Sea Level Rise, Tidal Range and Wave Height

The time series of tide gauge data was collated from the Permanent Service for Mean Sea Level (PSMSL) which is responsible for the collection, publication, analysis and interpretation of sea level data from the global network of tide gauges (`http://www.pol.ac.uk/psmsl/`). In order to construct a time series of sea level measurements at each station, we make use of the Revised Local Reference ('RLR') dataset which contains monthly and annual mean values of sea level for six tide gauge stations from southern India. Table 2.1 gives details of the stations. Additionally, available data sets from National Institute Oceanography and other published sources were collated. Tidal ranges were obtained from tide tables for the area.

While there are a few publications of wave heights observed during severe storms, monsoons and the 2004 tsunami itself along coastal Indian sites (Survey of India; Vijayarajan et al., 1976; Sundar et al., 1999; Shankar, 2000; Vethamony et al., 2000; Nagarajan et al., 2006; Vethamony et al., 2006), data on daily measurements of wave heights are restricted and not available from the Survey of India. The mean wave heights observed at these tide stations was compiled from various publicly available sources. The NOAA Wave Watch III model provided potential wave heights derived from model predictions (NOAA, 2008).

Regional Coastal Slope

The regional slope of the coastal zone was calculated from topographic and bathymetric elevations extending 50 km landward and seaward of the shoreline (figure 2.3). We make use of the SRTM (Shuttle Radar Topographic Mission) version 4 dataset for elevation (`http://srtm.csi.cgiar.org/`) with a horizontal resolution of 90m and a vertical resolution of 16m (Jarvis et al., 2004) and improved shelf bathymetry from National Institute of Oceanography (see Sindhu et al. (2007)). The regional slope not only permits an evaluation of the relative risk of inundation, but also the potential rapidity of shoreline retreat, since low-sloping coastal regions should retreat faster than steeper regions (Pilkey et al., 1987).

2.3 Analysis

The coastline was digitised from PAN sharpened LandSat ETM images and was used as a baseline for all further analysis. Although Global Shoreline Data (Satellite Derived High Water Line Data) is available for the Indian Ocean[3] the coastline was digitised to avoid issue of geo-referencing. To calculate the Coastal Vulnerability Index (CVI) we adopt methods similar to those developed by U.S. Geological Survey (see Thieler and Hammar-Klose (1999)). This approach is similar to Gornitz et al. (1994) and Shaw (1998). To calculate the index, a 1 km^2 grid was overlaid on the coastline and data from qualitative and quantitative sources were extracted. Data sets like sea level rise, mean wave heights and tidal range were restricted to few monitoring stations. A Thiessen polygon[4] was generated to assign data to each grid cell. In order to compute the slope from coastal plains to the continental shelf, the slope for each grid cell was calculated within a 5 km radius.

We followed an approach similar to that used by Thieler and Hammar-Klose (1999) to rank the coastline. The ranks were assigned based on data value ranges, while the non-numerical geomorphology variable is ranked according to the relative resistance of a given landform to erosion.

Erosion/accretion rates between -20% and +20% over the decade was ranked as moderate to accommodate for possible natural variations due to differences in sediment flows and other natural causes. Increasingly higher erosion or accretion rates were ranked as correspondingly higher or lower risk.

Relative sea level rise was ranked based on the global estimate of 1.8mm/year which is applicable to all coasts, the ranking reflected regional sea level rise to tectonic effects. Tidal range was ranked such that microtidal coasts were at high risk and macrotidal coasts were at low risk, a microtidal coast, is essentially always "near" the high tide and therefore always at the greatest risk of inundation from storms. Wave energy increases as a function of wave height, this was used here as an indicator of wave energy, which drives the coastal sediment budget. Thus wave height is a proxy indicating the ability to transport coastal material.

The data was ranked (table 2.2) and the coastal vulnerability index calculated as the square root of the geometric mean of the ranked variables:
$CVI = \sqrt{(a \times b \times c \times d \times e \times f) \div 6}$
Where:
a = Erosion/accretion
b = Geomorphology
c = Sea level rise
d = Mean tidal range
e = Mean wave height
f = Coastal slope

Finally, we tested how well the Coastal Vulnerability Index explains the observed impacts of the 2004 tsunami with respect to both human mortality and damage to physical structures.

2.4 Results

Of the 2400km of coastline covering 112 taluks spread across the states of Andhra Pradesh, Tamil Nadu and Kerala, about 88 percent of the coast did not show any erosion or accretion for the period 1990-2000 (figure 2.4 on page 40).

While a very small percentage showed accretion (areas around Mandapam in Rameshwaram district)

[3] http://www.nga.mil/portal/site/nga01/
[4] polygons whose boundaries define the area that is closest to each point relative to all other points.

Figure 2.3: SRTM Ver.4 data merged with improved shelf bathymetry data from National Institute of Oceanography.

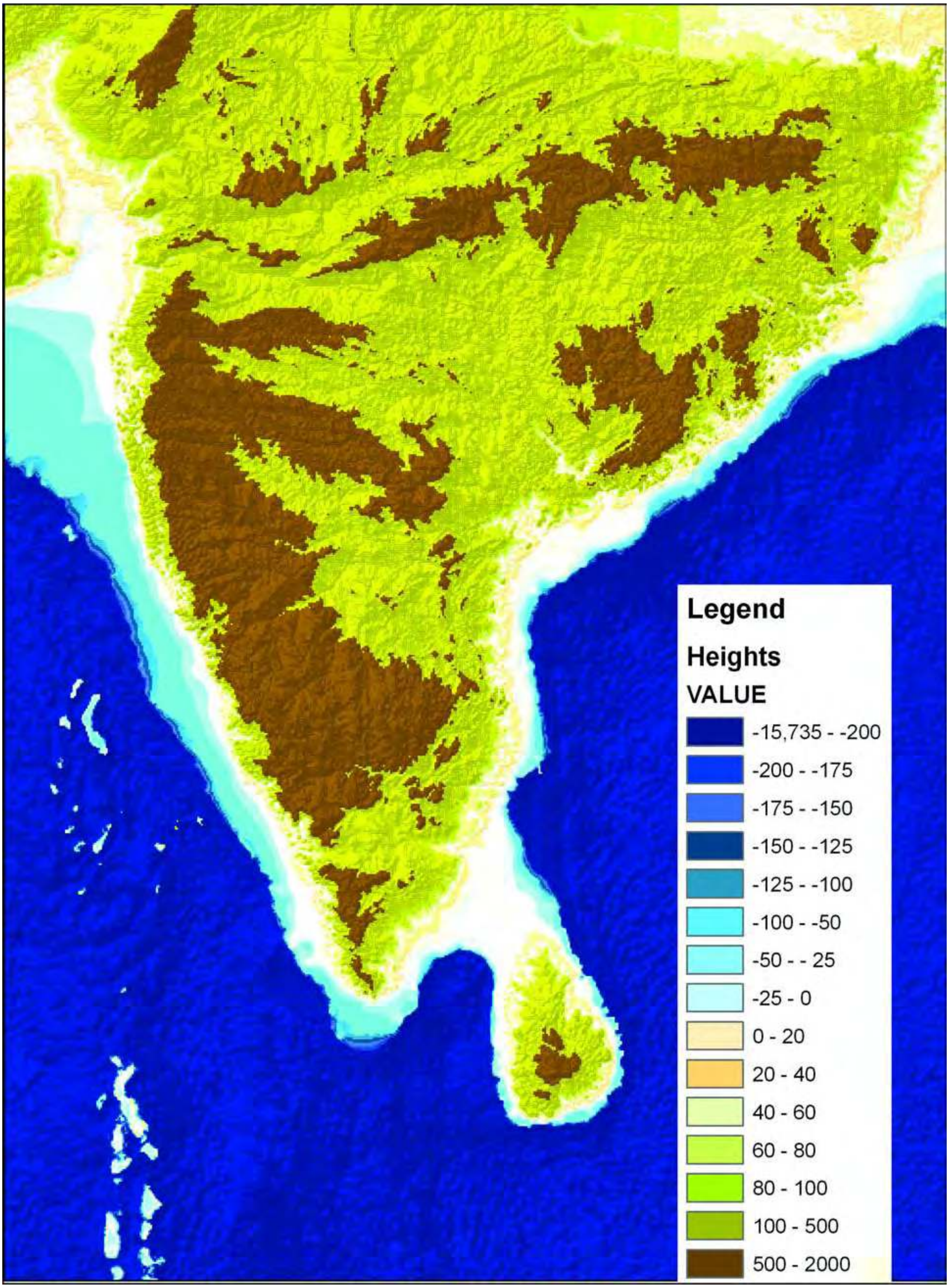


Figure 2.4: Coastal erosion and accretion across the study area between the years 1990 and 2000.

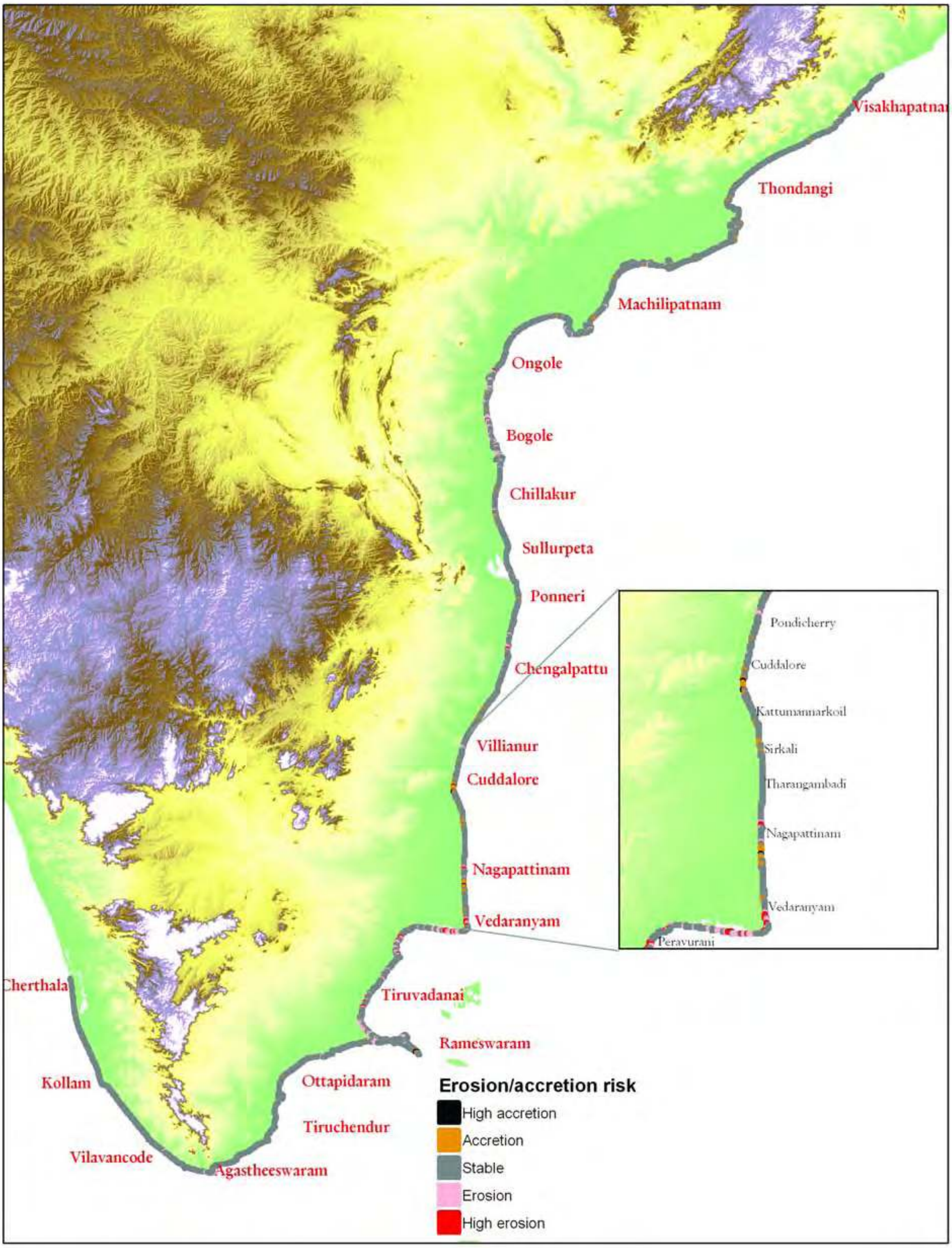
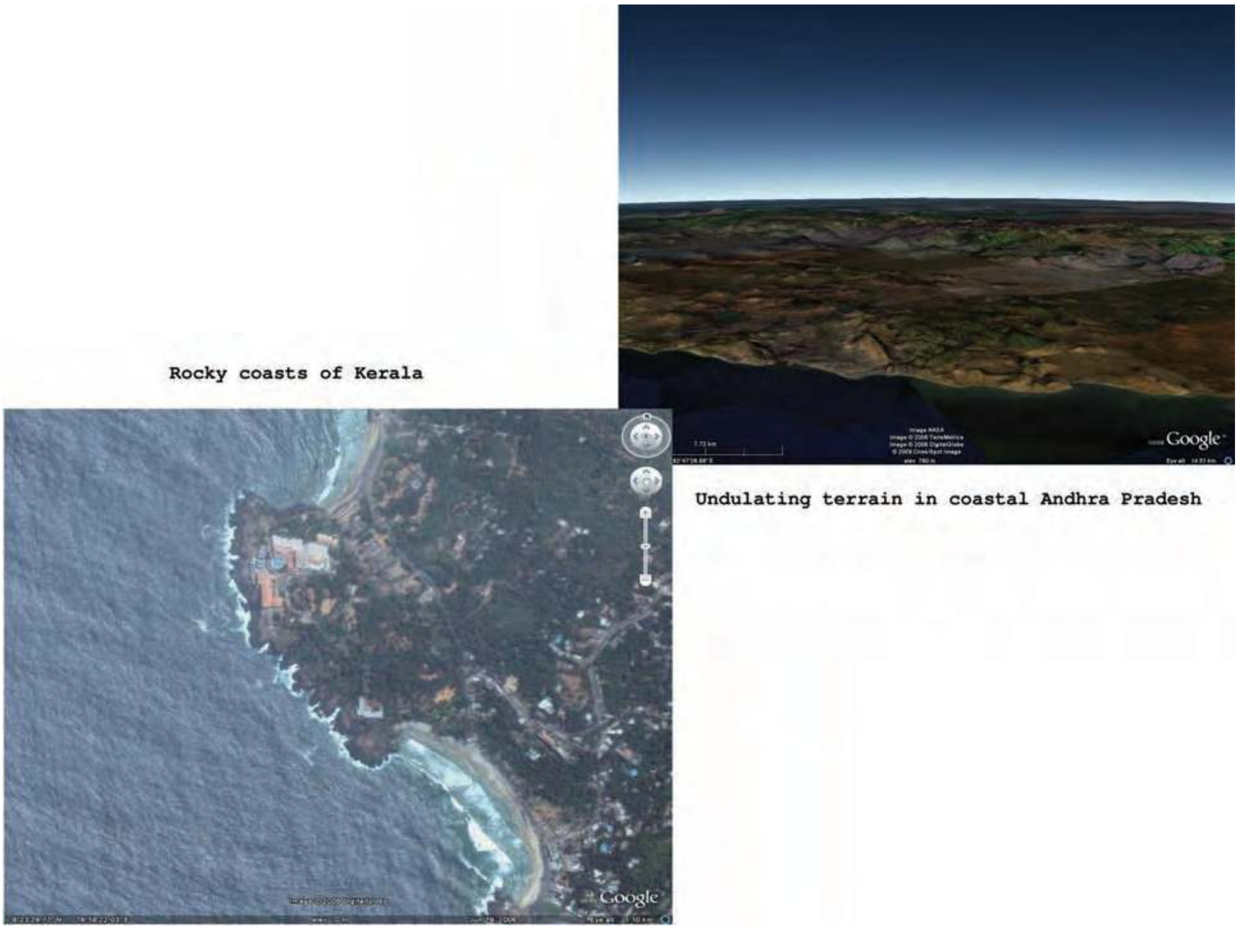


Table 2.2: Criteria for ranking of coastlines from 1 (very low vulnerability) to 5 (very high vulnerability) for each of the risk variables considered in this study.

Level of Vulnerability	Very low	Low	Moderate	High	Very High
Parameter	1	2	3	4	5
Erosion/Accretion (percent change)	100 to 50	50 to 20	20 to -20	-20 to -50	-50 to -100
	Accretion		Stable	Erosion	
Geomorphology	Rocky, steep cliffs	Medium cliffs, indented coasts	Alluvial plains	Estuaries and backwater	Sandy beaches, mudflats, mangroves, deltas, coral reefs and salt marshes
Sea level rise (mm/year)	<1.8	1.8 - 2.5	2.5 – 2.95	2.95 – 3.16	>3.16
Mean tidal range (m)	>6	04/06/08	02/04/08	01/02/08	<1
Mean wave height (m)	<0.55	0.55 - 0.85	0.85 - 1.05	1.05 - 1.25	>1.25
Coastal slope (%)	>1.611	0.681-1.611	0.323-0.681	0.160-0.323	<0.160

Figure 2.5: Examples of variation in geomorphology along the coasts.



during this period, nearly 10 percent of the gird cells recorded erosion (for example, coastal stretch around Muttupet and Point Calimere). The geomorphology expresses the relative erodibility of different landform types and it was observed that vast stretches of the coastline are highly susceptible to erosion as the predominant coastal features are sandy beaches, mudflats, mangroves, river deltas, and salt marshes. The rocky and elevated areas are noticed in parts of Kerala and Andhra Pradesh (figure 2.5 on the previous page). The regional slope which indicates relative risk of inundation shows nearly half the coastline is vulnerable to inundation. While most areas recorded a mean wave height of 1m, areas around Tuticorin and Nagapattinam recorded significantly lower wave heights (0.6m and 0.8m respectively). No macrotidal coasts are found along the entire coastal stretch and the study area is dominated by microtidal sites. Of these microtidal sites, areas around Nagapattinam have a tidal range of less than 1m and are highly vulnerable to inundation due to storm surges. Figure 2.5 on the preceding page provides further details of the above findings. All of the long term monitoring stations along the coast show low risks associated with increasing sea level (figure 2.6 on the next page) and estimated sea level rise is less than the global estimate of 1.8mm/year. Thus, the index reflects vulnerability due to inundation, tidal action and wave energy. These key variables are likely to determine impacts due to extreme weather events and tsunamis.

The distribution of CVI values are shown in figure 2.11 on page 47. Using quartile ranges of the CVI scores, the coastline was classified into low, moderate, high, and very high vulnerability categories. A total of 915 (38%) km of coastline is categorised as highly vulnerable of which nearly 410 km is classified as very highly vulnerable. Figure 2.10 on page 46 depicts the CVI values along the coastline. The most vulnerable areas are characterised by shallow coastal slope, low tidal range and waves with high energy, while the least vulnerable zones are characterised by higher coastal slopes and smaller waves. Figure 2.9 gives details of how each of the ranked variables contributes towards the characterisation of shore line. While almost all the variables used in developing the vulnerability index seem to contribute towards the overall vulnerability, erosion and accretion contribute more to the scores at finer levels of analysis, this is largely because most of the coastal zone has remained unchanged ($\pm$ 20% change) over the last decade.

Our analysis shows that the largest stretch of relatively less vulnerable zones are found in the southern most part of India between Kollam and Ramanathapuram. While relatively large stretches between Cochin and Kollam, Thuthukudi and Sirkazhi, Ulvapadu and Nagayalanka are highly vulnerable. Other areas are interspersed with zones of low moderate and high vulnerability.

Figure 2.11 on page 47 shows the recorded mortality at a taluk level and the corresponding vulnerability scores. Impacts of the tsunami were observed irrespective of the vulnerability categories that the taluks fell in. Our analysis shows that areas with high mortalities are associated with high or highly vulnerable zones, with the exception of Kanyakumari and Cuddalore which are classified as low and moderate vulnerability. A similar pattern is observed when damage to property is considered. These trends do not change when human densities for these taluks are taken into consideration. Although there is a weak positive relationship between the observed impacts and the coastal vulnerability index this is not statistically significant (figure 2.12 on page 47).

It is also important to note that irrespective of the surrogate used to measure the impact of the tsunami, a majority of the taluks with high levels of impact are those with coastlines ranked as moderate or high vulnerability.

Figure 2.6: Percentage distribution of coastline into ranks for risk variables (1 = very low risk to 5 = very high risk). A) Erosion/accretion, B) Geomorphology, C) Mean tidal range, D) Mean wave height and E) Coastal slope.

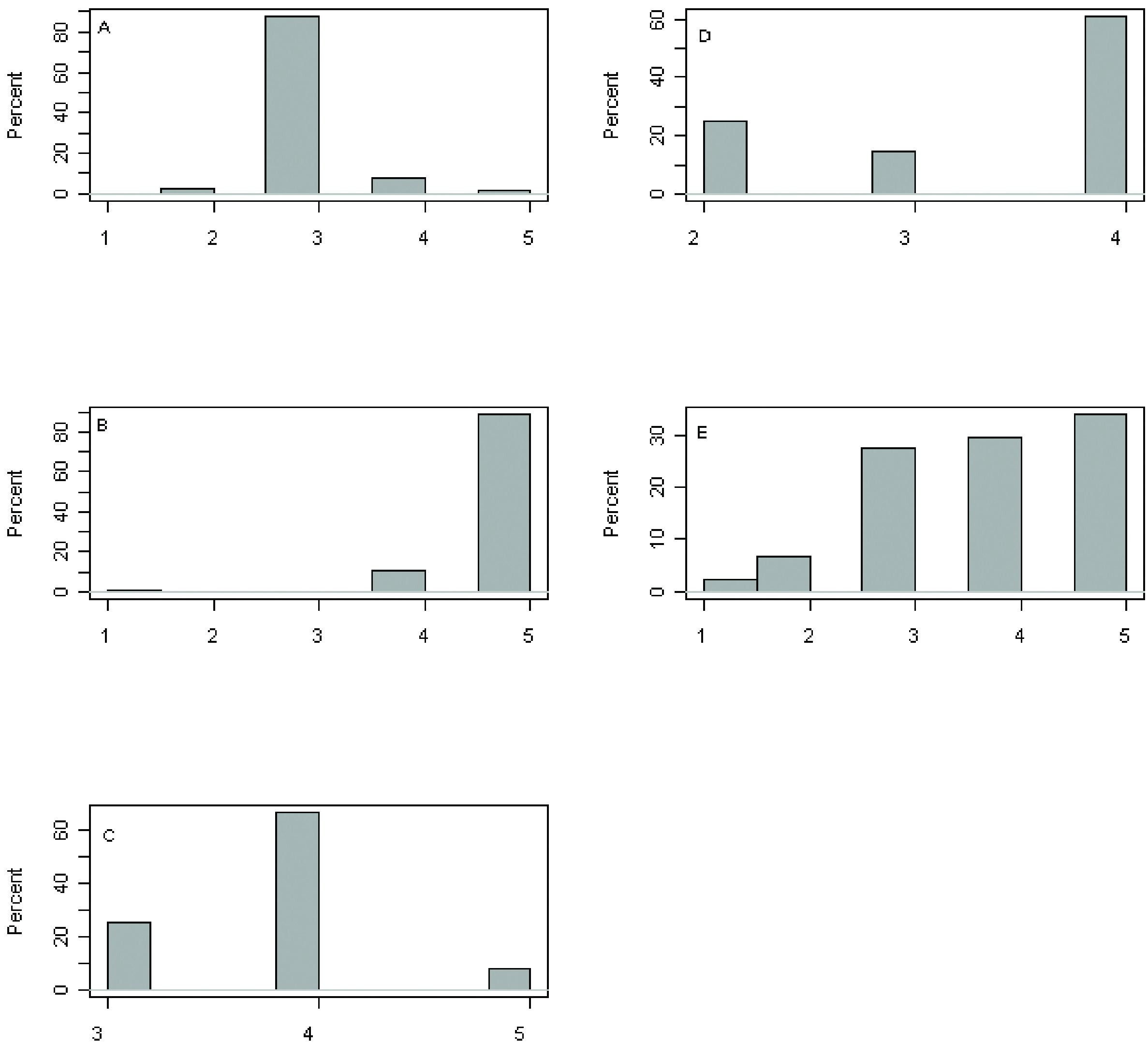


Figure 2.7: Sea level trends along the Indian coast.

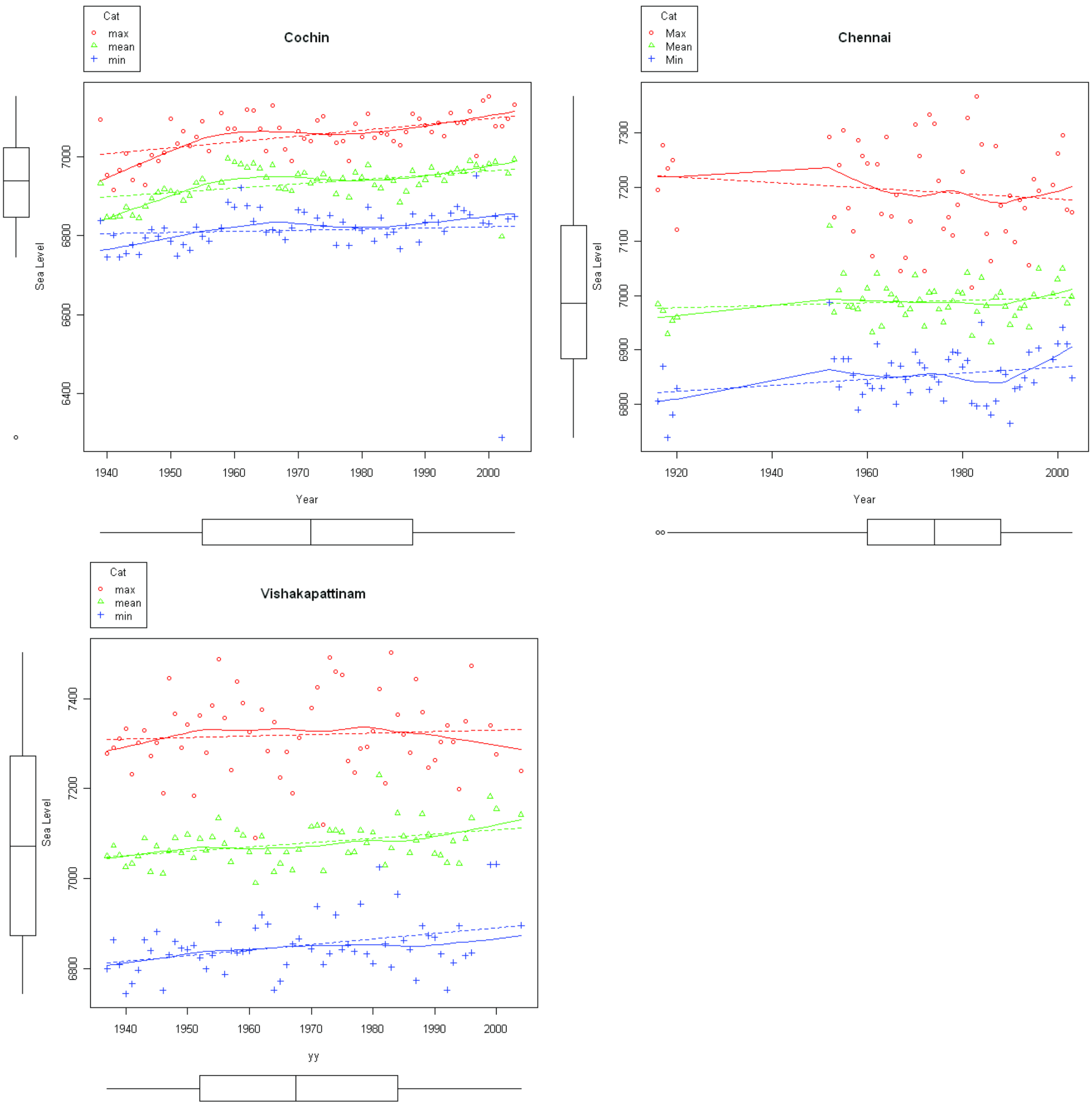


Figure 2.8: Percentage distribution of coastline into different vulnerability categories.

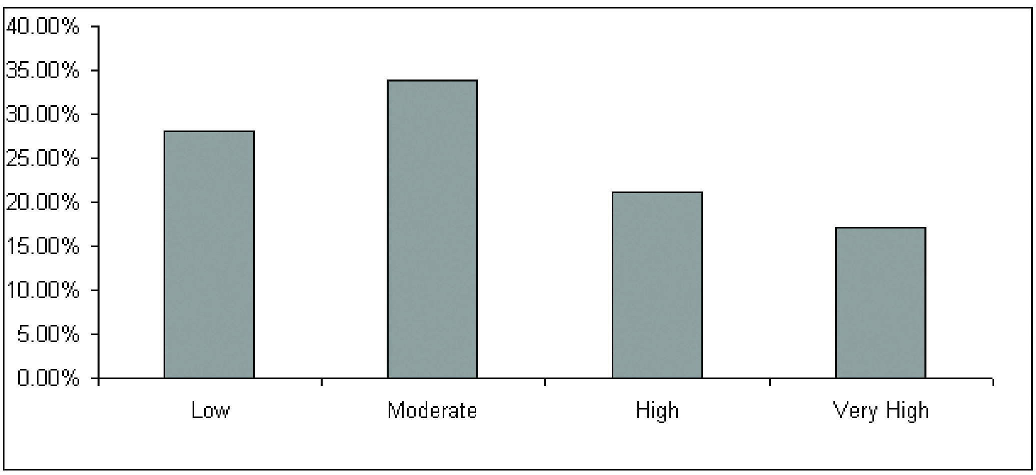


Figure 2.9: A decision tree indicating risk variables that contribute significantly towards the overall categorisation of the coast into vulnerability zones.

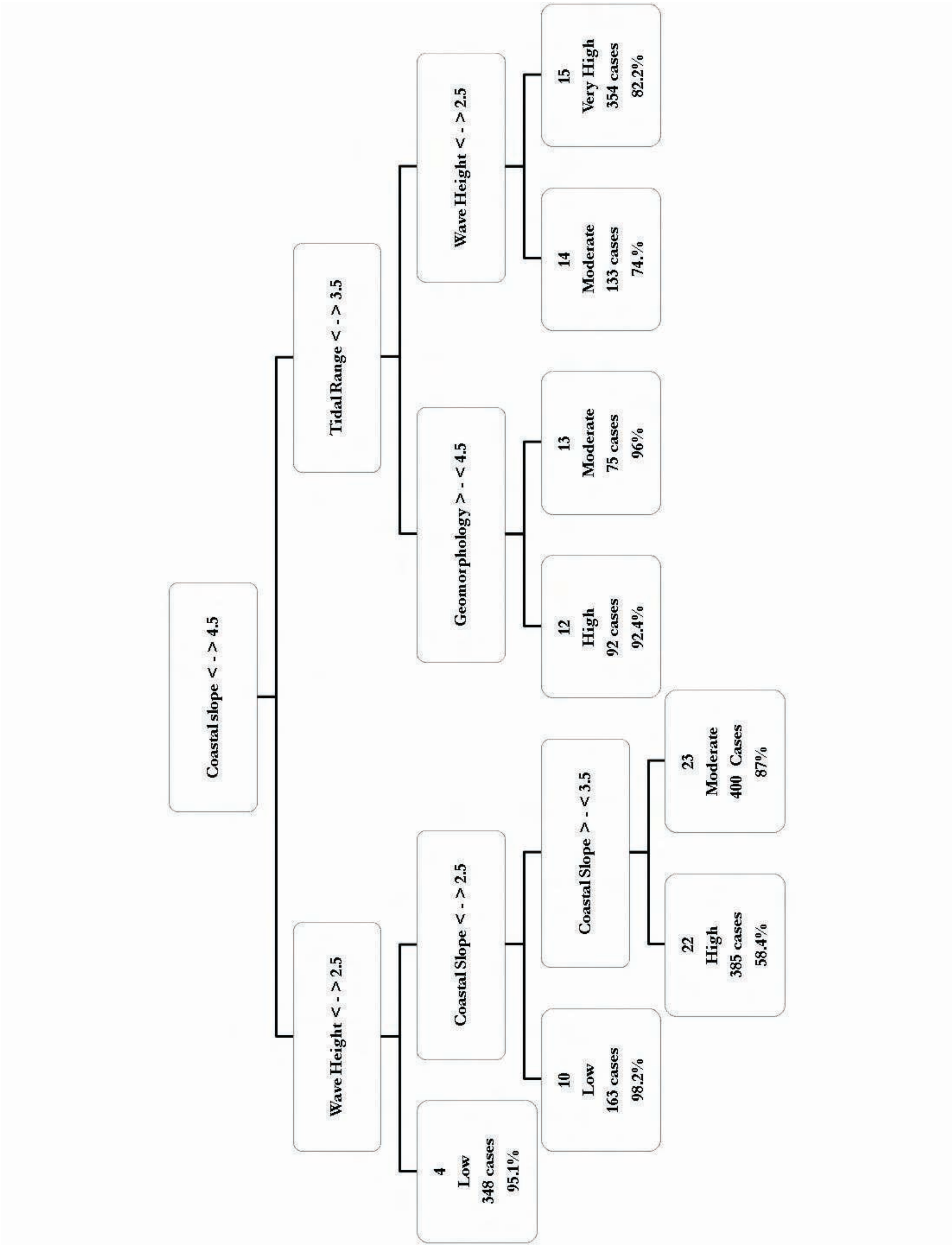


Figure 2.10: Coastal Vulnerability map of the southern coast of India which incorporates coastal erosion/accretion rates, geomorphology, wave energy, tidal range, topography and bathymetry.

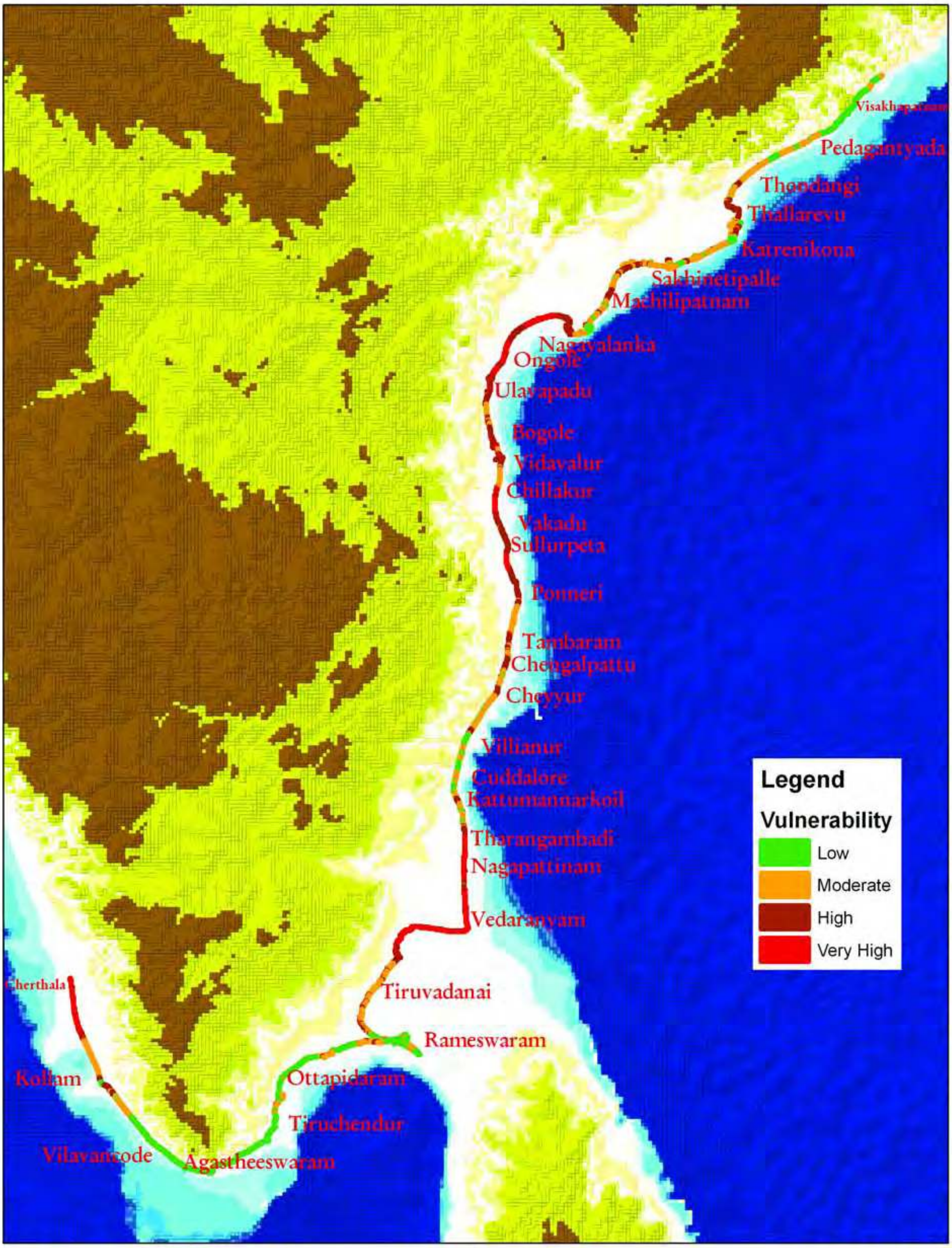


Figure 2.11: Mortality and damage caused by the 2004 Tsunami at the Taluk level and the corresponding vulnerability scores.

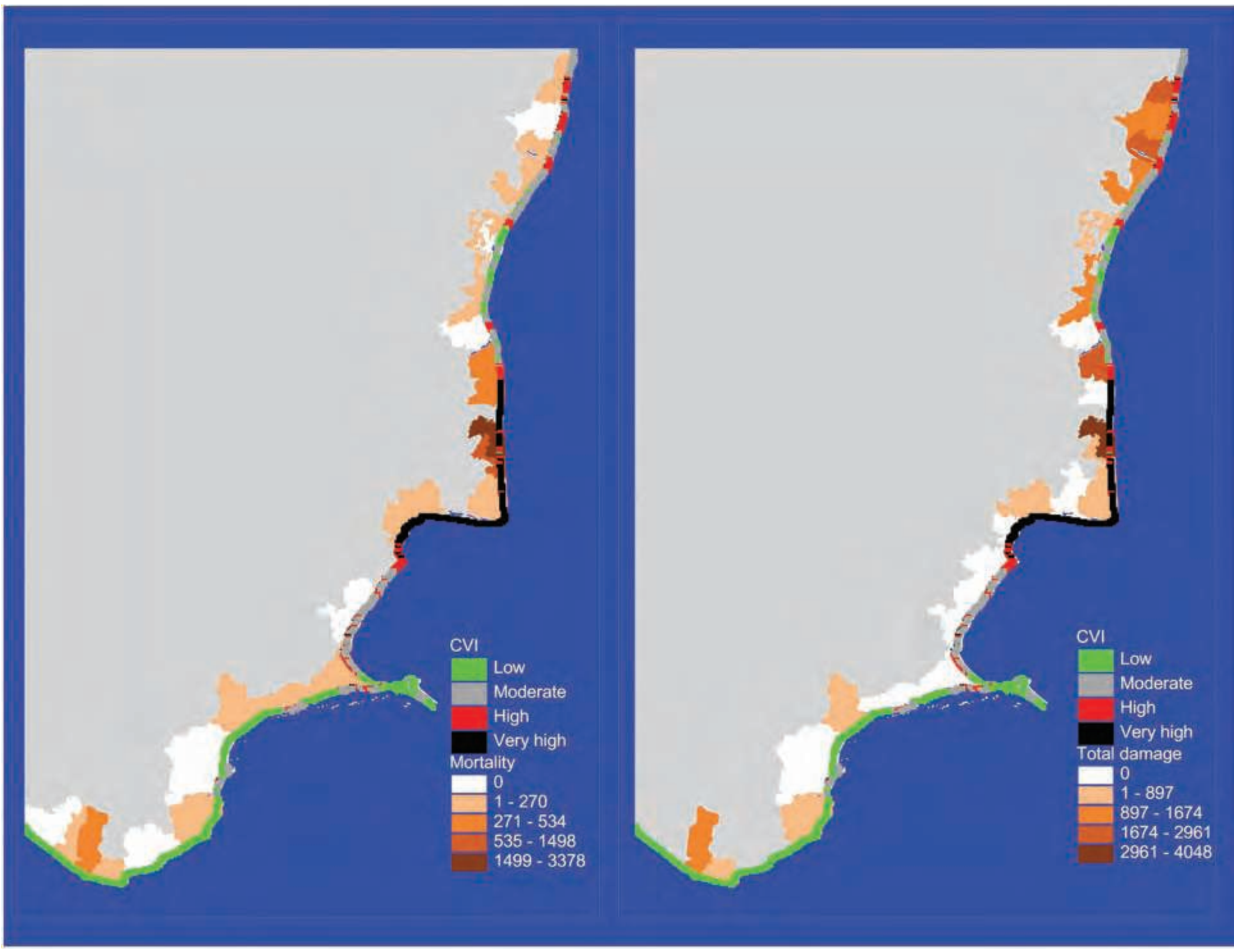
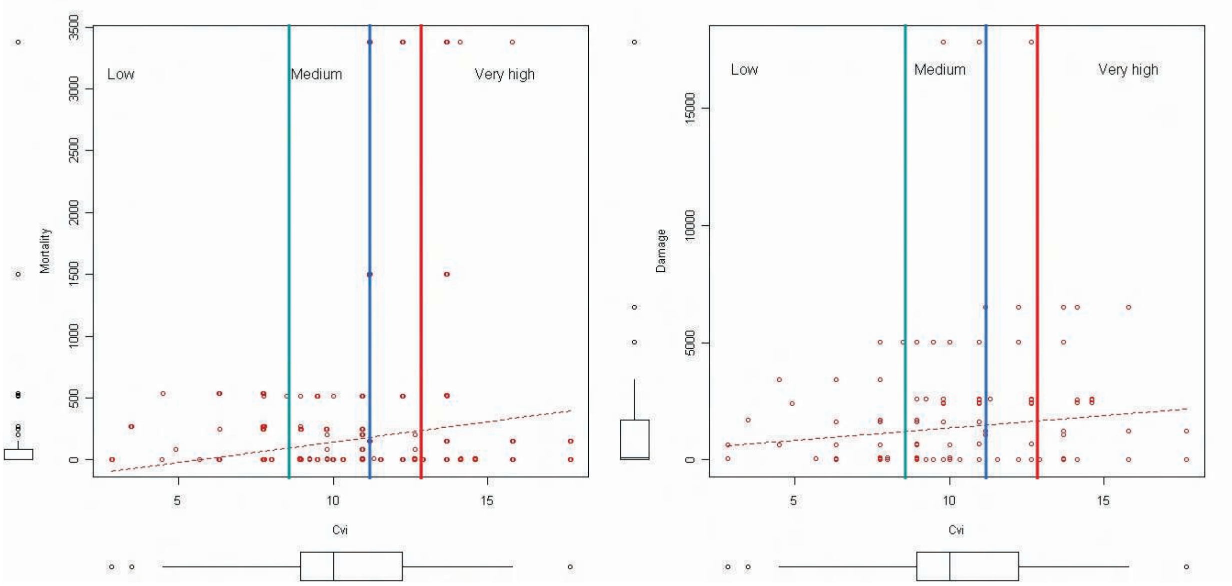


Figure 2.12: Although a weak positive relationship exists between the coastal vulnerability index and impacts (left: mortality and right: damage) caused by the 2004 tsunami, it is not statistically significant. The vertical lines represent the cut off points for different vulnerability categories.



Impacts on Coastal Ecosystems

There have been very few studies determining the impact of the tsunami or any other large scale natural disasters on coastal ecosystems which are predominantly human landscapes. To make an assessment of impacts, one requires to know the status of these ecosystems prior to the event. Unfortunately, there is very little baseline data available for the coastal stretches - barring a few locations with mangroves and tropical dry evergreen forests, virtually no base line is available for other ecosystems. This is compounded by the lack of information on distributional extent, key species of flora and fauna found here, disturbance levels, key disturbances, etc. Efforts to document coastal ecosystems did receive attention after the tsunami, but making good assessments of impacts has been hampered by the lack of proper baselines for comparison.

An exercise to determine the impact of the tsunami on coastal ecosystems will necessarily have to involve extensive field surveys to determine the exact nature and enormity of the impact, (if at all affected), on the ecosystems. Given that several years have passed after the event, field surveys at this point will be meaningless. Thus, it becomes necessary to employ other approaches. Analysis using satellite images was not possible either, as high resolution cloud free images for the coast was not available immediately before and after the tsunami. There has been one study by Daniels et al. (2006) that reports the impacts on coastal wildlife and associated habitats that they use. In this study, the coast line from Machilipatnam in Andhra Pradesh through coastal Tamil Nadu and Pondicherry up to Alapuzha in Kerala on the West Coast, was divided into twenty-three 50km segments (figure 2.13). Each of these segments was rapidly surveyed for habitat type and impact of the tsunami on it. This qualitative study was undertaken between February and May 2005.

There have been no other studies on the assessment of impacts of the tsunami on ecosystems. Hence, here we use information on ecosystems distribution from the Daniels et al. (2006) study and the coastal vulnerability index developed in the current study to determine which of these ecosystems is highly vulnerable in a future event such as the tsunami or cyclone and also to see how ground based assessments of impacts compare with the vulnerability index.

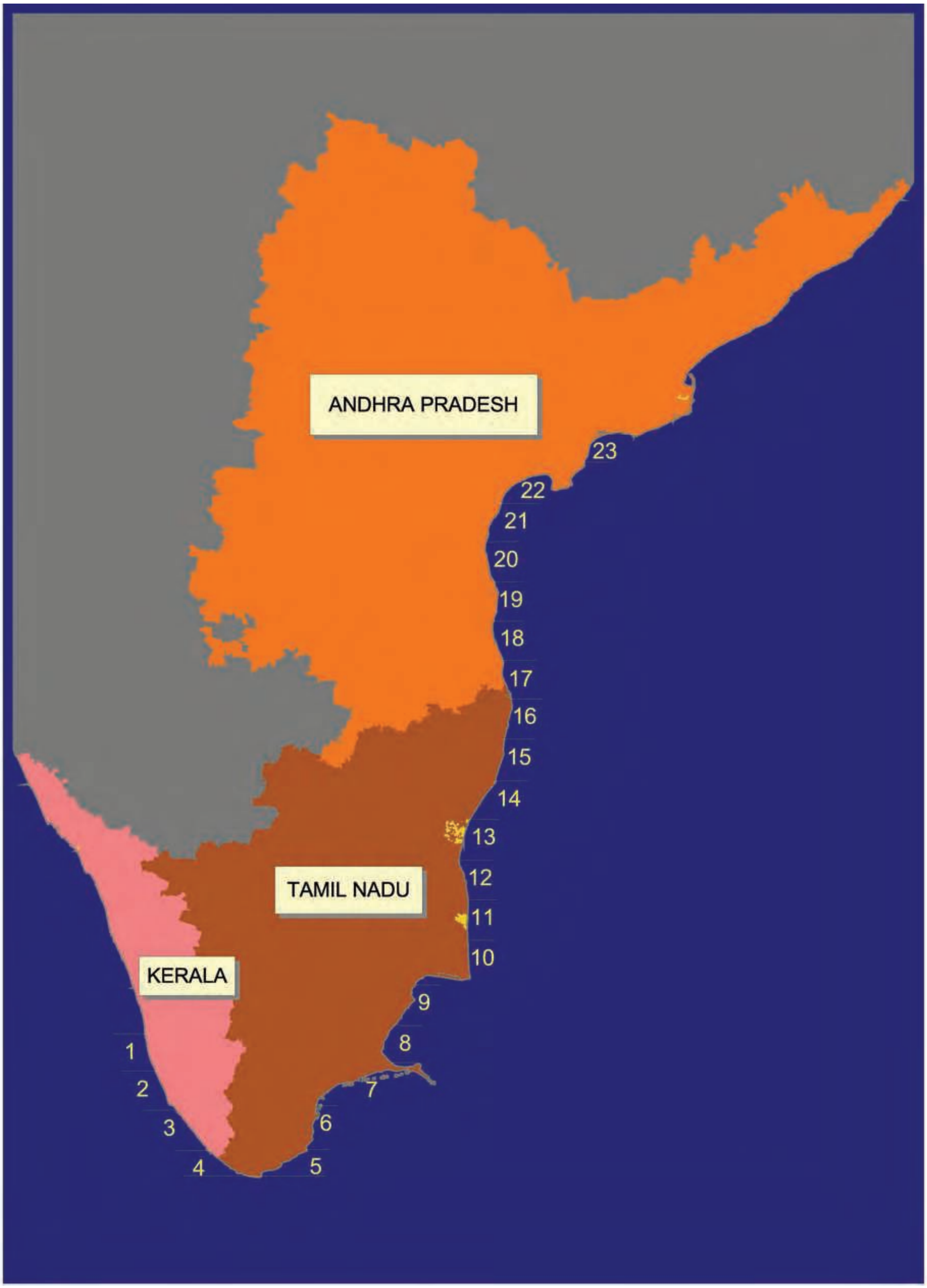
The types of natural terrestrial ecosystems that one comes across along the coast includes littoral forests, sand dune, grass / shrub ecosystems, and the types of aquatic ecosystems includes estuaries, creeks, backwaters, salt marsh, mangroves, sea grass, rocky inter-tidal, and fresh water pools / open wells. Man-made habitats that one finds along the coast includes, shelter belt and plantations, agricultural ecosystem, dykes and groynes, canals, salt pans, mangrove plantations, and aquaculture (Daniels et al., 2006).

Table 2.3 gives the predominant vulnerability index for each of the segments delineated by Daniels et al., 2006 and table 2.4 compares the vulnerability for each segment with the impacts reported for that segment in Daniels et al. (2006).

Based on the vulnerability index that was developed in this study, the segment 10 followed by the segment 11 are the most critical regions for ecosystems, both natural and man-made. Segment 10 which includes the region between Nagapattinam to Muttupet has all ecosystems and habitat types, while segment 11 which includes the region around Karaikal has all ecosystems other than sea grass and rocky inter-tidals.

Littoral forests in the regions between Nagapattinam and Muttupet, around Karaikal and Tarangambadi in Tamil Nadu and Pondicherry, and around Alluru Kottapatinam and Chirala in Andhra Pradesh

Figure 2.13: Coastal vulnerability is summarised for 50km segments (segments delineated as in Daniels et al. (2006)). This is then compared with the information for ecosystem distribution and impacts of the tsunami reported in Daniels et al., 2006.



are very highly vulnerable. Daniels et al. (2006) report moderate impact of the tsunami on the littoral forests in the Tamil Nadu belt, mainly in terms of soil erosion and temporary wilting of grasses and scrub vegetation, and no impact in these stretches in Andhra Pradesh. Similarly, the dune ecosystem is very highly vulnerable in the region between Nagapattinam and Muttupet, around Karaikal and Tarangambadi and Chirala. However, the impact of the tsunami on this ecosystem has been reported as moderate to high in these regions with no impact in the region around Chirala. Other regions where sand dunes were highly impacted were regions around Parangipettai, Pondicherry, and Pulicat with impacts in the form of breaches, change in species dominance, and wilting of vegetation. Based on our analysis, the grass and scrub ecosystems that are highly vulnerable are those in the region between Nagapattinam and Muttupet and in the regions around Alapuzha in Kerala. The impacts on the tsunami on this ecosystem has been reported as being low in Alapuzha regions, and medium to high in Nagapattinam-Muttupet region. However, a high impact has been reported from other regions including, Parangipettai, Cuddalore and Pulicat.

Aquatic ecosystems are very highly vulnerable in the same regions between Nagapattinam and Muttupet. In addition, the back waters and inter tidal zones found around Alapuzha also came under the very highly vulnerable category. Daniels et al report predominantly medium to high impact on aquatic systems between Nagercoil and Pondicherry, with coasts along Kerala showing low impact on estuarine ecosystems and back waters. Mangroves on the other hand have been reported to be most impacted in Tondi region (which shows up with a moderate level of vulnerability from our analysis) and around Parangipettai.

Other than identifying vulnerable ecosystems, the current study throws light on how the vulnerability index related to observed impacts of the tsunami along the coast for different habitat types. The overall agreement between the vulnerability index and the observed impacts to as recorded by Daniels et al. (2006) was 41%. With sufficient baseline data and quantitative assessments of impacts these results could have been improved.

2.5 Lessons Learnt

Erosion and accretion did not influence the overall vulnerability index at a very broad scale but it does contribute significantly at finer scales indicating local changes occurring at specific sites. In the present study we make use of percentage change in coastal dune systems as an index of shore line changes, a better estimate of the same could have been obtained through the use of very high resolution time series of satellite and aerial images to estimate actual shore line changes (`http://woodshole.er.usgs.gov/project-pages/DSAS/index.htm`). While the availability of such data was a constraint in this study we hope future initiatives (Ministry of Environment and Forest, 2008) will actually undertake a more exhaustive and in-depth analysis. Given that the effects of erosion and accretion was not noticed throughout the coast and bulk of it remained stable between 1990-2000 it is important to acknowledge that it is one of the parameters that is directly affected by human interventions. While the current study does not account for changes brought about by constructions of sea walls, groynes (figure 2.14) and other structures, it is equally important to include impacts of such engineering options (`http://czm.feralindia.org/?q=node/11`) on changes in coastline and therefore the overall vulnerability of the area. It is also important to note that erosion and accretion is affected by sediment flows from upland streams and rivers, changes brought about to these systems

Table 2.3: The vulnerability of ecosystems and habitat types along the coast. Segments are same as those delineated by Daniels et al., 2006 and data on habitat presence in a segment is from Daniels et al., 2006. X denotes the presence of the ecosystem type in that segment.

		Natural terrestrial ecosystem			Natural aquatic Ecosystems							Manmade habitats/ecosystems							
Vulnerability	Segment Reference No.	Littoral Forest	Dune Vegetation	Grass/Shrub	Estuary	Backwater	Creek	Salt Marsh	Mangroves	Sea Grass	Rocky Inter Tidal	Freshwater Pools and Open Wells	Shelter belt/plantation	Cultivation	Dykes/Groynes	Canals	Salt Pans	Mangrove Plantation	Aquaculture
Very High	1			X		X					X	X	X	X	X	X			
	10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	11	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X
	18																		
	21	X															X		
	22	X	X														X		X
High	12	X	X	X	X	X	X	X	X			X	X	X	X		X	X	X
	15																X		
	17		X	X									X						X
	20												X						X
Moderate	2			X	X	X						X	X	X	X	X			
	3			X	X	X						X	X	X	X	X			
	8	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
	9	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
	13	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X
	14	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X
	16			X	X	X	X								X				
	19												X		X				X
	23	X	X													X	X		X
Low	4	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		
	5	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X
	6	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	
	7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 2.4: Coastal vulnerability index for the segments delineated by Daniels et al and the level of impact reported in their report. L = Low; M = Moderate; and H = High.

		Natural terrestrial ecosystem				Natural aquatic ecosystems							Manmade habitats/ecosystems							
Vulnerability	Segment Reference No.	Littoral Forest	Dune Vegetation	Grass/Shrub	Beach	Estuary	Backwater	Creek	Salt Marsh	Mangroves	Sea Grass	Rocky Inter Tidal	Freshwater Pools and Open Wells	Shelter Belt/plantation	Cultivation	Dykes/Groynes	Canals	Salt Pans	Mangrove Plantation	Aquaculture
Very High	1			L	L		L							L	L	L				
	10	M	H	M	M	M	M	M	H	M			L	H	L	L	L	L	L	H
	11	M	M	H	M	L	M	L	M	L			H	H	H	L	M	L	L	M
High	12	M	H	H	M	M	M	L	H	H			H	H	H	L	M	L	H	H
	15														M		M		L	M
	17		H	H																
	20																			
Moderate	2			L	L	L	L						L	L	L	L				
	3			L	L	L	L							L	L	L				
	8	M	M	M	L	M	M	H	M	H			L	M	M	H	M	H	H	M
	9	M	M	M	M	M	M	M	H	M			L	H	L	L	M	L	L	M
	13	M	M	H	H	L	M	L	H	M			H	M	H	L	M	L	M	H
	14	M	H	M	L	L	L	L	M	M			H	M	M	L	M	L	L	H
	16			L																
Low	4	L	M	M	M	M	M	L	M	L		M	H	M	M	M		M		
	5	M	M	M	M	L	M	L	M	L		M	M	M	M	M		M		
	6	M		L	L	L	L	L	L	L	M		L	L	L	L		L		
	7	H	L	L	M	M	H	L	L	M			L	H	L	M	H	H	L	L

Figure 2.14: Groynes constructed along and to the North of the Pondicherry coast.

equally affect the overall sediment budget. With most of the river systems being harvested and bulk of the water being utilised it can only be speculated that sediment flows into the sea are already on the decline. Therefore problems affecting the coastline cannot be resolved through efforts along coastal areas alone. A more holistic and ecologically sound approach needs to be adopted.

The other parameter that did not contribute to the vulnerability index is sea level rise as most tide monitoring stations in the southern states did not show an increase, (Kochi 1.75mm/year, Vishakhapatnam 1.09mm/year, (Unnikrishnan and Shankar, 2007) more than the predicted global level of 1.8mm which we used as a benchmark to account for local tectonic activity. While sea level rise itself might not be of concern in the southern Indian context, be it a global effect or a more localised effect due to tectonic activity, it is important to note that some of the sites like Chennai have not shown a significant increase in sea level, and in addition, they also show trends of declining intra-annual variations, implying that the seasonal effect on tides is on the decline. This loss of seasonal variation in tides has been attributed to changes in monsoons and surface runoffs (Shankar, 2000), but the consequence of this is that such changes make the coastal stretches more vulnerable to extreme events throughout the year. This is important as tidal range is one of the important parameters that contribute to the overall vulnerability of the area.

Tidal range and wave heights used are based on model predictions rather than actual measurements. Availability of both these datasets is highly limited and amongst the few available sources, the best ones have been made use of here. While we use a more conservative estimate of both, it is well documented that both these parameters are strongly influenced by the onset of monsoons and also during extreme weather events (Survey of India, web page accessed: 2008 : Tsunami – Paradip port: 2.16m above chart datum, Vishakhapatnam port: 2.34m, Chennai port: $>$2.80m, Tuticorin: 1.62m, Cochin: 1.43m, Marmagao: 1.28m; Vijayarajan et al., 1976: Monsoon - Arabian Sea: 3.2 m and Bay of Bengal: 3.1 m; Sundar et al., 1999: storm 6-10 August 1981: surge of 0.75m at Paradip and 20cms at Vishakhapatnam).

The current study highlights potential sources that can change the coastal stretches during extreme events. With no previous assessment of coastal vulnerability being undertaken, this effort into understanding coastal vulnerability with respect to inundation, coastal line changes and influence of tides provides useful insights. This study improves our understanding of coastal vulnerability to extreme weather events like cyclones, tsunamis and sea level rise. The approach of using physical parameters to classify coastal stretches clearly highlights the importance of coastal slopes (elevation and bathymetry), wave energy, tidal range and geomorphology in determining the levels of vulnerability. While this approach was developed to understand the impacts of sea level rise due to global warming, the index also provides a good estimate of vulnerability due to extreme weather events as risk due to sea level rise was ranked low for the entire coast. The relatively flat coastal stretches with sandy beaches, estuaries, mudflats and backwaters are amongst the most vulnerable zones to future extreme weather and underwater seismic events. While these stretches are highly vulnerable it is the same stretches that are undergoing large scale conversions. For example most of the estuary and backwater systems are being converted to aquaculture and shrimp farms, coastal mudflats are constantly under pressure and are increasingly utilised for salt productions and sea walls are being constructed along large stretches of the coast. In addition, there are a number of proposals for new ports and up gradation of existing facilities, both of which are likely to change the erosion and accretion rates along the East coast.

While physical parameters do predict coastal vulnerability, the issue is further complicated with an increase in the number of people living along the coast, thereby directly exposing them to risks associated with extreme weather events. This is partially reflected in the inability of the current index in explaining the observed impacts in areas like Chennai and Kanyakumari which have relatively higher densities of people. This clearly highlights the need to develop a fine scale vulnerability index at a village or settlement level for better disaster management and planning to mitigate losses.

2.6 Future Steps

As a part of the National Disaster Management plan, it would be ideal if future programs invested in refining the resolution of some of the available data sets. There is a need to increase the number of tide monitoring stations and to add more data buoys along the coast to help refine the tide data sets. A dynamic and real time model which also monitors daily climatic, hydrological flows and off-shore weather conditions should be put in place with parameters used in this approach.

While this can be easily done, provided adequate budgetary allocations and a national mandate, the issue of increasing number of people being exposed to such hazards is more difficult to resolve and address. Policy level interventions are required to ensure that people are not unduly exposed to natural disasters. This also brings up the need to address issues of those who are already in highly vulnerable zones, to provide them with a better early warning system, emergency evacuation plans, and medical rehabilitation schemes that are badly needed, but currently lacking. The tsunami did highlight some of these issues and ensured a few steps were taken in this direction. However it is still a long way before we are equipped to cope with situations similar to the recent cyclones and the past tsunami.

To assess the impacts of natural disasters on ecosystems, baseline data for a period prior to the event is required. This is sadly lacking for the coastal ecosystems, but efforts to document coastal ecosystems has received some attention after the 2004 tsunami

Also, there are no frame works drawn up to put these baselines in place and there is a requirement to put together protocols to monitor each of these ecosystems, which will be the first step in gathering baseline information. Given that each of these ecosystems is unique, and the parameters that need to be recorded for each varies (for example, for a dune system, one will have to record the beach profile, species found etc. while for mangrove ecosystem, the tree species, its girth, sapling recruitment etc. will be required), a single and common protocol for all ecosystems will not be effective.

For long term monitoring and to study impacts of natural disasters on coastal ecosystems, it is necessary to first develop protocols for baseline data collection. This should be followed by identifying specific sites for each of these ecosystems that should be monitored for specific ecological parameters relevant to that particular ecosystem. Such long term data will in addition help us in understanding the impacts of climate change on these ecosystems. In addition to possible impacts on the coastal ecosystems from natural disasters like a cyclone or tsunami and from climate change, the large human population along the coast and the rapid rate of infrastructure and industrial development along the coasts, threats to coastal ecosystems are very high. Thus, efforts to record baseline information and monitor the remaining patches of these ecosystems are crucial for their continued existence.

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Chapter 3 Land Use Change on the East Coast of India Over the Last Three Decades

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Contents

3.1 Introduction

Few studies have assessed landuse changes in predominantly human dominated landscapes with most work focusing on land use changes in forested habitats with human settlements within and around them (Nagendra et al., 2006; Ostrom and Nagendra, 2006; Robbins et al., 2007). These studies have contributed towards understanding the drivers that bring about these changes and finding from these have implication for nature reserve management and management of biomass based resources. However, little is known about changes in land use patterns in predominantly human landscapes, especially the coastal stretch. While there are quite a few studies that have looked at urbanisation rates around cities using demographic data (Pathak and Mehta, 1995; Brockerhoff, 1999; Mukherji, 2001; Datta, 2006), there are very few assessments done on using spatial data (Lata et al., 2001; Bhagat and Mohanthy, 2008). Understanding what changes are occurring becomes especially important in vulnerable zones

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as changes to natural ecosystems make these man-made habitats less resilient in the event of natural disasters like cyclones, storm surges, floods, unseasonable rains and even the less frequent events like the tsunami. Although a few studies have looked into changes in cropping patterns and growth in shrimp and aquaculture ponds along backwaters (Bhatta and Bhat, 1998), there are none which assess changes occurring within the entire landscape and none to identify drivers that bring about these changes.

No comprehensive analysis of coastal vulnerability and changing vulnerability patterns along the Coromandel Coast as a function of changes in land-use has been done. Neither has there been an analysis of the potential implications these changes on human communities living along the coast nor the fate of coastal ecosystems. Given that some natural disasters like cyclones, associated floods and storm surges are likely to increase in their intensity and frequency with global climate change (Webster et al., 2005b). These human landscapes are in greater need to be resilient to cope with such changes more frequently. Thus the objectives to this study were - i) to understand the kind of landuse changes that have taken place in the last three decades along the Coromandel coast and how these relate to changes in coastal vulnerability, ii) to assess the implications of changing climatic patterns on land-use patterns and the potential future consequence of increasingly stochastic weather on coastal vulnerability, iii) understand the implications of various policies on the observed land use change.

For the purpose of the present assessment we considered both physical and socio-economic (largely economic) vulnerability that human populations are exposed to. Both aspects are equally important to understand how the observed landuse changes impacts people living along the coast and how changes in human communities bring about land use change. The spatial scope of this study was limited to the Coromandel coast covering the coastal districts of Chennai, Cuddalore, Kanchipuram, Nagapattinam, Thiruvallur, Villupuram and the state of Pondicherry.

Spatial Scales

The study was carried out at two spatial scales, one at the district level and the other at the taluk level. The time scale for the former was 1980-2000 the later was restricted to 1990-2000. This was driven by the non availability of both satellite data and digital census data at a finer resolution. The assessment of land use change at the district level was carried out using a time series of secondary data sources (district statistical handbooks) whereas the assessment at the taluk made use of remotely sensed data.

3.2 Methods

GIS and Databases

District and taluk boundaries were obtained from the CensusInfo v2.0 published by the Directorate of Census Operations, Government of India (Office of the Registrar General and Census Commissioner India, 2001). The layer was rubber sheeted[6] to the best possible extent to match satellite imageries used in this study. This GIS layer was then linked to a data base containing census and land use classification information obtained from the District Statistical Handbook.

Census data for the years 1981, 1991 and 2001 was compiled at a district level as village level data was not available in digital format for 1981. Data for 1991 Directorate of Cenus Operations (1991) and

[6]The process by which a layer of spatial data is distorted to allow it to be seamlessly joined or fit to another spatial object.

2001 Directorate of Cenus Operations (2004) was obtained at village level and these were compiled at a taluk level for further analysis. As new districts and taluks were formed after 1991 the data had to be reorganised to match the 2001 taluks. This was possible only at the rural level as there was no information available on how urban area and town panchayats were reorganised during the formation of new districts. The Census village links provided by the Directorate of Census Operations was used for matching the two data sets (Directorate of Cenus Operations, 2008). Across all census datasets only data field that were consistent across years have been retained for further analysis. As districts have been reorganised several times in the recent past, both the census and land use change dataset were reorganised into to match 1981 district boundaries.

Land Use Change Assessment.

To assess the changes in landuse patterns we use decadal mosaics of LandSat TM and ETM satellite images. These images correspond to the post monsoon seasons for the time frame 1990-2000 and are at 30m pixel resolution. Datasets at the same spatial and spectral resolution are not available at the same resolution for the 1981 period. To avoid inaccuracies due to different spatial and spectral resolutions in the classification process, we restricted the analysis to the satellite data for the period 1990-2000.

The mosaiced images were subjected to standard procedures of geo-referencing and edge matching before subjecting to image classification. Given the lack of ground truth data for the two time periods, a supervised classification was not possible and would have proven unreliable if training site data from the current time frame was used to classify images. Both images were classified, using an image processing software, into 27 categories using an unsupervised K-Mean-clustering technique (Richards and Jia, 1999) thus allowing the use of similar techniques without any subjective judgement. The resulting images were reclassified into 9 categories. A similar exercise was carried out on images for the current time period to assess error, if any, in the classification procedure. This was compared with an unsupervised classification and with ground truth sites that were collected during the course of the study.

The nine land use categories, as per district statistical handbook, are defined as:

Forest Area: This includes all land classified either as forest under any legal enactment, or administered as forest, whether State-owned or private, and whether wooded or maintained as potential forest land. The area of cropped land in the forest and grazing lands or areas open for grazing within the forests remain included under the "forest area".

Area under Non-Agricultural Uses: This includes all land occupied by buildings, roads and railways or under water, e.g. rivers and canals, other land put to uses other than agriculture.

Barren and Un-culturable Land: This includes all land covered by mountains, deserts, etc. which cannot be brought under cultivation except at an exorbitant cost. Such land whether in isolated blocks or within cultivated holdings, is included under this category.

Permanent Pasture and other Grazing Land: This includes all grazing land whether it is permanent pasture and meadows or not. Village common grazing land is also included under this heading.

Land under Miscellaneous Tree Crops: This includes all cultivable land which is not included in 'Net area sown' but is put to some agricultural use. Land under casuarina trees, thatching grasses, bamboo bushes and other groves for fuel, etc. which are not included under 'Orchards' are classified under this category.

Culturable Waste Land: This includes land available for cultivation, whether taken up or not taken up for cultivation in the past, but not cultivated for varying reasons during the last five years or more in succession including the current year . Such land may be either fallow or covered with shrubs and jungles which are not put to any use. They may be accessible or inaccessible and may lie in isolated blocks or within cultivated holdings.

Fallow Lands other than Current Fallows: This includes all land which was taken up for cultivation but is temporarily out of cultivation for a period of not less than one year and not more than five years.

Current Fallows: This represents cropped area which is kept fallow during the current year.

Net Area Sown: This represents the total area sown with crops and orchards. Area sown more than once in the same year is counted only once.

Gross Cropped Area: This represents the total area sown once and/or more than once in a particular year, i.e. the area is counted as many times as there are sowings in a year. This total area is known as gross cropped area.

Socio-Economic changes

To assess socio-economic changes we use the census data for the period 1981-2001 The classes of information include demographic and economic indicators. The economic indicators considered are changes in the proportions in the following categories.

Agricultural Labourers: A person who worked in another person's land for wages in cash, kind or share was regarded as an agricultural labourer. Such a person had no risk in cultivation but merely worked in another person's land for wages. An agricultural labourer had no right of lease or contract on land on which he worked.

Cultivators: A person was considered was was engaged either as employer, single worker or family worker in cultivation of land owned or held from government of held from private persons or institutions for payment in money, kind or share of crop. Cultivation included supervision or direction of cultivation.

A person who had given out his/her land to another person or persons for cultivation or money, kind or share of crop and who did not even supervise or direct cultivation of land was not treated as cultivator. Similarly, a person working in another person's land for wages in cash or kind or a combination of both was not treated as cultivator.

Cultivation involved ploughing, sowing and harvesting and production of cereals and millet crops such as wheat, paddy, jowar, bajra, ragi, etc., and pulses, raw jute and kindred fibre crop, cotton, etc., but did not include fruit growing, vegetable growing or keeping orchards or groves or working on plantations like tea, coffee, rubber, cinchona and other medicinal plantations.

Household Industry: Household industry was defined as an industry conducted by the head of the household himself/herself and/or by the members of the household at home or within the village in rural areas, and only within the precincts of the house where the household lived in urban areas. The larger proportion of workers in a household industry should consist of members of the household including the head. The industry should not be run on the scale of a registered factory.

The main criterion of a household industry was the participation of one or more members of a household. This criterion applied in urban areas too. Even if the industry was not actually located in the house but was located somewhere within the village limits in the rural areas, there was greater possibility of the members of the household participating in the industry. In the urban areas where organised industry was more prominent, the household industry was to be confined to the precincts of the house where the participants lived. In urban areas even if the members of the household by themselves ran an industry but at a place away from the precincts of their home, it was not considered a household industry.

A household industry is one that is engaged in production, processing, servicing, repairing or making and selling (but not merely selling) of goods. It does not include professions such as those practised by a pleader or doctor or barber, musician, dancer, dhobi, astrologer etc. or merely trade or business, even if such professions, trade or services are run at home by members of the household.

Main Workers: Main workers were those who had worked for the major part of the year preceding the date of enumeration i.e., those who were engaged in any economically productive activity for 183 days (or six months) or more during the year.

Marginal Workers: Marginal workers were those who worked any time at all in the year preceding the enumeration but did not work for a major part of the year, i.e., those who worked for less than 183 days (or six months).

Non-Workers: Non-workers were those who had not worked any time at all in the year preceding the date of enumeration.

3.3 Results

Landuse Change

The significant changes observed in the landuse patterns for the entire state for the period 1970-2006 are summarised in figure 3.1. Increase in areas put to non-agricultural use or urbanisation, decrease in area under cultivation and increase in other fallow lands are some of the significant changes occurring along the coastal districts and these trends are reflected throughout the state. Areas under forest cover and permanent pastures showed non-significant decline throughout the coastal stretch. The area under current fallow, or land not cultivated showed strong inverse relationship with the net sown area, thus was not considered for further analysis

While all coastal districts record increase in area under non-agricultural use the highest percentage change is recorded in Karaikal (85. 7%) followed by Chengalpet and Pondicherry town (27.8% and 23.5% respectively) and the least percentage change is recorded in Pudukottai district (1.4%).

Other fallow land or land temporarily out of cultivation for a period greater than one year and not more than five years increases across all coastal districts. The rate of change is highest in Pudukottai district followed by Chengalpet and Ramanathapuram. While all other districts show increase in area under fallow lands, only South Arcot district shows a decline in this category. It is also interesting to note that the rates of change increase drastically in the mid eighties and again in the early nineties.

Majority of the coastal districts showed a decline in proportion of area being cultivated more than once and consequently the gross area under cultivation. Pudukottai district records the highest decline in area proportion of land sown more than once, where as Chengalpet district show an increase in both land being cultivated more than once in a given year and consequently gross area under cultivation. The net sown area also declines in most coastal district, except South Arcot, Chengalpet and Kanyakumari district which show an increase in productive use of land. When one compares the districts with respect to proportion of land cultivated more than once all districts show a decline except Chengalpet, and the highest decline is observed in Pudukottai district. This can probably be explained by the availability of both ground water and surface water. Category wise trends have been presented in figure 3.2.

Given these trends in coastal taluks along the Coromandel coast, we carry out landuse change analysis using a series of images. Assessment of the spread of urban areas is carried out using stable night light images (NOAA's National Geophysical Data Centre, 2006) for the years 1992 and 2003 (figure 3.3). The most significant spread of urban areas is around already existing towns and cities like Chennai, Pondicherry - Cuddalore and Karaikal - Nagapattinam. These trends are similar to those at the district level. The only taluks which do not show substantial increase in rates of urbanisation are Cheyyur in Kancheepuram district, Vedaranyam in Nagapattinam district and Thiruthuraipoondi in Thirvarur district.

The results of the landuse changes along the coastal stretch at a taluk level for the same period were analysed using LandSat images (figure 3.4). The key changes occurring are, increase in area being put to non-agricultural use, decrease in net sown area and increase in area under miscellaneous tree crops, table 3.1 provides percentage change in key categories between the two time frames.

To assess our ability to predict these landuse classes we subject a recent set of images to a similar classification process to estimate the possible error. Results of the accuracy assessment are provided in the following table (table 3.2) and our overall index of accuracy was 0.583.

While the overall accuracies were within reasonable limit for a single season image classification, on examining the error matrix it became clear that not all classes were classified to great levels of confidence and thus the necessity to look at areas undergoing change using a time series of images.

Rather than looking at rates of change across landuse categories we looked at areas that had either witnessed an increase or decrease in vegetation cover over a decade. While datasets for the same period were not available, we made use of a decadal data set that was available for the period 1985-1996. To assess the change in vegetation cover, we used Calibrated Vegetation Index (CVI) as proxy for vegetation cover or vigour. Issues of higher NDVI values as sensors degrade and drifts in sensors are overcome in the derived CVI data product. The CVI is calculated from albedo values rather than raw channel reflectance values of the visible red channel and the near-infrared channel imaged by the AVHRR sensor (Kidwell, 1991). One kilometer maximum CVI data set for the dry period from 1986-1996 was

Figure 3.1: Observed changes in landuse patterns at district level for the states of Tamil Nadu and Pondicherry, 1970-2006

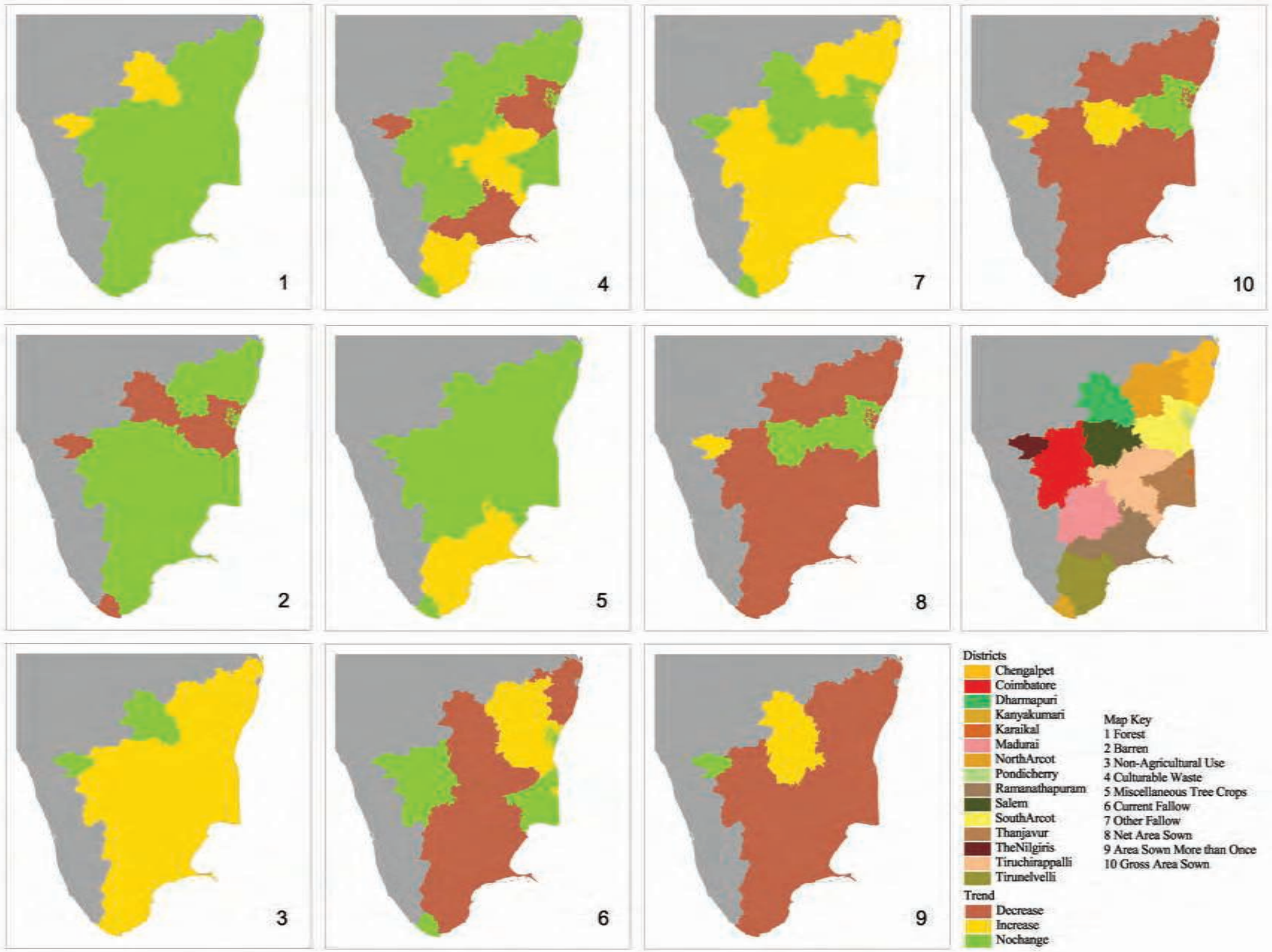


Table 3.1: Percentage change in key categories across the time frame 1990-2000, results from remotely sensed data. Pixels were cleaned up using a 3 X 3 majority filter.

Taluk	Fallow / Scrub	Misc. tree crops	Cultivated land	Non-Agri. use
Ariyankuppam	-12.00%	-10.00%	-6.00%	26.00%
Bahour	-7.00%	6.00%	-11.00%	11.00%
Chengalpet	2.00%	-23.00%	-2.00%	26.00%
Cheyyur	-10.00%	-7.00%	-1.00%	25.00%
Cuddalore	-5.00%	-1.00%	-4.00%	14.00%
Kattumannarkoil	-9.00%	6.00%	-16.00%	16.00%
Kilvelur	-26.00%	21.00%	6.00%	6.00%
Kottucherry	-36.00%	3.00%	-10.00%	28.00%
Mannadipet	-3.00%	10.00%	-20.00%	13.00%
Nagapattinam	-26.00%	15.00%	12.00%	3.00%
Nedungadu	-28.00%	11.00%	-13.00%	3.00%
Neravy	-47.00%	37.00%	3.00%	15.00%
Nettapakkam	8.00%	1.00%	-19.00%	11.00%
Ponneri	9.00%	-22.00%	2.00%	11.00%
Poonamallee	4.00%	-30.00%	-11.00%	14.00%
Sirkazhi	-28.00%	5.00%	3.00%	21.00%
Tambaram	7.00%	-27.00%	-4.00%	26.00%
Tharangambadi	-27.00%	-1.00%	7.00%	23.00%
Thirumalairayan Pattinam	-8.00%	-6.00%	3.00%	8.00%
Thirunallar	-23.00%	31.00%	-13.00%	21.00%
Thiruthuraipoondi	-25.00%	21.00%	8.00%	9.00%
Tindivanam	-6.00%	3.00%	1.00%	9.00%
Thirukazhikundram	4.00%	-26.00%	-7.00%	32.00%
Vedaranyam	2.00%	11.00%	-8.00%	8.00%
Villianur	-2.00%	2.00%	-5.00%	6.00%
Villupuram	-5.00%	13.00%	7.00%	18.00%

Table 3.2: Error matrix showing proportion of pixels under different categories the rows indicate ground truth data and the columns indicate classes derived from the unsupervised classification.

	Scrub / fallow	Miscellaneous trees	Water bodies	Built up	Barren / uncul-tivable	Cultivated	Error of Commis-sion
Scrub/fallow	0.51	0	0	0.3	0	0.02	0.73
Miscellaneous trees	0.01	0.82	0	0	0	0.82	0.68
Water bodies	0	0.12	1	0	0	0	0
Built up	0.35	0	0	0.27	0.08	0	0.73
Barren/uncultivable	0.09	0	0	0.11	0.92	0	0.27
Cultivated	0.04	0.05	0	0.32	0	0.16	0.83
Error of Omission	0.49	0.18	0	0.73	0.08	0.84	

Figure 3.2: Trends in proportion of land under different categories of use in coastal districts over three decades.

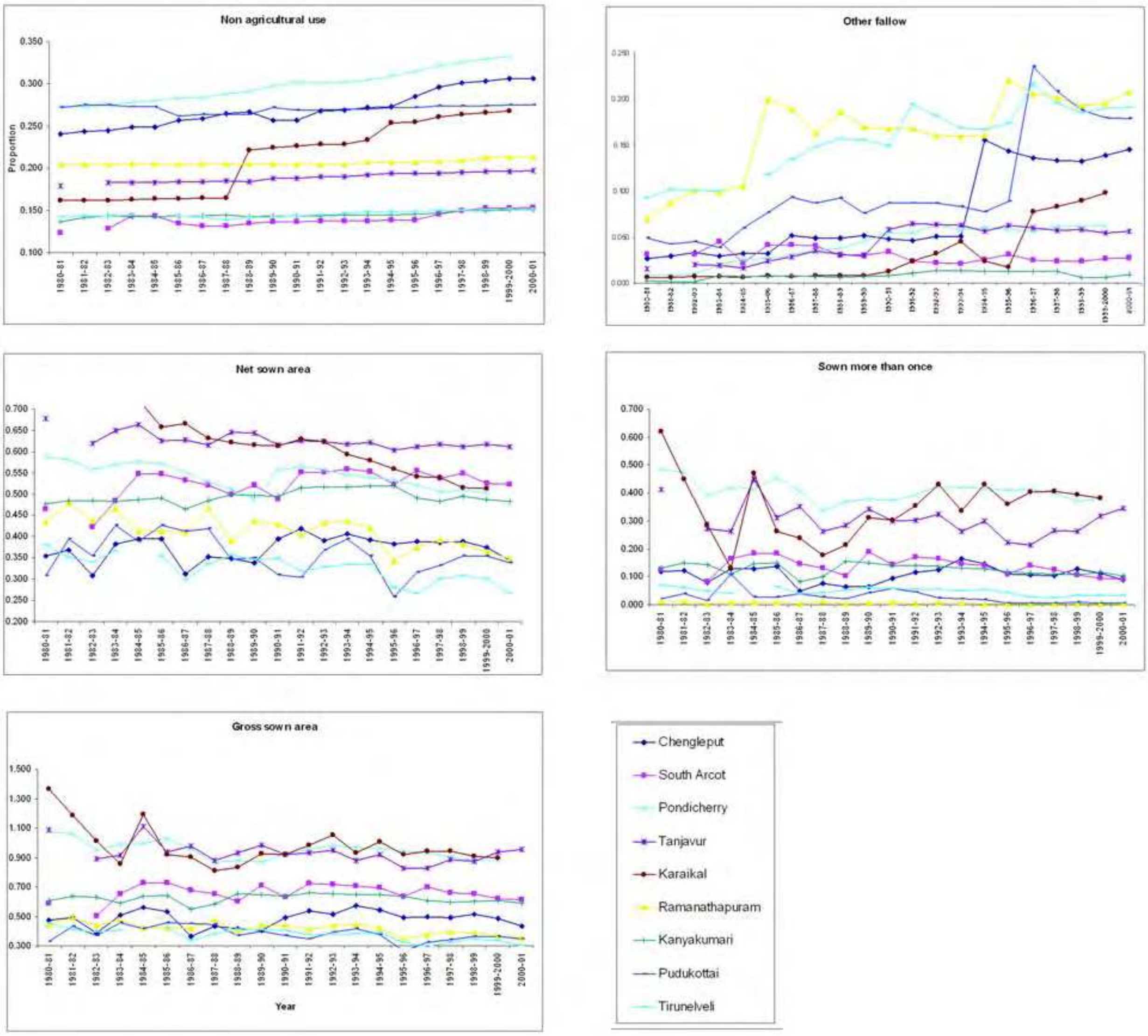


Figure 3.3: Spread of urban areas along the Coromandel coast in comparison with the Coastal Vulnerability Index. Stable night light images for the years 1992 and 2003 are also shown.

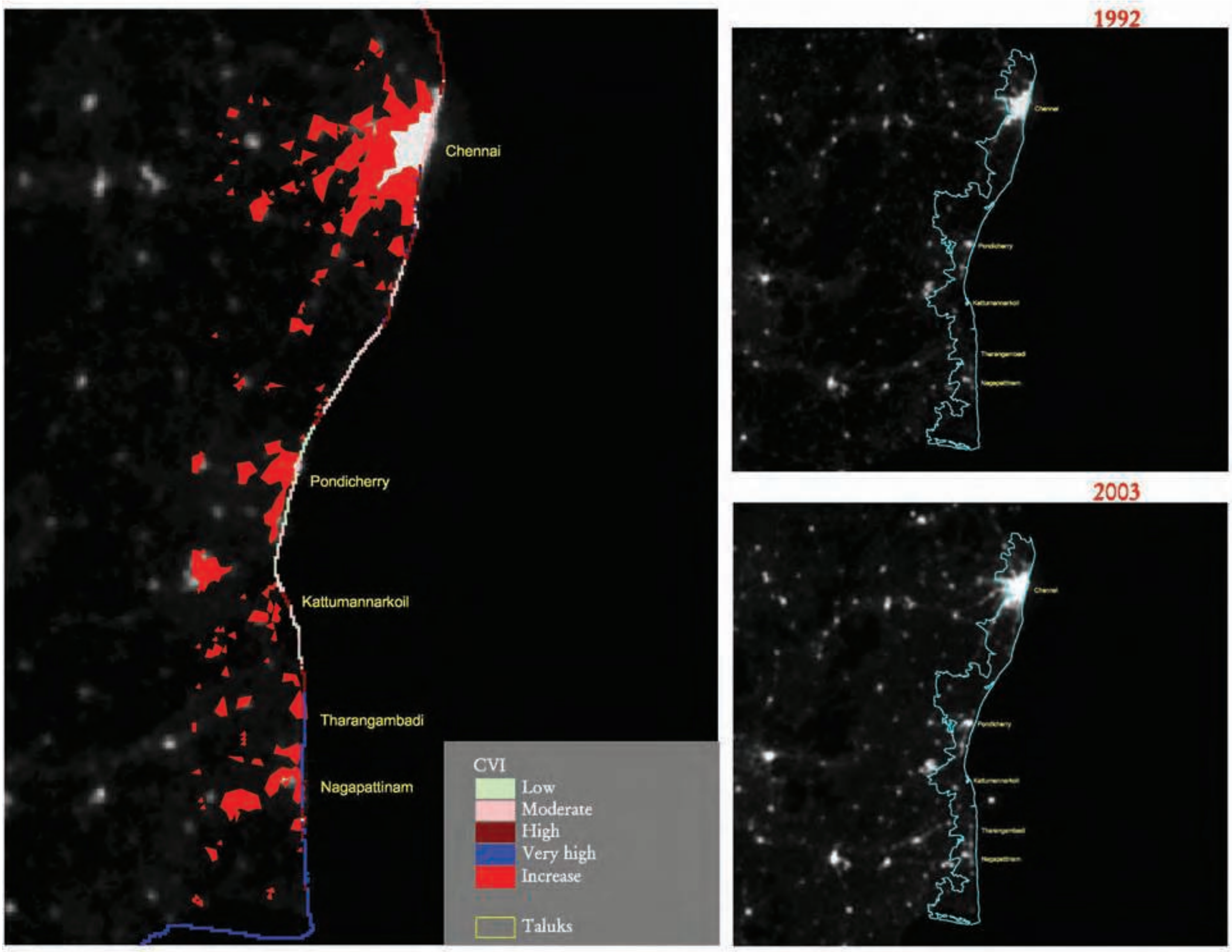
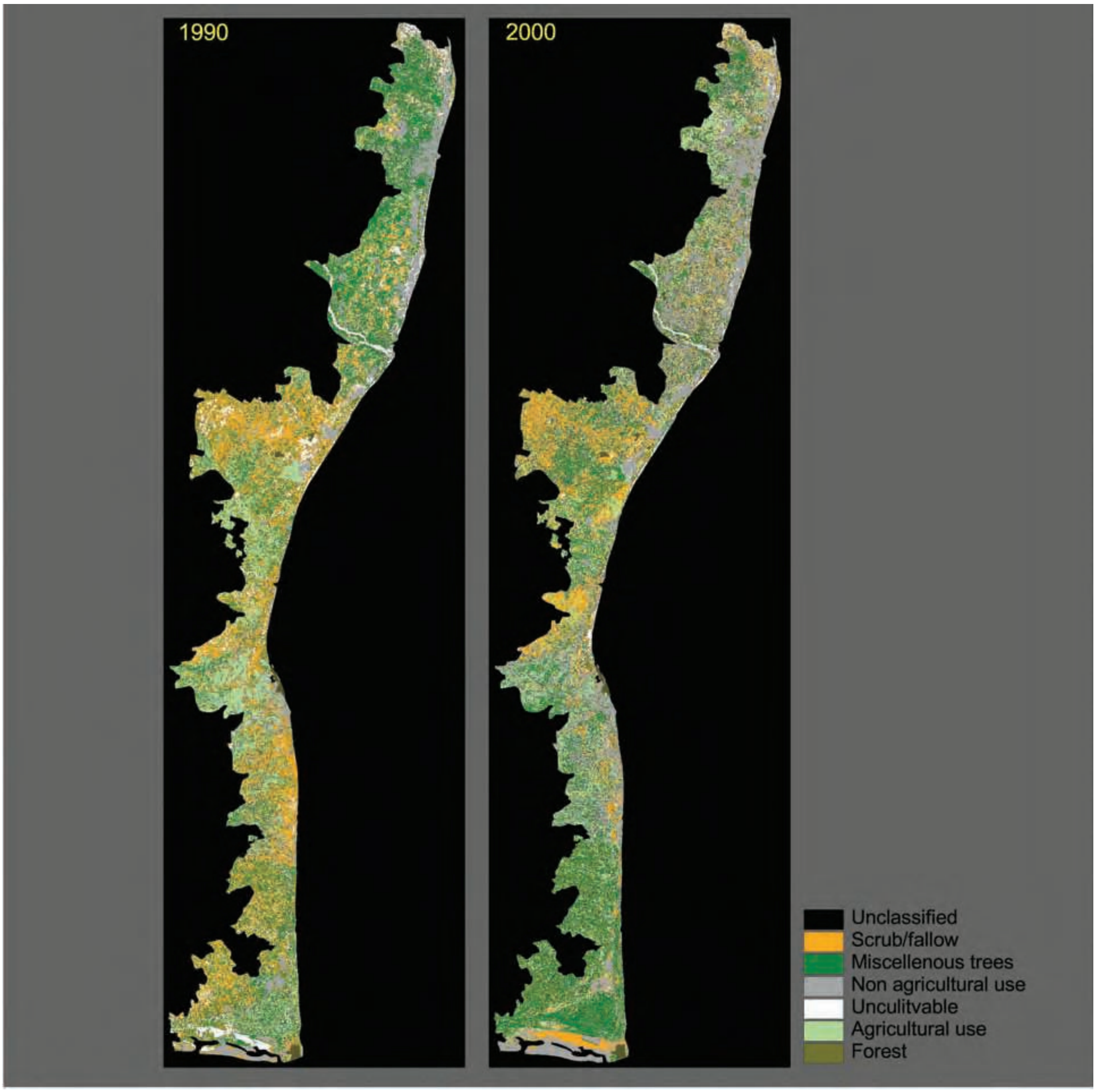


Figure 3.4: Land use patterns derived from single date image using k-means unsupervised classification for the years 1990-91 and 1999-2000.



obtained for analysis (http://www-cger.nies.go.jp/grid-e/gridtxt/grid27.html). All pixels in the taluks along the Coromandel Coast for each time-series of CVI values from 1986-1996 was analysed for trend over time. Negative slopes (decrease in CVI over time) indicate loss of green biomass over time. The greater the magnitude of the negative slope, greater is the rate of decrease in biomass. The slope was generated for each pixel, and a final map of change was developed using standard deviations (figure 3.4).

The two date change analysis approach has been used successfully in completely forested habitats but fails to work very well in predominantly human landscapes. In this study the single date image for the year 2000 showed more greenness, due to more rainfall received in the preceding months. Thus the results of the two date classification were affected by seasonal changes and actual landuse changes across the two time frames. Given these limitations, we highlight the advantage of using a time series of satellite images over two-date post-classified change detection, which has severe limitations. In the latter approach it is difficult to achieve consistency in the classification scheme for two different time-periods which necessitates very high accuracies for both image classifications to have some degree of confidence in the estimation of change categories. This is especially true if the percentage of pixels undergoing change are comparable to the compounded misclassification of pixels in the two time-periods.With the availability of SPOT (ftp://free.vgt.vito.be) and MODIS (ftp://e4ftl01u.ecs.nasa.gov/) datasets on public domains since 2001, such assessments are now easily possible at monthly scales.

Other than these trends we also looked at modifications of coastal estuaries and back water systems along the Coromandel Coast over the last decade. Given the low resolution of the two datasets applying standard remote sensing techniques was not possible, thus we used a visual estimation technique to detect the growth of salt pans and aquaculture ponds. Of the 45 sites examined along a stretch of 450 Km., 40% showed new or increased areas under salt pans or aquaculture ponds over the last decade (figure 3.6). A large number of these changes were observed in the coastal stretch between Sirkazhi and Nagapattinam.

The key land use changes along the Coromandel Coast across different spatial scales and for different datasets was a decrease in area under cultivation, increase in urbanisation, increase in fallow land and increased modification of backwater and estuarine systems.

Socio-Economic changes

We made use of Primary census data for the coastal districts and taluks to understand how socio-economic changes affected landuse patterns. We restricted our analysis to the period 1981 to 2001. The trends from the analysis of census data are presented in figure 3.7. The general trends observed in the coastal districts were an increase in human populations, decrease in proportion of cultivators and substantial increase in marginal workers.

The analysis of changes in the economic indicators (tables 3.3 and 3.4) showed a reduction in workers in the agricultural sector. This was most prominent in Pudukottai while Pondicherry showed the least decrease. This trend was reflected in the proportion of cultivators to total workers for all districts (with Pudukottai and Pondicherry showing the maximum and minimum difference), and in the proportion of agricultural labourers to total workers in most districts. Agricultural labourers to total workers was seen to reduce most in Kanyakumari district and was seen to increase in Pudukottai (maximum), South Arcot and Thanjavur districts.

Figure 3.5: Areas undergoing change in vegetation cover was derived from a time-series of one kilometer maximum CVI data set for the dry period from 1986 - 1996.

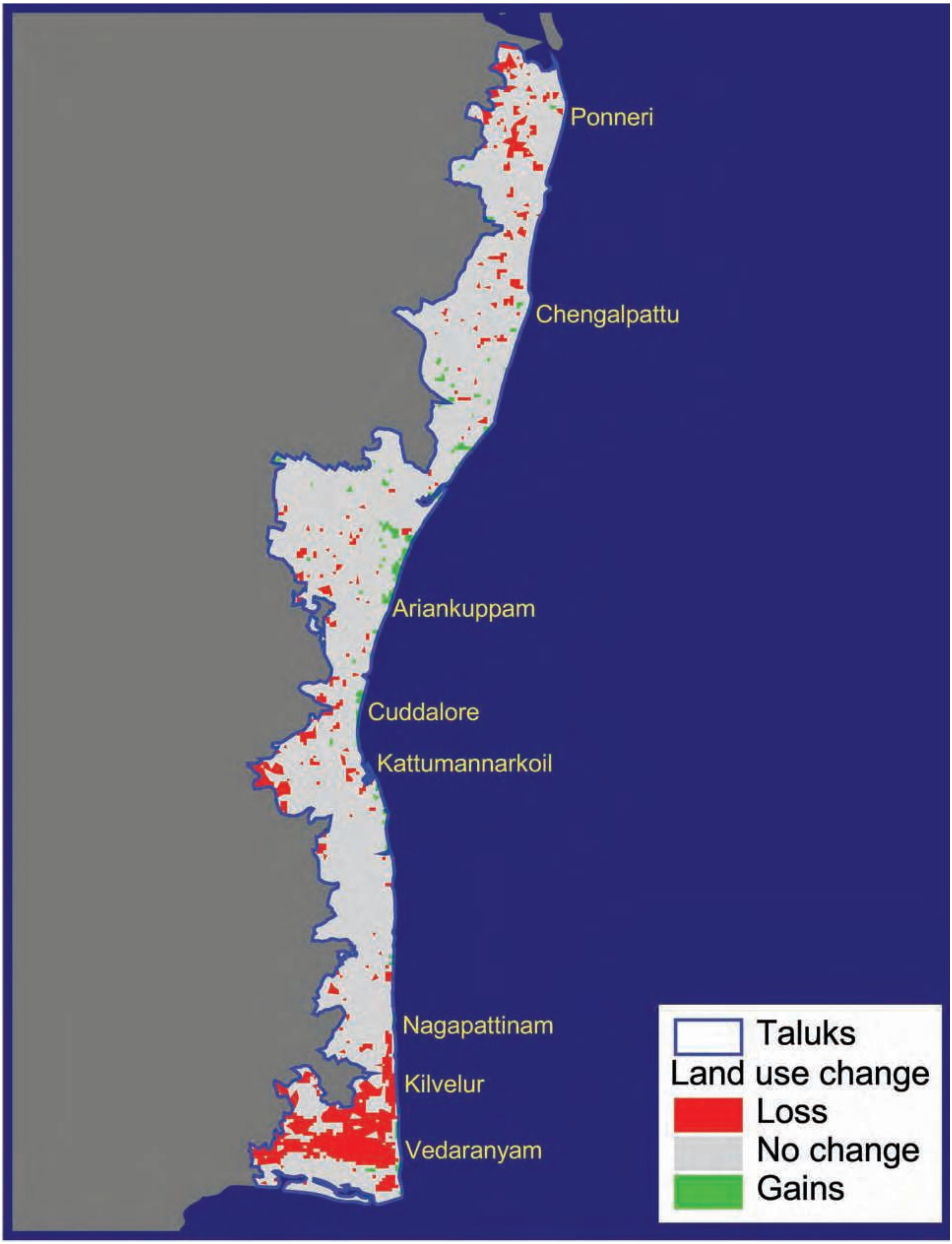


Figure 3.6: Increase in area under salt pans and aquaculture. The inset shows the sites that show an increase. The images for one of the locations (the red spot) has been shown the change.

Table 3.3: The percentage changes in economic indicators at the district level for the coastal region. Parameters are labeled as follows: 1: Agricultural labourers to total workers; 2: Cultivators to total workers; 3: Household industry workers to total workers; 4: Main workers to total population; 5: Marginal workers to total population; 6: Non-workers to total population; 7: Other workers to total workers; 8: Work participation rate; 9: Workers in agriculture sector; 10: Workers in non-agriculture sector.

District	1	2	3	4	5	6	7	8	9	10
Chengalpet	-8.5	-6.7	1.4	-5	5.6	-0.6	13.8	0.6	-6.8	13.9
South Arcot	2.3	-8.5	1.2	-5.1	7.4	-2.3	5	2.3	-8.4	5
Pondicherry	-8.6	-3.5	0.9	0.4	1.8	-2.2	11.2	2.2	-3.6	11.2
Thanjavur	2.2	-7.6	0.8	-5	5.1	0	4.5	0	-7.6	4.6
Karaikal	-8.8	-4.1	1.2	-1	2.6	-1.7	11.8	1.7	-4.3	11.8
Pudukottai	8.1	-12	0.9	-2.5	4.9	-2.4	3	2.4	-11.9	3
Ramanathapuram	-2.8	-10.3	1.6	-3.1	2.1	1	11.5	-1	-10.3	11.5
Tirunelveli	-6.3	-10	5	-2.8	3.3	-0.5	11.2	0.5	-10.1	11.3
Kanyakumari	-23.2	-10.4	4.2	-2	4.2	-2.2	29.4	2.2	-10.5	29.3

It is interesting to note that the proportion of main workers in these districts decreased while, the marginal workers and household industry workers increased. Other than in Thanjavur and Ramanathapuram districts, the proportion of non-workers decreased. These were also the districts where work participation rate reduced.

All taluks except Tarangambadi showed an increase in population in the taluk level analysis. While the maximum change in population was seen in Poonamallee followed by Tambaram, population increase was least in Ariyankuppam. Similarly, Poonamallee showed the most increase in workers in the non-agricultural sectors and a maximum reduction in workers in the agricultural sector.

The workers in the agricultural sector was seen to reduce at the taluk level as well. This was reflected in the proportion of agricultural labourers and cultivators of the total workers in all the taluks. The percentage change of agricultural labourers to total workers was seen to reduce most in Poonamallee taluk, and was least in Tindivanam. Reduction of cultivators to total workers was most for Vedaranyam. A reduction in proportion of household industry workers to total workers was observed across all taluks, with Tambaram showing the most and Kattumannar Koil showing the least. Across all taluks, the proportion of the workers categorised as "other workers" increased and was most for Poonamallee and least for Kattumannar Koil.

Of the total population, the proportion of main workers reduced (Cheyyur showing maximum reduction) for all taluks except Thirumalairayan Pattinam which showed an increase. On the other hand, there was an increase in the proportion of marginal workers which was highest for Cheyyur and least for Thirumalairayan Pattinam. The proportion of non-workers in the population was seen to increase in some coastal taluks and decrease in others - maximum increase was seen in Sirkazhi and Nedungadu showed the maximum decrease and consequently maximum reduction in work participation was seen in Sirkazhi and maximum increase in Nedungadu.

Due to small sample sizes we made use of data visualisation rather than performing statistical tests to explore cause and effect between the observed land use changes and changes in demography and economic parameters at a district level. The rate of change in area under non agricultural land is correlated to the rate of change in total populations, i.e., districts with higher rates of population increase showed higher proportion of land under non agricultural use for the period 1981-2001. Chengalpet

Table 3.4: The percentage changes in economic indicators at the taluk level for the coastal region. Parameters are labeled as follows: 1: Population Changes; 2: Agricultural labourers to total workers; 3: Cultivators to total workers; 4: Household industry workers to total workers; 5: Main workers to total population; 6: Marginal workers to total population; 7: Non-workers to total population; 8: Other workers to total workers; 9: Work participation rate; 10: Workers in agriculture sector; 11: Workers in non-agriculture sector.

Taluk	1	2	3	4	5	6	7	8	9	10	11
Ponneri	63.10%	-0.32	-0.06	-0.06	-0.12	0.09	0.03	0.2	-0.03	-0.38	0.2
Poonamallee	214.60%	-0.41	-0.11	-0.11	-0.1	0.06	0.04	0.46	-0.04	-0.51	0.46
Tambaram	118.70%	-0.3	-0.07	-0.14	-0.07	0.04	0.03	0.38	-0.03	-0.37	0.38
Chengalpet	22.90%	-0.24	-0.05	-0.07	-0.1	0.08	0.03	0.17	-0.03	-0.29	0.17
Tirukalukundram	3.90%	-0.22	-0.1	-0.03	-0.11	0.11	0	0.12	0	-0.32	0.12
Cheyyur	64.80%	-0.33	-0.11	0	-0.2	0.2	0.01	0.04	-0.01	-0.44	0.04
Tindivanam	3.20%	-0.06	-0.06	-0.01	-0.03	0.03	0	0.07	0	-0.12	0.07
Viluppuram	15.40%	-0.18	-0.09	-0.01	-0.08	0.1	-0.02	0.08	0.02	-0.27	0.08
Cuddalore	31.90%	-0.26	-0.05	-0.02	-0.11	0.1	0.01	0.1	-0.01	-0.31	0.1
Kattumannar Koil	17.90%	-0.22	-0.09	0	-0.12	0.14	-0.03	0.03	0.03	-0.31	0.03
Sirkali	20.20%	-0.16	-0.07	-0.02	-0.11	0.06	0.05	0.08	-0.05	-0.23	0.08
Tharangambadi	-0.40%	-0.11	-0.06	-0.02	-0.07	0.03	0.03	0.09	-0.03	-0.16	0.09
Nagapattinam	36.70%	-0.24	-0.07	-0.02	-0.1	0.08	0.02	0.13	-0.02	-0.3	0.13
Vedaranyam	20.10%	-0.08	-0.11	-0.02	-0.09	0.07	0.01	0.04	-0.01	-0.19	0.04
Thiruthuraipoondi	11.20%	-0.11	-0.1	-0.01	-0.09	0.08	0.01	0.06	-0.01	-0.21	0.06
Mannadipet	20.00%	-0.12	-0.1	-0.04	-0.04	0.04	0	0.17	0	-0.21	0.17
Villianur	4.60%	-0.26	-0.03	-0.1	-0.07	0.06	0.01	0.24	-0.01	-0.29	0.24
Ariankuppam	1.60%	-0.09	-0.03	-0.08	-0.01	0.02	0	0.16	0	-0.13	0.16
Nettapakkam	16.90%	-0.22	-0.02	-0.04	-0.02	0.05	-0.03	0.17	0.03	-0.23	0.17
Bahour	15.30%	-0.11	-0.04	-0.05	0	0.01	-0.01	0.17	0.01	-0.15	0.17
Nedungadu	9.80%	-0.15	-0.05	-0.11	-0.01	0.05	-0.04	0.18	0.04	-0.2	0.18
Kottucherry	14.40%	-0.2	-0.03	-0.04	-0.02	0.04	-0.02	0.15	0.02	-0.23	0.15
Thirunallar	17.10%	-0.2	-0.05	-0.06	-0.03	0.03	-0.01	0.21	0.01	-0.25	0.21
Thirumalairayan Pattinam	15.90%	-0.11	-0.03	-0.05	0.02	0.01	-0.03	0.17	0.03	-0.14	0.17

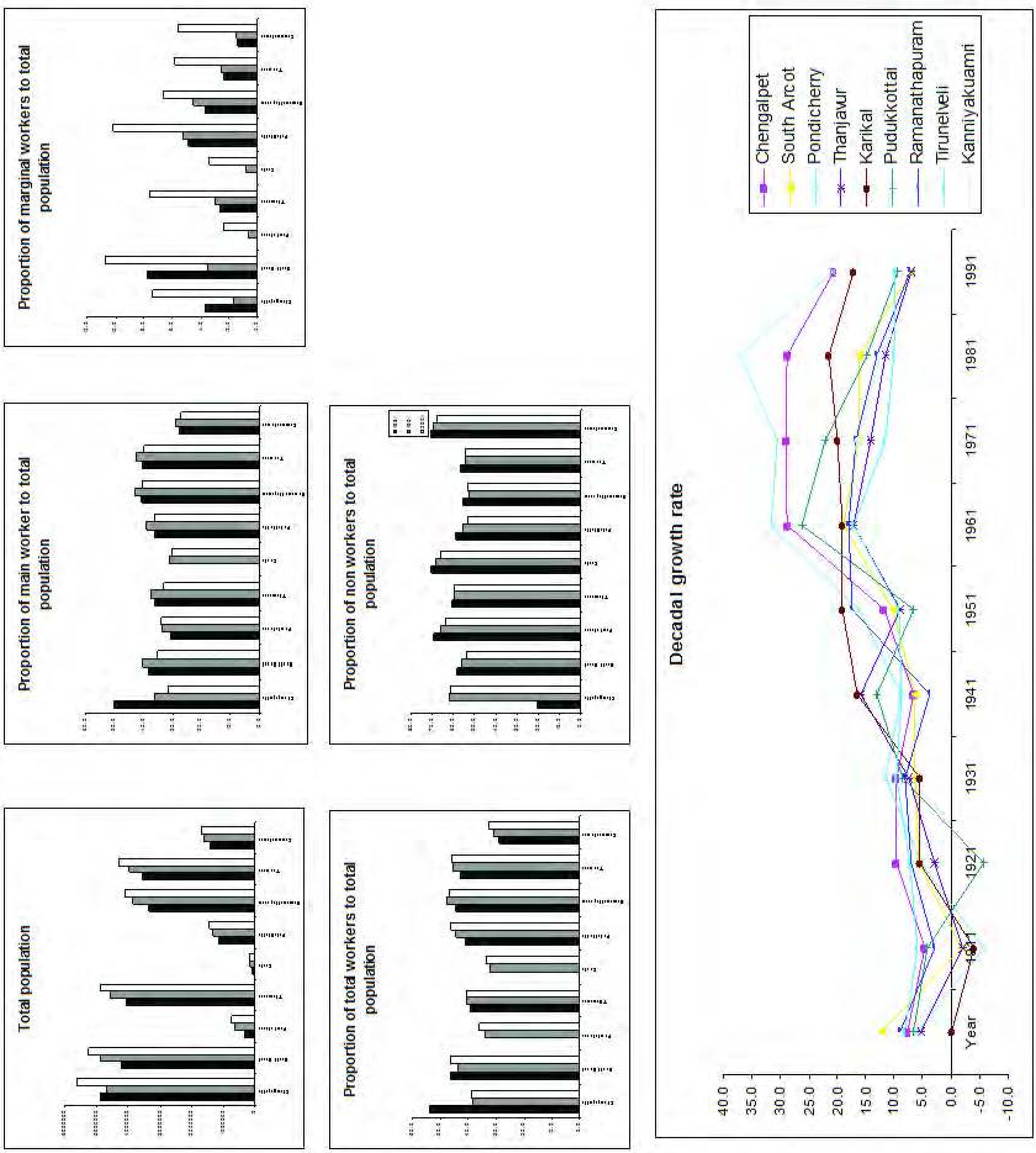


Figure 3.7: Trends from analysis of census data.

district showed the highest increase in the rate of change in land under non agriculture followed by South Arcot districts, the same districts were ranked second and first for rates of population change.

The percentage change in area under net sown area, area sown more than once and gross area under cultivation decreased with decrease in percentage change of cultivators to total workers. Whereas the same land use categories increased with decrease in percentage change of agriculture labourers to total workers, i.e, districts with increase in the proportion of agricultural labour to total workers recorded lower percentage change in area productively used.

3.4 Discussion

Landuse Change and Vulnerability

The observed increase in urbanisation is directly linked to population expansion; with the need to meet demands of expanding population also due to migration. While an overall slow down in growth at the district level been observed for the 1990-2000 period, the changes at a taluk level do not necessarily follow the district level trends. This is even more pronounced in taluk that adjoin already urbanised areas like Chennai, Pondicherry and Nagapattinam. This spill over effect is not only observed from the satellite images it is also corroborated by increase in rural populations over the last decade (for example, Poonamallee and Tambaram taluks). This growth in populations is also due to migration rates as these taluks are adjacent to urbanised areas. The results from our analysis is similar to Srinvasan and Peter (2002), who in addition simulate the urban sprawl up to 2009. As a result of this more people reside along the coast and therefore a larger proportion of people as compared to the previous decade are now exposed to risks associated to cyclones, storm surges and even events like a tsunami. When compared with the Coastal Vulnerability Index (See previous chapter for details), areas undergoing large scale urbanisation are associated with moderate to very high values of coastal vulnerability. Such expansion does not only put people at risk. Events like cyclones, storm surges and tsunamis also impact property and costs associated with such damages can be substantial in urban areas. While it is impossible to prevent the growth of urban areas which is likely to continue, it definitely calls for better disaster preparedness and management all long the coast.

Other landuse changes that have been proposed along the coast include expansion of existing ports and proposals for new facilities. Along with these large engineering projects. The other initiatives of concern are the construction of sea walls. Earlier studies (Scaivaina, 2008), (Rauf and Srinivas, unpublished manuscript) which looked into coastal changes due to construction of the Pondicherry port clearly indicate changes in natural sediment flows and thus the alteration of coastal beaches and sand dunes. While the impacts of the recent construction of sea walls are yet to be thoroughly assessed, high resolution images do indicate the potential impact they have on dune structures (`http://czm.feralindia.org/?q=node/11`). The loss of shoreline and the natural coastal protection that dunes offer directly affect coastal vulnerability. Such modifications are making these natural formations highly vulnerable and restoration costs at a later date can prove to be expensive. It also translates to huge losses to coastal fishing communities who are dependent on these dune structures for their day to day activities.

Other modifications like increase in salt pans and aquaculture ponds along estuaries and backwaters have direct impacts on environmental quality and flows (Bhatta and Bhat, 1998). With the recent regularisation of this industry we can only result in a further increase in these activities. While these natural systems are becoming vulnerable the potential environmental and ecological impact of these modifications needs to be assessed in detail at the earliest. At the same time the impacts of the aquaculture industry on economic and land tenure system that are being affected by this expansion and calls for a more holistic assessment and conservation of our backwater systems.

While the rate at which population is growing explains the observed increase in area under non agricultural use, the non availability of agricultural labour seems to better explain the decline in net sown area. Decline in net sown area was also observed with decline in cultivator and workers in agriculture sector but the trends were not as significant. As net sown area decreases there is an increase in marginal labourers. While there is an increase in work participation on the whole the increase in marginal labourers is an issue of concern. There is a strong case for a more holistic approach involving other economic parameters, hydro-geological, environmental and climatic variables among others to understand whether declining agricultural labour is affecting productivity or if decline of the agricultural industry is leading to unemployment.

Implications of Climate Change on Land-use Patterns

Land use patterns and changes in land use are a complex issue that is influenced by several factors including economic, social and environmental changes. A detailed study of the reasons for the current decline in agricultural use of land incorporating these was beyond the purview of this report. However, in the following section, we highlight some important points with reference to the chief land use changes seen within the study area over the last three decades in the context of climate change.

Agriculture is a major part of the Coromandel coast with 40% of the land under agriculture and 2.3 million people involved in the industry. About 60% of this land is rain fed and thus even small changes in the rainfall patterns can have drastic impacts on crop production. The influence of climate change and the variations in climate on agriculture in India has been well studied (see Challinor et al., 2006b; Mall et al., 2006b). With the increase in populations a corresponding increase in food production is necessary to ensure food security (Challinor et al., 2006b). This would increase water requirements, not only for domestic, but also for agriculture and other industries. Even minor deviations from the normal pattern of rains affects agriculture and food security adversely, with the possible and impending global warming and climate change, there is a real risk of declining agricultural production. Kumar and Parikh (2001a), estimated the relationship between farm-level net revenue and climate variables and found that the coastal districts of Tamil Nadu showed a negative relationship and the loss was amongst the highest.

Variability in the inter-annual monsoon rainfall can lead to large-scale droughts and floods, which also affects the agricultural production (Parthasarathy and Pant, 1985; Parthasarathy et al., 1992; Selvaraju, 2003; Kumar et al., 2004). In addition to these climatic factors, urbanisation and industrialisation have rapidly reduced the per capita availability of arable land in India from 0.48 ha in 1950 to 0.15 ha by 2000 which is likely to further reduce to 0.08 ha by 2020 (Mall et al., 2006b).

Land used for non-agriculture purposes has been on an increase in the study area. This is primarily land that is being urbanised, taken up for infrastructure development and for industrial development. The coastal districts are vulnerable to unseasonal distasters like the tsunami and damages due to cyclones, storm surges and increase in wave heights during monsoons which can potentially inundate areas causing damage. Earlier in this report we discussed coastal vulnerability for the southern coast of India. Large stretches of the coast are highly populated and trends indicate a further increase in population densities. Several of these areas fall in the moderate and high vulnerability categories. Thus, in the present scenario of increasing diversion of land for urbanisation, the loss of life and infrastructure due to vagaries and changes in climate is high. The rapid urbanisation with poor planning and civil infrastructure in place is quite common in megacities like Mumbai, Chennai and Bangalore (Anonymous, 2006b, 2005a, 2003b) all of which have witnessed severe inundation in the recent past during heavy monsoons.

Studies have shown that there is a direct relationship between variability in rainfall and loss of vegetative cover (Ali and Pelkey, unpublished manuscript). While, another study has shown that the loss of vegetation cover coincides with the El-nino years (Krishnaswamy and Srinivas, unpublished). While there are no vast tracts of forests in the study area results from the above study are equally applicable to Tropical Dry Ever Green forests of Point Cailmere and mangrove patches of Pichavaram, found along the Coramandel coast. The impact of such landuse change and climatic changes are definitely going to change the structure and nature of these natural patches in the coming decades.

Policy Implications of Observed Landuse Change and Vulnerability

We look at how some the key policies that are in place and those that are have been proposed are likely to affect land use patterns and therefore vulnerability along the coastal zone.

In the recent past the most widely discussed issue with respect to coastal zones protections has been the proposed Coastal Management Zone notification 2008 by the Ministry of Enviromenent and Forests (`http://envfor.nic.in/legis/crz/so-1761(e).pdf`). A flurry of opposition to the amendment was witnessed when the document was posted for public to comment on. While details of this are available on line on various forums (`http://www.ceeindia.org/cee/cmz2008.html`, Menon et al. (2007b)) we here provide a gist of the proposed amendment and some of its implication for the existing acts with respect to the trends in the observed changes in land use patterns and the issue of coastal vulnerability.

The CMZ notification is aimed to nullify if not dilute the existing Coastal Regulation Zones act of 1991. The original CRZ was essentially meant to protect the coast from environmental degradation while recognising that some provision has to be given for the use of the coast by fishing communities and for activities that required foreshore access. It provides set back lines with an intention of creating a no activity zone close to shoreline with the objective of minimising the impact of shore based activities on coastal ecosystems and to reserve a zone for fishery and other activities which require shorefront. The proposed notification allows large scale development in all zones and fails to restrict expanding urbanisation. It also fails to ensure livelihood, rights and access of coastal communities to the shore. With over 35 lakh fisher folk in Tamil Nadu alone, this notification is going to have a huge impact on this particular community by curtailing their rights to access and development, where as it allows other development activities a clean chit.

The CRZ notification has never been implemented in letter and spirit, 19 amendments have been made to since it has been approved, which have made it ineffective in its primary objective - to protect the coast and coastal communities. While several violations along coast have gone unnoticed or no legal action has been initiated so far, the proposed notification will only regularise these encroachments.

While the notification places a lot of importance on human lives and property it fails to address the issue of protecting coastal habitats, which is the primary objective of the Environmental Protection Act, under which the current notification is proposed.

There are serious issues with the proposed setback line which claim to be based on vulnerability analysis of the coast. No scientific guidelines have been followed in drawing up the vulnerability line. Futher there is a severe lack of data to estimate coastal vulnerability and the entire exercise was conducted in a non participatory fashion, excluding coastal communities who are the major stakeholders. Scientist and civil society was also not involved in the process and the lack of transparency in the whole process are some of the reasons it has been rejected. This stance has not limited to just coastal communities and conservation groups even the State Government of coastal states have out right rejected the move to table this bill in the Parliament.

Policies like this are likely to change the nature of the coast. Other than impacting coastal communities they will promote industries, settlements, uncontrolled tourism and hazardous industries to come up in the coastal belt while displacing the traditional fishing community from the coastal area.

It is evident that the proposed notification will legalise and contribute to urbanisation of the coastal stretches, which has been checked by existing acts. Such an attempt will only increase human population along the highly vulnerable coastal stretches and thus increase costs of rehabilitation and relief in the event of a cyclone or storm surge. The proposed amendment also fails to acknowledge that vulnerability itself is a dynamic parameter determined by several different variables and having a fixed line of exclusion or inclusion based on a one time estimate of vulnerability is going to be meaningless. If implemented, it will result in the vulnerability line being pushed further inland, as associated changes along the shoreline are going to increase the vulnerability estimates.

The Coastal Aquaculture Authority Bill, 2004 was passed in by the Indian Parliament in 2005 (The Rajya Sabha - Government of India, 2005). This bill recognises aquaculture ponds in coastal areas as a regular industry. Thus banks and insurance companies, which had previously placed shrimp farming in the negative list, will now be able to support aquaculture projects. What this translates to is that that shrimp farming is finally being recognised and given a legal status. The sector can now grow in an organised way with the State Governments, the Centre and other authorities concerned encouraging coastal aquaculture.

This is a legislation that has been awaited by the aquaculture industry for close to a decade. The Bill was first introduced in the Rajya Sabha on 1997 but has been on the back burner ever since. In a historic judgement the Supreme Court banned all aquaculture farms 1996 and recommended setting up of an Authority to monitor and license shrimp farms and to demolish the farms that do not confirm to regulations. However it merely functioned as a license issuing authority. Both the 1997 and 2004 bills specify that no farms are to come up within the CRZ1 zone and along backwater and estuaries. This has however never been implemented and licenses have been issued ever since the establishment of the Authority. Also mandatory in the 1997 bill was an EIA clearance before setting up of shrimp farms, however a loophole stating only farms greater than 4 hectares needed to go through the process made this provision redundant. In the current Bill the requirement of an EIA has been done away with and farms smaller than 2 hectares need not apply for a license nor register themselves with the authority. While the bill still claims to follow CRZ notification and the rules of the Environmental Protection Act, 1986. It directly contravenes the provisions specified in the act which preserves all water bodies from being impacted by any human intervention. Even before the 2005 our own analysis of satellite images for the year 1990 and 2000 clearly show that about 40% of the backwater systems along the Coromandel coasts has been impacted by commercial shrimp farms both legal and encroached. With the bill being modified and cleared, a rapid spread and growth of the industry can be expected over the next decade.

While the Rs 3,500 crore industry is likely to benefit from this bill, issue of illegal encroachments, leasing of agriculture land, diverting agricultural land for shrimp farming are some the issues that remain unresolved. The current shrimp farming practises that are adopted by these industries make the land uncultivable even if reverted to back to agricultural use due high dependence on artificial fertilisers and improper disposal of effluents from the farms. This not only affects the farm itself also due to unregulated disposal of effluents adjoining agricultural lands are becoming less productive. Aquaculture and related activities are not just restricted to agricultural lands but have also encroached on coastal mudflats, salt marshes and sea grass beds that were once common in our brackish water systems.

The Government of India makes increasingly large investments into watershed development programmes (the integrated watershed development programme alone increased from Rs.176.66 lakh ($410,837) to Rs.271,278,23 lakh ($630,879,604) in the period 1995-96 to 2007-08 Ministry of Rural Development, Government of India (2008). The bulk of the watershed development projects in India follow the Common Guidelines for Watershed Development, revised in early 2008, and designed so that areas with a high concentration of socially and economically poorer sections get prioritised. These guidelines also tend to favour arid and semi-arid areas, for which there are additional schemes, and low rainfall areas and regions with large area under waste or degraded lands.

Unfortunately, watershed development guidelines fall short of taking into account the goods and services provided by watersheds in other areas. This includes catchments of some of our most important rivers and, perhaps more urgently, coastal areas.

The Coromandel coast is amongst the most rapidly urbanising regions in India. It is also a intensely cultivated strip with a large area under irrigated crops and net area sown. There are number of competing demands for water in coastal belts, some of the most obvious ones being irrigation, domestic and industrial as well as the less appreciated role of environmental flows that determine the future of various backwater habitats. Given that rainfall along the Coromandel coast averages about 1,200 mm a year , much of this water demand is met through tapping of aquifers and piping of water from shallow lakes to urban centres.

Watershed development projects can play a vital role in restoring the recharge of over-drafted aquifers and tanks in the region, provided there is a simultaneous shift to less water demanding crops and industries in this region. Another important function that can be performed through watershed development is the restoration of natural drainage patterns and riparian vegetation. This has a buffering impact on peak flows that occur during cloud bursts.

There is clearly a need to re-visit the criteria used to select regions for watershed development and the inclusion of watersheds that contribute significantly to surface and ground water resources and drainage of low lying regions and thereby significantly reduce local vulnerabilities. These programmes can act as effective defences against the negative impacts of landuse change in coastal areas.

One of the least studied aspect of fisheries is the impact of upstream landuse and habitat modification on productivities and species composition of backwater regions. Changes that directly impact fisheries resources include construction of dams and diversion of flows to irrigation, pollution through agricultural runoff and industries upstream and local modifications from activities such as shrimp farms and salt pans. Another increasingly significant issue is that of obstruction or modifications of patterns of littoral drift leading to large scale accretion or erosion of beaches along the Coromandel coast.

While these changes in land use are likely to have a deleterious effect on marine productivity, even larger is the impact of fishing over-capacity. Marine fish landings along the East Coast have stabilised over the past decade. However the size of fishing fleets and gear have increased during this period. The Central Marine Fisheries Regulation Act has a number of provisions, ostensibly to decrease the pressure on marine fisheries resources. These include a "fishing ban period" and restriction of certain mesh sizes for nets. However few of these restrictions are enforced.

Among the most promising mechanisms for marine fisheries resources management has been the involvement of artisanal communities. Fisheries co-management initiatives have had mixed results along the coast, but have fared far better than any other effort in this direction. There are various limitations to the present co-management initiative, perhaps the biggest being their being limited to the artisanal sector. However these limitation are recognised by the various stakeholders and efforts are being made to broad-base them through greater participation of the concerned fisheries departments.

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Chapter 4 Coastal Bio-shields and their Putative Role During Large Weather Related Disturbance Events

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Contents

4.1 Background

Even four years after the Indian Ocean tsunami, one of the most widely debated topics has been the role of coastal vegetation in mitigating impacts of the tsunami. Following the aftermath, several publications, both in scientific journals and popular media (Anonymous, 2005; Ganesan, 2005; Kar and Kar, 2005; Kathiresan and Rajendran, 2005; Kumar, 2005; Anonymous, 2006; Dahdouh-Guebas et al., 2006; Raghunathan, 2006; Vermaat and Thampanya, 2006; Olwig et al., 2007), staked claims on the positive and protective role coastal vegetation provided in the event of such large scale natural disasters (see Mukherjee et al., 2007b for a compilation). Piloted and supported by this, huge amounts of money was spent in creating bio-shields along coastal stretches to act as natural defences against events like the tsunami (Mukherjee et al., 2007b). While these modifications to coastal stretches were being implemented, a few studies indicated that coastal vegetation had very little or no protective role to play in the events like the tsunami (Kerr et al., 2006; Bhalla, 2007; Madhusudan et al., 2007; Mukherjee et al., 2007b) and suggest that the role of other coastal features like topography, near shore

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Figure 4.1: Casuarina "bio-shieds". Will they work?

bathymetry, distance to continental shelf, etc. need to be considered as variables that explain the observed inundation distances.

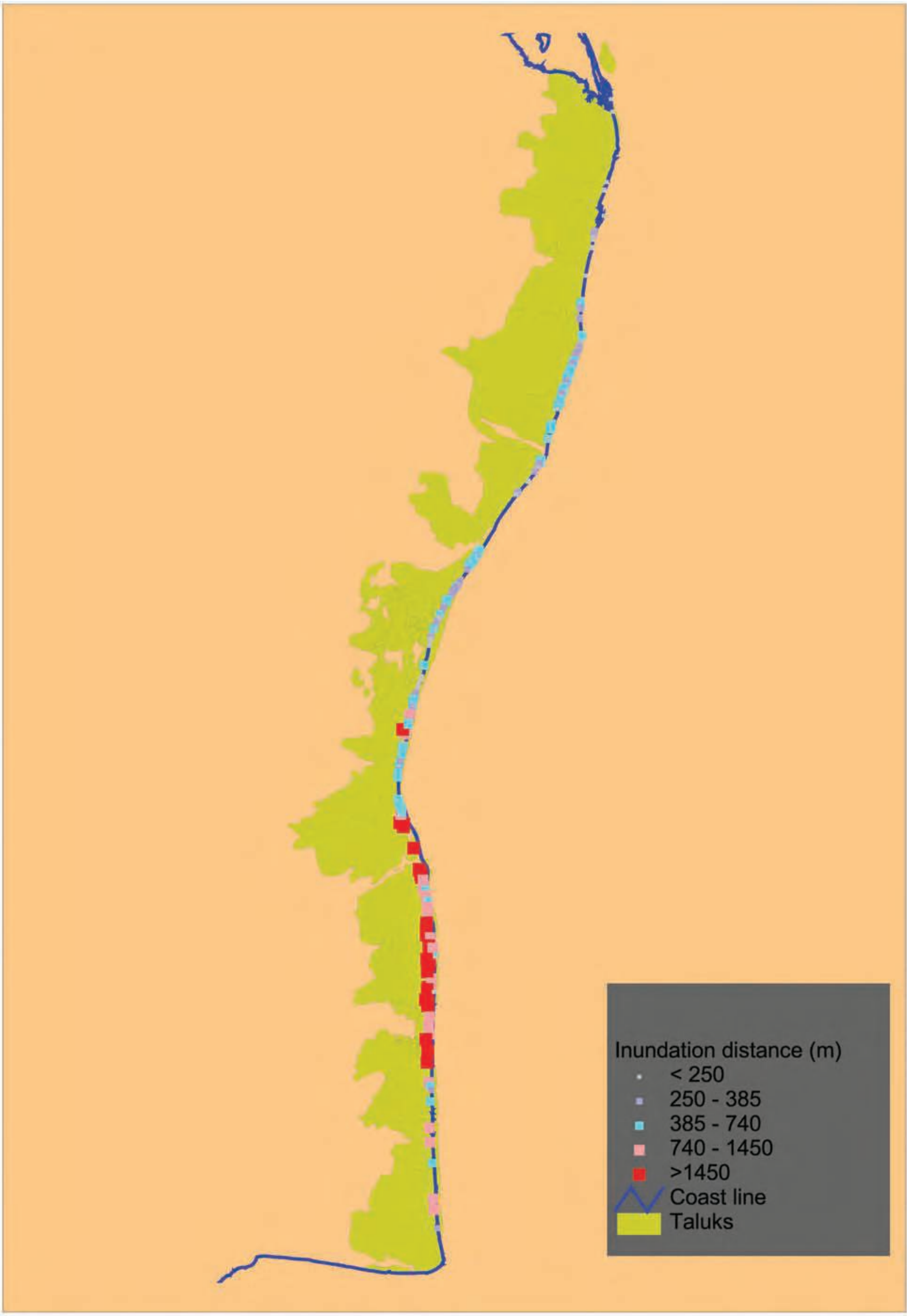
Results to date have been mixed, and one of the fundamental problems in addressing this issue has been that of methodologies used to arrive at conclusions regarding the role of bio-shields. While anecdotal, observational or univariate statistics invariably support the surmise of protective role played by coastal forests and bio-shields, the use of multivariate statistical approaches, which takes into account potentially confounding factors, have failed to find an association (Kerr et al., 2006, 2008). Nevertheless, the role coastal forests and plantations play in providing livelihood opportunities, timber and fuel wood, etc. to coastal populations cannot be dismissed, but it would be naive to believe that they alone served the purpose of coastal protection against tsunamis. Such a notion will only serve to instill a false sense of security and hope among people who continue to reside in these vulnerable zones. Resolution to this disagreement is imperative and will help in minimising loss of life and property in the event of such large scale natural calamities by adopting measures which will mitigate or reduce risks that populations are exposed to along the coast. This will be possible only by addressing methodological issues and by adopting a more robust analytical method than those previously used.

In this study we revisit this issue and develop a statistically robust framework to address it. We do this by first, looking at current methods employed by different authors in peer reviewed publications in analysing the role of bio-shields and second, reanalysing the previously collected data using a model selection procedure that selects a model that best explains the observed impacts from a set of competing models.

4.2 Study Area

The study area is spread along 360 km of coast line that extends between Chennai to Point Calimere (figure 4.2). The locations of maximum inundation distance are the same as that used by Madhusudan et al. (2007).

Figure 4.2: Inundation distances along the coast of southern India as a result of the 2004 tsunami.



4.3 Methods

Data Layers

Elevation

For each inundation point the elevation values were extracted from the SRTM (Shuttle Radar Topographic Mission) version 4 datasets (`http://srtm.csi.cgiar.org/`). The data set has a horizontal resolution of 90m and a vertical resolution of 16m (Jarvis et al., 2004) and can be used for coarse level analysis and across large landscapes. The percentage slope was derived from the maximum and minimum elevation values along the shortest line between the inundation point and the coast line.

Near Shore Bathymetry

We use the improvised bathymetry data sets from National Institute of Oceanography, where improved shelf bathymetry were derived by digitising depth contours and sounding depths less than 200 m from the hydrographic charts published by the National Hydrographic Office, India (Sindhu et al., 2007).

Vegetation Cover Index (VCI)

The Normalised Difference Vegetation Index (NDVI) along the shortest path from the inundation point to coastline is summed and divided by its length to estimate the vegetation cover index for each inundation point. NDVI was derived from LandSat ETM images for the 2000 period.

Distance to Continental Shelf

We extract the perpendicular distance from the coastline to the continental shelf, which was derived from the improvised bathymetry data sets from National Institute of Oceanography (Sindhu et al., 2007). Additionally the percentage slope of the continental shelf was derived as the difference between the near shore bathymetry and depth at the shelf along a shortest path of travel.

Inundation Points

The maximum observed inundation distances was compiled by Madhusudan et al. (2007) from various published papers, unpublished reports and from field visits. We use the same dataset in the current analysis of coastal vegetation and their protective role.

Modeling the Effect of Physical Features on the Observed Inundation Distance

While we could have taken many different approaches (data visualisation, hypothesis testing, multivariate statistics, etc.) to understand the role of physical features, we use a model selection approach using Akaike's Information Criteria (AIC) scores. This approach allows several competing models to explain the observed effects and also provides a frame work of evaluating the competing models. Given the dataset and the set of candidate models, this method also allows selecting a best approximating model or a set of candidate models that are plausible. To avoid biased inferences resulting from collinearity in variables, we constructed a pair-wise correlation matrix and selected only those combinations of variables that were not significantly correlated. For example continental slope and shelf distance were not modeled together as they were highly correlated.

A series of spatial models were constructed to explain the observed inundation distances and the role of various physical features and vegetation cover that could potentially influence the same. We took a stepwise approach in constructing the models, that is, we first modeled the inundation distance as a function of each of the six variables independently and then added additional variables to the most plausible models in a stepwise fashion. The procedure was repeated until there was no significant change in the explanatory power, as determined by the AIC weights of the model with the addition of variables. Models were ranked according to their △AIC scores. The model selection was based on the △AIC scores following the framework of Burnham and Anderson (1998) and Royall (1997).

It is well acknowledged that geographical data are continuous and location based observations are often affected by nearby observations; under such circumstances the observations will not be independent of each other. This lack of independence or spatial correlation must be accounted for during the analysis stage to produce unbiased results. While this can be overcome with well designed data collection surveys, it was not possible in this case as data was collected opportunistically. When surveys options are limited or not possible the same can be accomplished through spatial modeling of datasets.

Spatial autocorrelation can be classified as high-high or "positive effect" when areas with high values are surrounded by areas with high values and areas with low values are adjacent to areas with low values. A low-low spatial correlation or negative effect results from areas of low values being surrounded by area of high values and vice versa, leading to a checkered distribution of data values. Both these circumstances indicate spatial dependence in data, emphasising that the neighbourhoods have an influence on each other. The presence of spatial dependence violates the assumption of independence in standard regression analysis.

For the purpose of spatial modeling, a definition of what constitutes neighboring locations needs to be specified. The neighbourhood structure defines which locations have a potential influence on each other, the neighbours, and rules out any potential influence of regions that are not considered to be neighbours. The neighbourhood structure is used to test for spatial autocorrelation and to specify the spatial component in the autoregressive spatial model.

A test for spatial autocorrelation in the response variables was performed as an exploratory exercise. Spatial autocorrelation in the inundation distance was estimated using Moran's I statistic (Cressie, 1993). This was done in order to decide on the need for a spatial regression model (Cressie, 1993). Moran's I tests whether the error terms are randomly distributed over the study area, the value of the Moran's I statistic ranges from 1 to -1. A value approaching 1 indicates the presence of positive spatial autocorrelation, where regions with large error terms are adjacent to other areas with large error terms. A negative value near -1 indicates the presence of negative spatial autocorrelation, where regions with large error terms are neighboring regions with small error terms. A value near zero indicates the absence of spatial autocorrelation. In this case the significance of Moran's I statistic was determined by a random permutation approach (999 permutations), where a significant result indicates that there is spatial autocorrelation in the model error terms.

These were estimated for 2-175 km neighbourhood definition in order to determine the optimum neighbourhood distance for defining spatial autocorrelation structure for the spatial regression models (Cressie, 1993; Lichstein et al., 2002). The spatial autocorrelation dropped from 0.77 ($p \sim 0$) at 2km to 0.06 ($p \sim 0$) at 175 km. Much of the spatial autocorrelation is accounted for within 90 km. Thus,

Table 4.1: Summary of peer-reviewed scientific publications that analyse the role of different factors including vegetation in mitigating inundations resulting from the 2004 Indian Ocean tsunami.

Publication	Analysis Used	Role of Vegetation	
		Positive	No Effect
Kathiresan and Rajendran (2005)	Linear regression on individual variables		
Vermaat and Thampanya (2006)	Analysis of Variance	√	
Olwig et al. (2007)	Exploratory data analysis	√	
Bhalla (2007)	Linear regression		√
Danielsen et al. (2005)		√	
Kerr et al. (2006)	Multiple regression		√
Kar and Kar (2005)	None	√	
Dahdouh-Guebas et al. (2006)	Multivariate statistics, Clustering	√	
Chadha et al. (2005)	None	-	-
Murthy et al. (2006)	Exploratory data analysis	-	-
Ramanamurthy et al. (2005)	Exploratory data analysis	-	-
Jayakumar et al. (2005)	Exploratory data analysis	-	-
Kurian et al. (2006)	Exploratory data analysis	-	-

the need for a spatial regression that explicitly incorporates spatial autocorrelation was established and we chose a 90 km neighbourhood distance for defining our spatial regression models using an autoregressive structure. We use spatial error models with the assumption that the relationship between the inundation distances in neighboring cells is a result of the same relationship of the explanatory variables in the neighboring cells.

4.4 Results

We reviewed a total of 13 scientific publications that were relevant to this topic. The results of this exercise have been summarised in the table below (table 4.1). To address the issue of methodologies we compiled a list of all peer reviewed publications related to this issue and assess the conclusions made by presenting the methods they adopt. We restrict our effort purely to articles published in peer reviewed scientific journals as reports, web logs and popular media often lack information on the analytical approach adopted in arriving at conclusions. Nearly half the papers we reviewed claimed that vegetation played a significant role in mitigating the impacts of the tsunami. An equal number of papers attribute this to factors other than vegetation, while only two papers provided evidence against it. The kind of analysis that went into staking these claims varied from none to simple exploratory data analysis to simple linear regressions against observed impact and individual variables. Only one publication looked at the possible combination of more than one variable in a stepwise multiple regressions and concludes that they do not find any significant role vegetation provides as bio-shields against events like the tsunami.

With a divided set of results on the protective role of coastal vegetation, especially mangroves forest and Casuarina plantations, a number of articles are regularly cited to support the mitigation hypothesis, the most prominent of these are three journal papers (Dahdouh-Guebas et al., 2005; Danielsen et al., 2005; Kathiresan and Rajendran, 2005) and one report (UNEP, 2005).

Kathiresan and Rajendran (2005) reported a significant inverse association between human mortality and the extent of forests fronting coastal hamlets in Pichavaram, Tamil Nadu, India. However, a re-analysis of the same dataset by Kerr et al. (2006) found the relationship spurious when controlling for differences in hamlet elevation and distance from shore: Not surprisingly, a hamlet located further inland can have more vegetation fronting the hamlet.

In a second study from the same location, researchers apply a chi-square contingency test (a statistic designed for count data) to a continuous variable namely, land area (Danielsen et al., 2005) which are largely adjacent units of land, and therefore not statistically independent observations. Consequently, there is a high likelihood for such datasets to respond similarly to other factors including those that were not considered in the study. Other factors that are correlated across space that also arrest wave inundation includes distance from shore, elevation, topographic complexity, history of land use, near-shore bathymetry, etc.. The authors did not take into account nor acknowledge the likely impacts of any of these other factors which have subsequently been proven to be significant (Chatenoux and Peduzzi, 2007). Furthermore, Danielsen et al. (2005) propose a single explanation for observations having several equally reasonable and potentially correlated, but unconsidered alternatives, a criticism first broached by Dahdouh-Guebas et al. (2006). For example, Danielsen et al. (2005) highlight that three northern villages incurred minimal damage because they were situated behind dense vegetation. However, in figure 1 in their paper, no area elsewhere incurred damage this far inland even when lacking vegetation. The issue is surely multivariate and quantitative, since wave inundation can in some cases be halted by other types of land cover, as well as over the distances under discussion given slopes of even a few degreesKanoglu and Synolakis (1998). In situations displaying such a complicated pattern of response, it is necessary to formally assess the probability of competing explanations. Discussion of selected observations in light of one factor, however plausible apriori, is uninformative.

In the third of the series of papers supporting the mitigation hypothesis, Dahdouh-Guebas et al. (2005) score three discrete variables (pre-tsunami forest condition, forest degradation and tsunami impact) in a cluster analysis to explore the protective function of mangrove forests. However, the single dendrogram resulting from their analysis is not a statistical test of a hypothesis. A relevant question that could be asked is "Were sites with healthy forests less impacted than expected by chance?" Although the paper does not answer this, it is fortunate that we can address this issue more rigorously, as site frequency data are readily obtained without ambiguity from their paper. A 2 x 2 chi-squared test of the association between forest degradation (cryptic ecological degradation vs. no degradation) and tsunami impact (severe or little) is not statistically significant (n = 24, χ^2= 1.02, df = 1, p = 0.311). Similarly, we find no association between forest condition prior to the tsunami ("good" vs. "bad") and tsunami impact (n = 24, $\chi^2 = 1.35$, df = 1, p = 0.244). In other words, the pattern of damage (given the data) is no different from that expected by chance, and therefore, can not be linked to pre-tsunami forest condition. There is no statistical support for their unqualified statement "...where mangroves occur in the districts visited, they did in fact offer protection".

Efforts to challenge the mitigation hypothesis have included the following events - the episode began with the paper (by Kathiresan and Rajendran, 2005) entitled "Coastal mangrove forests mitigated tsunami". Re-analysis of this data revealed the correlation between mangroves and mitigation was spurious, as described in the earlier paragraphs (Kerr et al., 2006). However, following publication of Kerr et al. (2006) re-analysis, a third paper was published (Vermaat and Thampanya, 2006), presenting an alternate analysis of the original data which supported the original conclusions of (Kathiresan and

Rajendran, 2005). Despite the clear contradiction with the analysis of Kerr et al. (2006), the authors offered no explanation as to how such conflicting conclusions could emerge from the same data set, a situation wholly unsatisfactory for anyone hoping to make informed policy decisions on the basis of this research. Unfortunately adding to this situation, there was not sufficient detail in the paper to repeat the analysis. A corrected version of the paper (Vermaat and Thampanya, 2007) was published after Kerr et al, pointed out some of the elementary mistakes in the analysis to the authors. When done correctly, the result was identical to that presented by Kerr et al in 2006. In conclusion, there is no good quantitative data to support the mitigation hypothesis. How then should we treat the numerous anecdotal reports of a protective role for vegetation, many by people who were directly affected by the tsunami?.

First off, these stories of the mitigating effects of coastal vegetation should not be dismissed. They are an excellent starting point; they suggest that a proper study needs to be done. However, to be useful as data to test competing hypotheses, they need to have been systematically gathered along with data on other variables potentially accounting for mortality and damage. Were these anecdotes systematically gathered along with a fair representative of instances in which mangroves did not matter? If not, then an unbiased analysis is impossible. How do we know whether the coastal vegetation were the proximate cause saving these people? The amount of mangroves and other vegetation is correlated with a village's distance from shore, elevation, slope of the land and topographic complexity. How would you rule out those factors in these lovely stories? If these stories reflect a true and strong general effect from mangroves, then why is it that none of the properly done quantitative studies to date have been able to find this profound and strong effect?

Inferential statistics must always play a role in evaluating the probability of competing hypotheses concerning complex spatial variation in a multivariate setting. Indeed, such situations account for the development of inferential statistics: we simply don't know how to evaluate such complicated issues any other way. Further, caveats, even "important" ones, cannot ever, under any circumstances, transform anecdotes - certainly not those coupled to a flawed analysis - into valid support for a conclusion. To reiterate and re-emphasise, such half done and negligent work on the part of scientific community that can influence policy and knowledgeable spending towards prevention of disasters, will only give a false sense of security and hope to people living along the coast, rather than providing them with solutions that emerge out of proper data evaluation.

A Statistical Analysis

We unravel various processes that could potentially affect the observed inundation by analysing 643 inundation points collected from an earlier study along a coastal stretch of ~360km. The approach taken has been elaborated in great details in the previous section and our results shows that topographic and bathymetric relief are the most important factors that explain the observed impacts of the tsunami. As claimed by earlier studies we do not find any statistical evidence that suggests that vegetation alone played a significant preventive role during the 2004 tsunami along the Indian coast. Results of our modeling process are summarised in table 4.2. The confidence set of candidate models include all models with Akaike weights that are within 10% of the highest, which is comparable as a general rule-of-thumb for evaluating strength of evidence. Thus, we exclude all models with AIC weight of less than 0.059 from the model confidence set. This clearly eliminates all univariate models suggesting the

Table 4.2: Stepwise (forward) modeling procedure used to select the best model(s) that explain inundation distance following the tsunami. The Akaike's information criteria (AIC) and weights (Wi) are presented here. The variables used in the model are topography (elevation and coastal slope), bathymetry (near shore bathymetry, shelf slope and shelf distance), and VCI. The confidence set of candidate models are italicised.

Variable	AIC	ΔAIC	AIC wt (Wi)
Coastal Slope +Shelf Slope + NDVI + Near Shore	*9367.33*	*0*	*0.59*
Coastal Slope + Shelf Slope + NDVI	*9368.45*	*1.12*	*0.34*
Coastal Slope + Shelf Slope + Near Shore	9372.74	5.41	0.04
Coastal Slope + Shelf Slope	9374.48	7.15	0.02
Coastal Slope + NDVI	9377.33	10	0
Coastal Slope + NDVI + Shelf Distance	9377.38	10.05	0
Coastal Slope + NDVI + Near Shore	9378.26	10.93	0
Coastal Slope	9382.99	15.66	0
Coastal Slope + Shelf Distance	9383.02	15.69	0
Coastal Slope + Near Shore	9383.55	16.22	0
Elevation	9410.73	43.4	0
Shelf Slope	9450.77	83.44	0
Shelf Distance	9468.82	101.49	0
NDVI	9471.79	104.46	0
Near Shore	9480.78	113.45	0

Table 4.3: The relative importance of the variables determined using the AIC weights. Co-efficient for the parameters and their standard errors at 95% confidence interval calculated for the models in the confidence set are shown.

Variable	$\sum$AIC wt	Co-efficient	Std. Error
Coastal Slope	1	-41.75	±8.943
Shelf Slope	0.99	270.35	±152.143
NDVI	0.94	-3717.79	±1729.303
Near Shore	0.64	6.23	±6.864
Shelf Distance	0		
Elevation	0		
Intercept		1454.27	1322.14

need to use multivariate models when trying to understand the observed impacts of the tsunami, and clearly establishing that no single variable explains the observed inundations and that more than one variable plays a significant role in explaining the observed inundations.

While interpreting the results, AIC weight (Wi) is the weight of evidence that a model is the best approximating model, given the data and set of candidate models. Alternatively, the Wi can be interpreted as the probability that a given model is the best model, given the data and set of candidate models. For example, the model containing coastal slope and shelf slope is (0.01663/0.00025) = 70.45682 times more likely to be the best explanation for the observed impacts as compared to the model containing coastal slope only and 1.35 x 10^{21} times more likely than the model containing VCI only. Models containing only coastal slopes were 1.92 x 10^{19} time more likely to explain the observed inundation when compared to models containing only VCI.

The current approach also enables us to evaluate the relative importance of individual parameters by examining the AIC weights. The AIC weights for each model that contains the parameter of interest are summed and results are presented in table 4.3. Although topographic relief, bathy metric relief and vegetation cover index are highly plausible explanations for the observed inundation distances, both the physical variables perform better than the biological variable. More over when topographic relief and bathymetric relief are combined they are $(1.989/0.943) = 2.12$ times more likely the explanations of the observed inundation when compared to vegetation index alone, given the data and candidate set of models.

Model averaging across the confidence set of candidate models was undertaken according to Burnham and Anderson, 1998. The best model that explains the inundation for the given set of variables is as follows:

$Inundation = 1454.266 - 41.746 * (Coastal\, slope) + 270.347 * (Shelf\, slope) - 3717.769 * (NDVI) + 6.232 * (Near\, shore)$. In words,*an inundation distance reduces with increasing topographic slopes, increasing shelf slopes, near shore bathymetry and is inversely proportional to the vegetation cover.*

4.5 Conclusions

Our analysis clearly highlights that simplistic models with single parameters are insufficient to explain the observed inundation distances and that more than a single variable contributes towards explaining the observed effects. The results also indicate that other than coastal slope, no single variable is good enough to explain the observed inundation and that vegetation plays a role only when combined with elevation slopes. From our results we conclude that vegetation alone did not play a significant role in preventing inundation due to the tsunami and physical variables such as topography and bathymetry do play a more important role than vegetation. While vegetation and near shore bathymetry did contribute, in the final model, their role is important only in combination with topographic relief. Thus we do not hesitate to conclude that coastal vegetation does not provide adequate protection during events like the 2004 tsunami. The results from our analysis dismiss the mitigation hypothesis that authors of the many studies outlined above have put forward. Some authors appeal to common sense or the laws of thermodynamics. Sure, vegetation will absorb some of the energy from a tsunami but will they save lives because of this? Others have appealed to the precautionary principle, an argument we find particularly interesting, because it is, in effect, an admission of error. For example, some have argued that because there may be a risk to life in future tsunamis if mangroves and reefs are not rehabilitated the normal standards of statistical proof should not apply to their research. We find this is a very strange distortion of the precautionary principle. Which advice is more likely to put people at risk? Suggesting people are safe behind mangrove barriers, or suggesting they run to higher ground?

Other than scientific analysis review of literature clearly shows that an overriding importance is placed on anecdotal data to assess the value of coastal forest to mitigate tsunami damage, such as the recycled stories which regularly feature in most media reports following the tsunami, is quite puzzling. For example, Dahdouh-Guebas et al. (2005) state that "the closest scientific evidence for the buffering function of mangroves comes from socio-economic and ethno biological surveys that focus on the services of mangrove forests". However, the only statements by villagers in support of mitigation presented in this paper refer to the protective function of mangroves against cyclone generated waves, which are an entirely different beast to a tsunami. Similarly, when questioned on Danielsen et al. (2005), the editors of Science were unconcerned with the flawed statistical analysis, and felt the study should stand because it was backed up by the aforementioned anecdote of the three villages and "important" caveats about the studies' generality, what role then can anecdotes play in evaluating the effectiveness of vegetation against tsunamis?

Gopinath S (http://www.photoessays.net)

Even as the mitigation hypothesis was drawing attention, the action plan that was drawn up during the National Workshop on Formulation of Science Plan for Coastal Hazard Preparedness (2005) clearly acknowledges that vegetation alone will not be effective in the event of a tsunami "Vegetation such as mangroves is known to help mitigate the effects of storm surges and tsunami. It is, however, necessary to quantify the protection such natural buffer zones, now called bio-shields, provide to coastal habitation. For example, it is necessary to determine the thresholds beyond which they cease to be effective and the extent of protection they provide." (http://www.nio.org/jsp/science_plan.jsp) and recommend the need to analyse time series of different datasets to understand hazards along the coast.

In the action plan drafted by the Department of Science & Technology, Department of Ocean Development, Council of Scientific and Industrial Research and Indian National Science Academy, recommend the need to set up an operational early warning system and the need to evolve a national research agenda that will take a holistic look at the country's coastal hazard preparedness. In the same year the Government of India approved a $32 million project to put an early warning system in place by September 2007 (http://dst.gov.in/whats_new/press-release06/Tsunami.pdf). Although such sound scientific recommendations and steps were taken immediately after the tsunami, a sizable amount of money was spent on creating bioshields all along the coast (Mukherjee et al., 2007b), while the same could have been spent on strengthening existing disaster preparedness through various education, training and awareness programs for communities living along the coast to deal such emergencies.

While we make this conclusion on the role of coastal vegetation in events like the tsunami we do acknowledge the role coastal forests and plantations play in providing livelihood opportunities, timber and fuel wood, etc. to coastal populations. As vegetation might not protect people from disaster like the tsunami, the efforts to restore degraded coastal habitats should continue for ecological reasons and not on the false premise of coastal protection.

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Part III

Evolving Strategies for Restoration of Coastal Habitats

Chapter 5 Strategies for Restoration of Coastal Habitats: An Introduction

P. Dilip Venugopal, Abraham V. A. and R. S. Bhalla

Contents

5.1 Ecological restoration - A note on principles and practices

Restoration ecology is a relatively new multidisciplinary science. The practice of ecological restoration, on the other hand, is many decades old, at least in its more applied forms such as erosion control, reforestation, and habitat and range improvement. However, it has only been in the last 15 years that the science of restoration ecology has become a strong academic field attracting basic research (Young et al., 2005). Despite a relatively short history, restoration has evolved remarkably quickly as a discipline of ecology and boasts an international society and representative publications (Burke and Mitchell, 2007).

Definition/changes

The current definition from the Society for Ecological Restoration (Clewell et al., 2005) is “Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability.” However, the definitions have undergone many changes over the past years, as the complex processes and problems in ecological restoration have been better understood. Some of the previous definitions are being provided below.

For example, Davis (2000) believed that the term ’restoration’ was a misnomer and preferred the use of "ecological enhancement" or "ecological enrichment" or "ecological architecture." Recently, Davis and Slobodkin (2004) have suggested the following definition ‘‘Ecological Restoration is the process of restoring one or more valued processes or attributes of a landscape.’’ This has later been revised as the process through which scientists provide practitioners with the ‘‘clear concepts, models, methodologies, and tools’’ needed to support ecological restoration may be defined as restoration science (Clewell et al., 2005).

Motivation for restoration

What are the motives behind restoration? What are the objectives, motivations and rationale that drive restoration ecology? There are a multitude of overlapping factors that drive restoration projects, discussions on which can be found in literature and those listed by Clewell and Aronson (2006) have been provided below:

- Technocratic Rationale: Govt. agencies/Large Organisations satisfy mandates, tends to be autocratic.
- Biological: Recover lost aspects of local biodiversity
- Heuristic: Demonstrate ecological principles
- Idealistic: Cultural & Societal concern and/or spiritual upliftment
- Pragmatic: Restore natural goods & services

Science of restoration – Guiding principles

Current conceptual restoration approaches have evolved largely from ecological theory and studies in applied ecology. Ecological theory often incorporated into conceptual restoration models includes, ecological succession and disturbance, landscape ecology, community assembly rules, trophic interactions, population dynamics,species ecology, and soil ecology (Burke and Mitchell, 2007). See table 5.1.

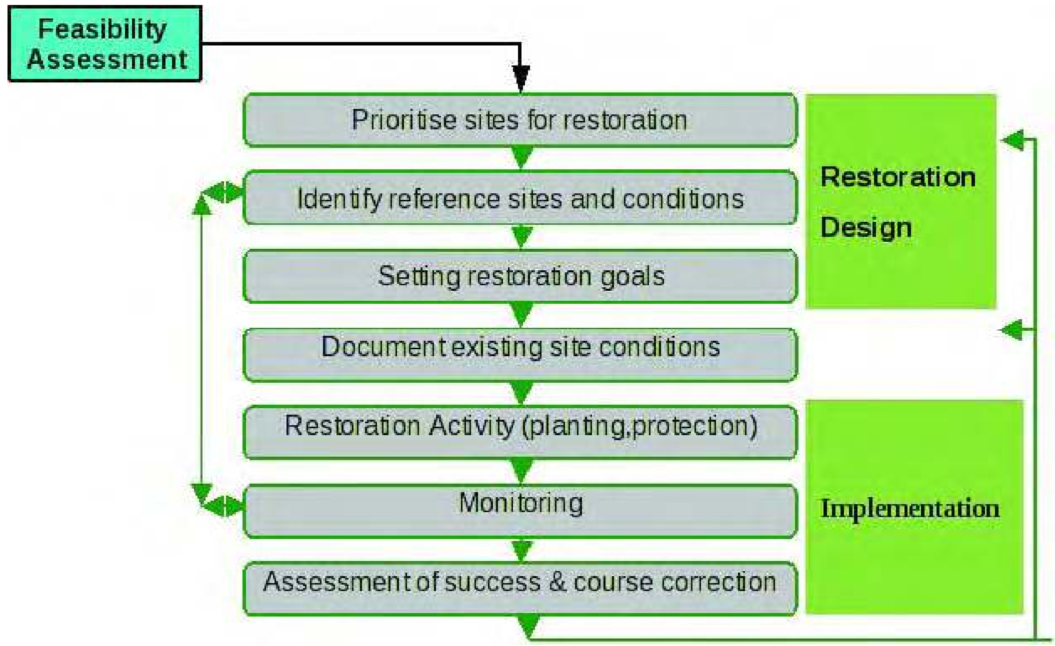
Procedures - Restoration Protocols

The components of a restoration protocol have been synthesised from different sources by (Giardina et al., 2007). Ecological restoration ideally encompasses a series of steps to maximise the likelihood of achieving diverse restoration goals. These steps need not necessarily follow a sequential manner. Developing an ecological basis for achieving these restoration goals requires science-based information.

Table 5.1: Five stages of restoration can be guided by theory and concepts drawn from ecology and restoration experience (from Zedler (2005)).

Stages of Restoration	*Questions*	*Guiding Theory/ Concept*	*Origins of Theory/ Concept*
1. Goal setting; developing the conceptual model	Which restoration targets are suitable for the landscape?	1. Suitability model	Restoration experience
	Can individual restoration projects aim to achieve multiple goals?	2. Biodiversity, ecosystem function	Ecology and conservation biology (predicting impacts of lost species richness)
	Are biodiversity and ecosystem services compatible goals?	3. Eutrophication	Lake ecology (limnology), landscape function
2. Prioritizing sites for restoration within the region	Of the most promising sites, which would have the fewest constraints?	4. Reversibility of degradation, alternative states	Restoration experience, rangeland ecology, landscape ecology
	Is it better to restore a few large or many small restoration sites?	5. Island biogeography	Ecology of islands that differ in faunal diversity
3. Manipulating abiotic conditions on site	What habitats will support the desired species?	6. Niche	Community and population ecology
	What physical preparations are needed?	7. Primary (and secondary) succession	Community ecology, gradients in composition, disturbance regimes
	What physical conditions would support the most species and functions?	8. Topographic heterogeneity	Ecology and conservation biology (explaining biodiversity patterns)
4. Manipulating the biota on site	Which functional groups are needed; which should be introduced and when?	9. Secondary succession and land-use legacies	Old-field ecology, extrapolations (space-time substitutions), disturbance regimes
	How should we prepare the site for desired species?	10. Assembly, interspecific interactions	Plant community ecology, animal population ecology
	How can we control unwanted invaders?	11. Invasion	Alien species ecology
	Will the system respond to bottom-up or top-down manipulations?	12. Food web dynamics	Animal ecology, population ecology; limnology
	Does genotype matter? If so, which propagules should be sought?	13. Extended phenotypes	Ecological genetics, restoration ecology, plantanimal interactions
5. Ecosystem maintenance	Will the restored system persist?	14. Resilience	Ecosystem dynamics and management, restoration experience

Figure 5.1: Protocols for restoration adapted from (Nature Conservation Foundation and Vattakanal Conservation Trust, 2006) and (Clewell et al., 2005).



Restoration that focuses on one step or one attribute will be of reduced impact relative to restoration conducted within a broader framework. Restoration practice should address the following targets:

- species targets (species, genetic representation, population viability, and resilience of restored populations) and
- ecosystem targets (vegetation structure, ecological function, and ecosystem services)

Structure can include habitat morphology or for forests, tree age classes and canopy layers. Function can include attributes relating to bio-geochemistry (nutrient cycling, organic matter processing), physiology (canopy photosynthesis, light interception), or recruitment (avenues of native species regeneration). Finally services most often relate to products of human value: timber and non-timber products, clean water, carbon sequestration, biodiversity and aesthetic or recreational services (Giardina et al., 2007).

The following representation adapted from Nature Conservation Foundation and Vattakanal Conservation Trust (2006) and summarised from the primer for restoration developed by Clewell et al. (2005) illustrate the protocols.

When and where to restore?

Clewell et al. (2005) provide direction on when and where does the need for restoration efforts arise. They are required when

1. The natural recovery of the original vegetation ad associated animal communities is difficult.
2. Unless assistance to recovery is provided, natural recovery may take decades to centuries.
3. Specific conservation goals have to reached.

Restoration may be necessary in a wide variety of sites where:

1. Seed producing parent trees have become extinct, locally.
2. Forests were replaced by timber plantations or cash crops.
3. Settlements, plantations, or other land-use existed earlier but now abandoned.
4. Soil seed bank is depleted or lost due to disturbances such as fire and grazing.
5. soil nutrient status and symbiotic mycorrhizal fungal populations are lost or reduced.
6. Top soil is lost, eroded or depleted due to mining.
7. Open areas have been created due to clear-felling, fires, or landslides.
8. Heavy infestation of weeds, grasses, and vines, choke natural vegetation.

Also, determination of the scale of the restoration work as part of the goals and objectives is important for planning, management and cost estimation of the restoration project. Ecological restoration can be implemented at different scales (forest stands-watersheds-landscapes) and approaches (Passive – fencing; Active-Enrichment planting). Most restoration activities start at small scales with, for example, a focus on species representation through passive approaches like fencing to exclude ungulates. Passive approaches can be supplemented with active approaches (control of invasive plants, species enrichment through planting, and even stand establishment). These efforts will necessarily rely on available techniques appropriate for that scale and that span passive to active management (Giardina et al., 2007).

Problems and challenges

Some of the problems with the field of restoration ecology have been listed below -

1. Arbitrariness of determining which time period in the past should be the target of restoration efforts.
2. An implication of statis with the word 'restored', when nature itself doesn't remain static.
3. True restoration is impossible, given changes in climate, absence of keystone species or presence of new species (Davis, 2000).
4. Goal setting

   Goals are often determined by preconceptions or misconceptions, which place more value on particular ecosystem states or on how the ecosystem was, or might have been, at some particular time. These preconceptions may limit or bias the discussion of restoration possibilities, and therefore prevent the development of more effective and efficient strategies. Ecological restoration will always involve people interacting with ecology, regardless of whether this is to fulfil social, cultural, political, economic, or ecological objectives (Burke and Mitchell, 2007). So the ecological potential for restoration, matched against societal desires need to be considered in an iterative manner for setting restoration goals (Hobbs and Harris, 2001). Finally, setting realistic goals for restoration goes beyond scientific understanding of how ecosystems work and how we can reassemble them (Hobbs, 2004).

Other challenges in restoration ecology include,

- magnitude and scale
- economic and social costs of restoration are often prohibitive
- possibility of restored ecosystems to be sustainable in the future environment.

The need for a future-oriented restoration focusing on ecosystem functions rather than re-composition of species or the cosmetics of landscape surface has been proposed by (Choi, 2007) . He put forth that the paradigm has to change to be future oriented, with applicability of ecological theories to restoration practice, predictability of restoration outcome, and sustainability of restored ecosystems.

To conclude, a quote from Davis (2000) that describes a basic challenge in restoration, is given below *"Of course, the goals and methods (for restoration) will still be arbitrary, developed by the various stakeholders, because nature itself provides no specific prescription for human intervention."*

5.2 Project Background

The primary objective of this component was to set up protocols for restoration of coastal habitats and demonstrate the same in pilot restoration sites. Three different habitats along the Coromandel coast of India were identified for restoration, namely, mangroves, tropical dry evergreen forests and coastal sand dunes. Given that habitat restoration can takes decades or longer, the project was limited to initiation of the actual restoration process through participatory interventions wherein local communities were made more aware of the value of these systems and how they could be protected and restored.

The restoration strategy that was adopted comprised the following components:

Site selection Here we identified representative habitats along the Coromandel coast using GIS & RS and followed up with extensive field visits and ecological assessments of their status. The final set of sites selected for restoration satisfied a number of criteria including willingness of local communities to participate and contribute to their restoration and continued protection.

Restoration activities Herein we undertook the restoration of selected areas. This was a learning process as we tried to build upon existing knowledge on restoration and tried out techniques which were both low cost and low on maintenance. Most of the restoration work involved planting native species of vegetation in suitable and protected locations.

Community mobilisation This was a crucial component in the project strategy and involved various awareness generation activities followed by negotiations and micro level planning of restoration activities. The active involvement of communities essentially defined the level of success and likely long term outcome of this initiative. We formed eco-restoration committees which comprised of representatives from various groups in the village including the elected Panchayat, representatives of women self help groups, traditional Panchayats and temple authorities, the latter in the case of sacred groves.

Administrative arrangements One of the biggest challenges we faced was the need to work with various configurations of site ownership and control. Among the variety of institutions that had to be dealt with were the district administration, forest departments, temple authorities, elected Panchayats, representatives of women self help groups and traditional leaders. Administrative arrangements with these organisations were designed to ensure there was transparency and accountability at all stages of implementation.

Monitoring In-depth field studies were carried out to record various survival, growth and environmental parameters in the different restoration sites. In addition, a regular framework for monitoring the maintenance and upkeep of the satellite nurseries and sites was put into place. Monitoring of other activities, materials, labour and finances was done by regular maintenance of registers for the same. This was particularly important during the planting phase of the project and to track costs of inputs into the nurseries. Growth and survival rates were also regularly monitored at the mother nursery.

Project Area

Du to the short time span the restoration component of the project was restricted to the Tamil Nadu and Pondicherry portion of the Coromandel coast which extends from the South of Pulicat Lake to Point Calimere in Nagapattinam. Areas suitable for interventions were identified in this region through extensive surveys of about 150 potential sites. Given the existing restoration programmes of the Tamil Nadu Forest Department, none of the sites in the state were on forest lands. In the case of Pondicherry, the department facilitated the work at Karaikal in the initial period of the project. This site was handed over to the Forest Department of Pondicherry shortly after planting activities.

Land Tenure Systems

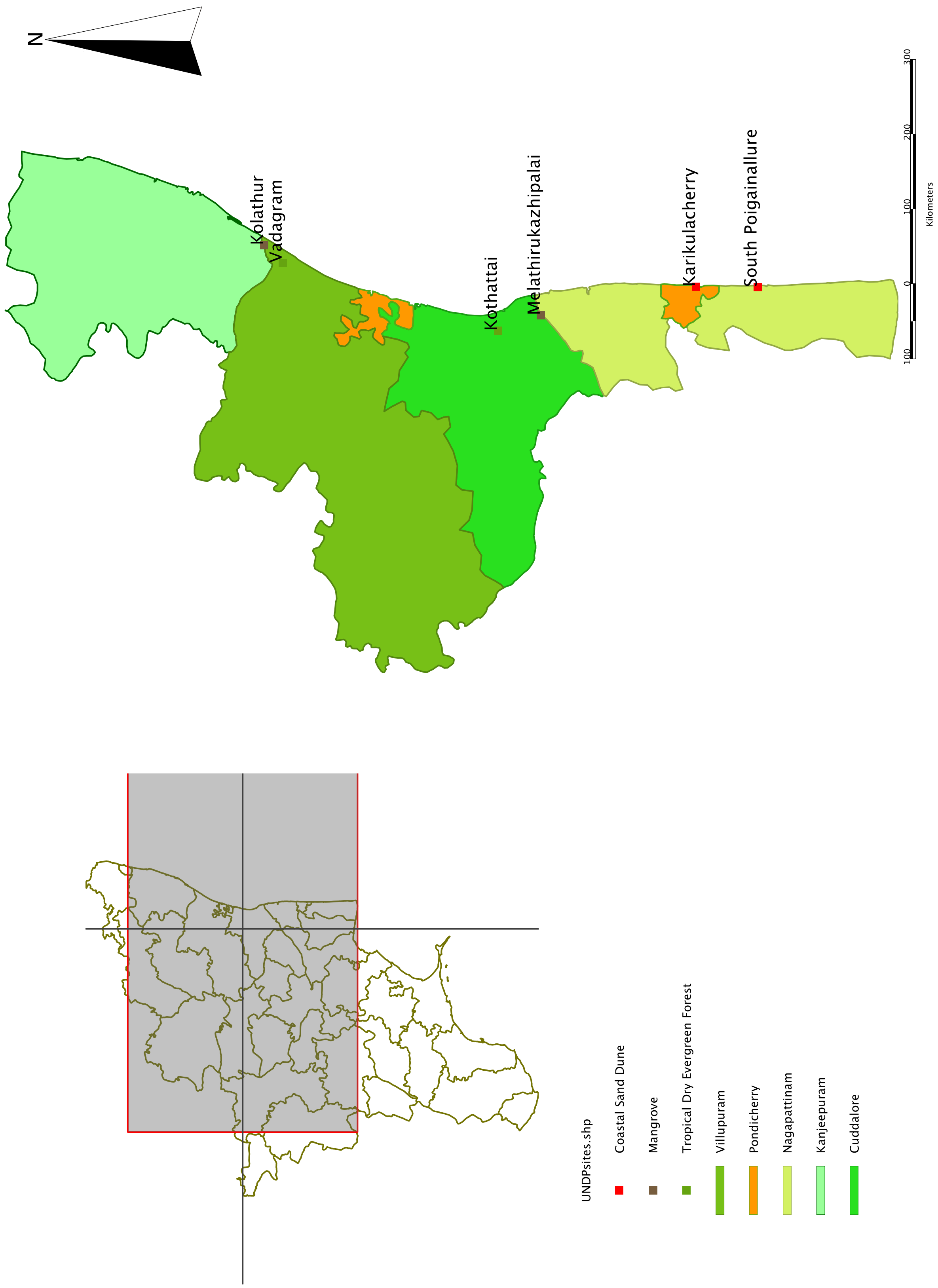
Land tenure was one of the important criteria used for site prioritisation. This remains one of the serious issues regarding the sustainability of the restoration effort. The bulk of the project area fell under revenue land or land administered by the Forest Department of Pondicherry. While the former were administered through the village Panchayat they continued to have varying degrees of control vested in the local administration. Forest lands were more stringently controlled by the Forest department, however, even there varying levels of community access and uses existed. Most of the coastal sand dune and initially identified mangrove sites fell under this category of land.

The second prominent form of land tenure was temple lands. Many tropical dry evergreen forest sites fell within temple groves. The ownership and administration of these groves was a mix between revenue/Panchayat and temple authorities. To add to the complexity, the authority for decisions regarding the land was not vested in any single group or individual, but in a combination of traditional leaders, temple[9] and Panchayat representatives.

The administrative powers and controlling stakes over these habitats are not clearly defined and are often based on local political allegiances and formations. The fate of the vast majority of these habitats appears to be bleak in the backdrop of competing demands for land and resources. This situation is only likely to get worse in the future with a dilution of legislation protecting coastal habitats from alteration (Menon et al., 2007).

[9] Hindu Religious and Charitable Endowments Dept.

Figure 5.2: A map of the project area showing the locations of the various sites.



5.3 Components of the Restoration Strategy

Site Selection Procedures

The primary criteria used for selecting sites for restoration were the ecological importance of an area and likelihood of restoration success. A number of parameters define these criteria and selection of sites can therefore be daunting task for restoration practitioners. Evaluation of a site for restoration requires a multidisciplinary approach and a mix of quantitative and qualitative assessments that encompass both ecological and sociological parameters. For instance, some sites may have a high level of species richness and abundance but are under severe pressure from local resource extraction or do not have any institutional mechanism for resource management. If selection were to be purely on ecological criteria, these sites would be selected. However it would be highly unlikely that any restoration effort made there would be sustainable.

Various authors have combined both important biodiversity features and high current or future threats to rank conservation priorities (Reyers, 2004). Generally, consideration of these factors is closely followed by an assessment of the complexity of the task and the investment required to achieve restoration success at a variety of sites using a variety of means (Diefenderfer et al., 2003). Various methods involving different technologies are being used in the site selection and ranking process to make optimal choices for locating, conducting, and sustaining restoration project sites (Borde et al., 2004). Although many areas may be identified as important for representing biodiversity, only a small number of them can realistically be protected in the immediate future, as they are dictated by funding and resource shortages and anthropogenic influences on the sites. It is therefore crucial to identify areas of high conservation value within this selected set of areas. These include areas with a high biodiversity or irreplaceability value, and those with different degrees of threat or vulnerability value (Myers et al., 2000).

We evaluated each potential site along a list of criteria that covered biological, physical, and socio-economic factors. While this significantly increased the amount of information required per site, it allows us to evaluate the sites in an holistic manner. The same information later fed into restoration planning for the sites shortlisted for restoration work.

Site identification and prioritisation

Identification of sites in habitats that were candidates for restoration in the project area involved extensive use of geographic information systems (GIS) and remote sensing (RS). Prelimnary surveys were conducted in over 168 sites along the Coromandel coast and these sites were selected using remotely sensed imageries. Subsequent field visits were made to collect information about extent of area, ownership of land, overall ecological status (using indicators) and willingness of local communities to participate in a restoration and conservation effort. Based on these variables, more detailed assessments that covered both ecological and socio-economic criteria were carried out in the resulting candidate sites. Details of these investigations are provided in subsequent sections.

The methods for assessing and characterising each site varies depending on the level of information and resources available. In most cases however, data gaps exist and therefore additional biological or physical data is required to determine site suitability. Information on social, economic and political aspects is considered especially important for projects that aim to involve local communities for restoration (see

Walters (2004) for a discussion). Disturbance regimes, current threats and future vulnerability values also need to be incorporated (Diefenderfer et al., 2003; Reyers, 2004). Data on historical habitat extent, surveys on substrate and vegetation and physical factors controlling habitat development provide useful assessment information (Borde et al., 2004). Data on biotic distribution and complementarity have been used for prioritisation for conservation (Sarkar et al., 2004; Justus and Sarkar, 2002; Sarakinos et al., 2001).

Detailed surveys undertaken documented the structure, species composition, levels of disturbance and details about ownership of land and existing management mechanism and control structures operating on each site. The ecological surveys led to earmarking a handful of the sites for actual restoration work. The selected sites typically had the following properties:

- ownership patterns conducive to the project, i.e. non-forest and non-private land with permissions to work on it from relevant authorities
- willingness of local communities to facilitate the restoration activities and subsequently protect the site
- remnant of native vegetation which could be supplemented by the project
- sufficient size of habitat or proximity to a large habitat patch.

Thus a total of three tropical dry evergreen forest sites, two sand dune sites and four mangrove restoration sites were selected covering a total of 45 hectares of land in four districts in Tamil Nadu (Kancheepuram, Villupuram, Cuddalore and Nagapattinam) and the Union Territory of Pondicherry.

Community Involvement and Mobilisation

A fundamental requirement for restoration projects of this nature is to ensure activities taken up during implementation are sustained and supported over time. Given that the span of most restoration efforts is between 2 and 6 years, time available for involving local stakeholders can be quite limited. In the case of the UNDP-PTEI project, this was under 2 years, leaving very little room for mid-course correction.

Thus the strategy for community mobilisation did not envisage any "social engineering" or institutional capacity building. For instance we did not attempt to tackle issues such as gender awareness and sensitisation, neither did we attempt to build an independent institutional mechanism for project implementation. Both of these would have figured prominently in a longer project. Instead, we utilised existing institutional arrangements and tried to work within the available space to ensure gender equity, transparency and accountability. While this posed some challenges, it gave us the necessary time to concentrate on the implementation rather than organisational aspects of the community structures.

In spite of these limitations, issues of gender equity were an integral design of the mobilisation strategy. Representatives of existing women SHGs were involved from the very beginning as members of the restoration committees. These women representatives selected persons to manage the nursery and were the conduit through which labour was hired. This ensured that a substantial proportion of the income generated through hire of labour for planting and subsequent watering was done through women. The fact that majority of the women SHGs represent members from below the poverty line additionally ensured that economically weak groups directly benefited from the project.

The mobilisation strategy comprised of three kinds of interventions:

1. Awareness programmes and materials.

2. Formation of an implementation framework or committee within existing social institutions.

3. Implementing activities through local stakeholders.

Mobilisation strategies did not differ significantly between the three habitat types, even though the details differed. For instance street plays conducted in TDEF, coastal sand dune and now mangrove sites had different scripts. The mobilisation continued after the completion of restoration targets. This was considered essential to maintain the momentum and re-enforce the value of conserving these habitats amongst the community representatives. Experience sharing workshops were held inviting community representatives and provided a forum for them to share their experiences with representatives from government departments. The forest department played an important role during these events and the Wildlife Warden of Nagapattinam participated actively in the programmes. Finally the monitoring of growth and survival of the saplings along with the recording of meteorological data served both as a means of external supervision, as well a means of awareness raising by involving school children in environment related training sessions and workshops.

Nursery Raising and Planting

The process of getting saplings of suitable species and sizes and having them sufficiently hardened to handle the stress of transplantation is a crucial component of a restoration effort. Virtually every other aspect of the restoration project is built around this component. Most restoration efforts are limited to the vegetative component of a habitat, primarily because vegetation is the simplest and most understood component. In fact, most restoration efforts are based on the simple principal of re-building the primary producers and their protection with the assumption that the other components will "bounce back". This is one of the major reasons why restoration efforts often target degraded or remnant habitats (Elliott et al., 2007).

Even though planting and protection are comparatively simple interventions, the former is not without its challenges. These start with the sourcing of planting materials, seeds and and propagules. In the case of coastal habitats and tropical dry evergreen forests in particular, the number of plant species exceeds 450. The successful reproduction of many of these species requires replication of conditions that do not exist in the controlled condition of a nursery thus limiting the number of species that can be successfully raised and subsequently re-introduced or planted at the site. For instance, a number of seeds TDEF species need to pass through the gut of a large herbivore before they can germinate. This project relied heavily on the expertise of the Auroville Botanical Gardens for TDEF and coastal dune species and resulted building a nursery which comprised of a subset number of species of the tree, shrub and lianas that a part of coastal habitats.

Raising saplings in controlled conditions is followed by the processes of transferring them to the restoration sites, hardening them and subsequently planting them. The process of building "satellite nurseries" was primarily designed to ensure saplings had the time to recover from transportation and for their hardening. In the case of mangroves, the largest cause of stress and mortality appeared to be the transportation of saplings and specific precautions were required to move the saplings safely to site. Once in the satellite nurseries, the saplings were allowed to recover but were thereafter subjected to more natural conditions. Intervals between watering were increased and many of them were subjected to higher intensity of heat and light. In the case of mangroves, fresh water was gradually replaced by brackish water from the estuary near which they were located. The period of stay in the satellite nurseries varied from one to three months during which the care of the saplings was transferred to the village restoration committee. This was a component of community involvement and local capacity buildling.

The final act of planting was timed, as closely as possible, to the onset of the north-east monsoon for the TDEF and sand dune species. Tidal cycles determined the period of planting for mangroves. Local labour was involved in all the planting, most of those employed were members of women self help groups. This was followed by a regime of regular watering and inspections supervised by animators and watchers appointed by the eco-restoration committees. In the case of the forest department sites in Pondicherry, the aftercare was handled by the department via its own arrangements with local communities.

Monitoring

Monitoring of the activities was done at two different levels. The first pertained to weekly visits to the sites wherein both the site and registers that were maintained for hired labour and regular watching and watering duties were verified. These site visits also noted observations on status of plants in terms of water stress, grazing and integrity of the fence. The second comprised a scientific monitoring framework designed to track changes in growth and survival of the saplings. This included weekly tracking of environmental parameters, climatic conditions and measurements of growth in the saplings in a sample set of quadrats on a quarterly basis.

The monitoring of project activities resulted in two different kinds of outputs. The first led to an adaptive management strategy wherein we were able to modify inputs in terms of labour, watering frequency and strengthening of fencing on an ongoing basis. The second provided us important information in terms of the relative performace on different species in terms of growth given a set of environmental variables. Unfortunately given the limited time-span of this project continuous monitoring of the sites was not possible. However efforts are underway to continue the monitoring and maintenance of sites over a longer period.

Administrative Arrangements

The Boxing Day tsunami of 2004 had an unprecedented amount of relief and support pouring in from various quarters. The government of Tamil Nadu was quick to create a framework that enabled civil society to participate in the relief and rehabilitation efforts. The sheer amount of funding and support for relief and rehabilitation activities resulted in conflicts about areas of operation between NGOs fairly early on in the "relief phase" of tsunami disaster support. The government of Tamil Nadu tried to coordinate relief and rehabilitation efforts by setting up district coordination centres which were headed by the respective district Collector offices at the district level and Relief Commissioners office at the state level.

The PTEI project was a late starter in this context and none of the implementing partners were part of the turf war described above. This did not pose a problem to the research and documentation components of the project. However as a partner involved directly in restoration activities, FERAL needed to ensure that:

1. Sites selected did not conflict with sites selected by other organisations.

2. Sites selected were not within the jurisdiction of the Forest Department of Tamil Nadu as permits for planting were not granted as they interfered with the department's own plans.

3. Sites that were in community or revenue lands were not earmarked for other development activities.

4. Local authorities, both democratic and traditional, concurred with the proposed activities.

In addition to the above, we were governed by a set of administrative and financial protocols that met the required standards of UNDP. This implied that all contracts and purchases above certain amounts were done through quotations and financial disbursements for activities were recorded in appropriate registers and vouchers.

5.4 Conclusions

The subsequent chapters dwell in greater detail on the strategies adopted and experiences gained during the pilot restoration of coastal sand dunes, tropical dry evergreen forests and mangroves. The reader needs to keep in mind that the aim of the project was to try and build a protocol for community based habitat restoration and to test it in real world conditions. Thus there were many instances of mid-course correction, including last minute withdrawal from sites. We have therefore put together what we believe are the important lessons from this project. This includes some of the major challenges and shortcomings of our strategy. We hope the lessons presented here will facilitate habitat restoration efforts elsewhere.

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Chapter 6 Administrative Frameworks for Community Based Habitat Restoration

Abraham V. A.

Contents

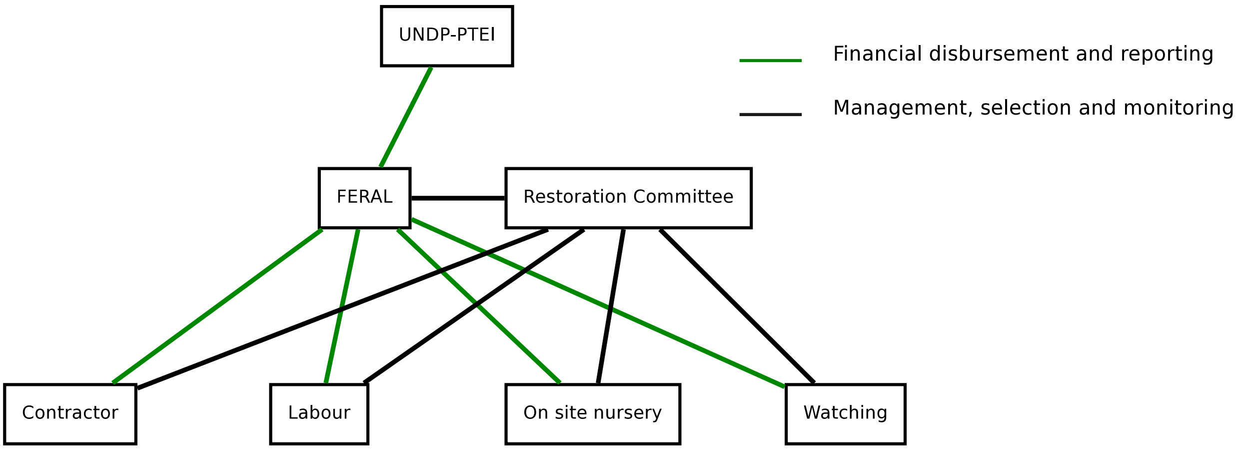
6.1 Introduction

Administrative protocols for community based natural resources management or conservation projects are a necessary and often a complex component (Matta and Kerr, 2007). Since the early nineties, the overall thinking on such projects has assumed a community bias, with greater emphasis on sharing administrative and implementation responsibilities with the "primary" stakeholders (Kerr, 2002; Government of India, 2000). Administrative structures often define the role various stake holders have in the partitioning and prioritisation of funds for different activities, and on the outputs of participatory projects.

Most projects and funding agencies expect administrative protocols to deliver on three counts; transparency, accountability and efficiency. Some agencies go to great lengths to achieve these and often the procedures adopted are very complex and quickly isolate the primary stakeholders from financial matters through sheaves of procedural paperwork. Other projects swing to the opposite end, leaving a lot space for financial decision making in the hands of communities and community based organisations (CBOs). This too poses a set of challenges as financial and administrative systems often need to be established from scratch and local capacities build in their functioning.

An example of a middle path is the common guidelines for watershed development. Elected Panchayat based watershed committees have the authority to prioritise works and clear payments for the same. The fact that money is held by them in a bank account makes it impossible to proceed without their conscent. The decisions that they ratify are often evolved through debating engineering solutions offered

Figure 6.1: Administrative arrangements made for the project ensured that the committees formed at the village had decision making powers even as financial and administrative procedures remained according to the requirements of the UNDP.



by the watershed development team, and the entire process is overseen by the district administration (Government of India, 2000).

Administrative framework for FERAL's component of the project was designed to meet both the requirements of the funding partners as well as the practical constraints imposed by field conditions. Substantial amounts of expenditure took place during the restoration activities. All these expenditure and activities were made in consultation and through a consensus with the respective eco-restoration committees. The requirements of accountability, transparency and efficiency were met by creating the administrative structure shown in figure 6.1.

The basic arrangements made were as follows:

- Financial disbursements and accounting was done by FERAL. This ensured all the documents met the standards of UNDP. On site documentation (maintenance of registers) was done by the concerned animators and watchers. These were monitored by the FERAL field staff on a weekly basis and formed the basis of release of payments for activities where required.

- A restoration committee was formed in all sites comprising representatives from the gram Panchayat (elected), traditional Panchayat and women self help groups. This committee ratified all decisions relating to physical activities to be carried out, including the formulation of a micro-plan. The committee also recruited persons to be appointed as watcher, village animator. In many cases the committee took up the fencing contract or selected contractors for the same. Finally the committee made arrangements for materials (compost) and labour for the actual planting and fencing activities.

- Local government agencies were contacted for permission and support for the restoration activities wherever this was a requirement. For instance, the district Collectors office was approached for permission to take up restoration activities in revenue lands and temple endowment authority in the temple lands (sacred groves). The forest department was an important partner in the entire effort. The Wildlife Warden of Nagapattinam and the Deputy Conservator of Forests of Pondicherry were involved in workshops organised by FERAL, and facilitated the activities by providing permissions to work and saplings for the actual plantations.

The following section briefly describes the administrative responsibilities assigned to the different players in the project.

6.2 FERAL

Management structure

A technical team consisting of the project head, ecologist and remote sensing and GIS specialist coordinated with the field staff on data collection and analysis to design the restoration plans. Day to day functioning was carried out by the administrative staff consisting of a project manager, office manager and the accounts manager. While there were prescribed formats and procedures for most administrative tasks, we had to evolve our own to deal with the requirements of running nurseries and implementation of restoration activities on field. This included systems to document procurements of materials such as polybags, compost, top-soil etc. as well as tracking the substantial labour requirements of the project.

Documentation and records

Daily records were maintained for the mother nursery and the information was collated into the following registers.

- Labour attendance and payment
- Purchase of manure, compost, poly bags and shade nets
- Saplings / seeds coming in and going out of the nursery
- Survival status

6.3 FERAL and the Village Panchayat

Eco-restoration committees were formed in selected villages before the restoration activity commenced. The eco-restoration committees comprised of the Panchayat leader(s), a village animator, watchman and at least 2 women representatives from local SHGs. Men and women were equally represented in the committees. All the members of the eco-restoration committee were other than the Panchayat representative were paid a stipend from the project. The roles and responsibilities for the village level staff were defined in a formal letter which was signed by the Panchayat leader before commencement of the restoration activity (see Annexure B.1). The role of the Panchayat leader was to coordinate village meetings and obtain approval for restoration activities from the community.

6.4 FERAL and Forest Department

FERAL built a good working relationship with Forest Departments in implementing the restoration activity. Permissions for doing research and collection of seeds from the forest department areas were solicited. At Karukalacherry, the restoration activity was done jointly with the Forest Department of Pondicherry who provided 10000 saplings for planting at the sand dune site. This site was handed over to the department shortly after completion of the planting.

6.5 Fencing Contract

Fencing the planting areas was one of the major activities that had to be implemented through the village Panchayat. The responsibility of identifying the contractor was taken by the village Panchayat leaders. Once the contractor was identified, a memorandum of understanding (MoU) was signed between FERAL and the village Panchayat (at Vadagaram) and the contractor (at Kothattai). The MoU specified the design of the fence, quality and specification of the materials and mode of payment. The office manager coordinated the fencing activity and regularly inspected the sites for quality and progress.

6.6 Conclusions

Administrative arrangements required for community based restoration projects are the foundation on which the implementation and activities rest. These arrangements form the basis of monitoring financial inputs, formalising contracts with communities and tracking inputs of labour and materials into specific sites. There are a range of techniques that can be adopted for creating a suitable administrative framework for community based restoration. Its components however, remain largely constant and include financial frameworks and mechanisms by which activities are funded, procurement rules and guidelines, contractual arrangements with communities or their representatives and keeping of records and books for the various activities.

Examples of similar frameworks can be seen in the micro-credit system, experiences in joint forest management and community based watershed development projects. Given that community based restoration is highly location and community specific, it is essential that projects evolve their own set of administrative systems keeping in mind the crucial role they play in subsequent project activities.

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Chapter 7 Community Involvement in Habitat Restoration

R. S. Bhalla

Contents

7.1 Introduction

Views expressed in literature on the subject of community based restoration and natural resource management are often divergent. One, strongly urges the involvement of communities in restoration efforts and suggests that working through communities is among the most effective ways to conserve and restore such habitats. Thus we have examples from tropical dry evergreen forests and sacred groves (Bhagwat and Rutte, 2006), mangroves (Selvam et al., 2003) and other coastal ecosystems (Yap, 2000).
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On the other hand many authors have found that changing socio-economic and political situations have led to the weakening or even disappearance of community institutions (Matta and Kerr, 2007; Chandrakanth et al., 2004). Others have found that factors driving communities to conserve habitats are often not concerned with restoration of ecosystem function, but with specific services Gilman and Ellison (2007). These “community managed” habitats therefore tend to deviate significantly from natural ecosystems at a local (Palmer et al., 2005; Walters, 2004; Johansson and Nilsson, 2002) and at regional scales Turner (2000).

The experience of involving communities in restoration projects in India has largely been in the area of joint forest management (with its various offshoots) and watershed development. In the past two decades there has been a trend from technical towards inclusive, community based projects (Kerr, 2002). It is now considered “common wisdom” to involve the primary stakeholders in natural resource management or conservation efforts, whether these programmes are run on community controlled or government lands. This is in spite of the fact that many community controlled initiatives have collapsed or reverted back to institutions such as the forest department for their survival. There are various reasons for this, a major one being the need for a constant source of external financial and management support for these programmes. The nature of usufructs from natural systems and ecological services are usually spread out and difficult to quantify. Communities cannot therefore be expected to invest in protection of a region for in-tangible benefits. The other reason is that the biggest single incentive for communities to participate in many restoration and watershed development programmes is the employment gained during their implementation. Avenues for post-project employment are limited and therefore most projects find a rapid decline in "community support" for older programmes.There are a number of additional constraints that limit the role community based organisations can play in habitat restoration. Many of these were present in the field sites and are summarised below to situate the reader in a social context.

Caste based semi-feudal systems still dominate settlement based decision making in rural Tamil Nadu. While representation of Dalit communities has increased over the years, it remains marginal. This is even more accentuated in the context of control over community and natural resources such as forest patches, irrigation tanks, rivers and backwaters which have traditionally been vested in the upper castes. The role of elected Panchayats in most of these areas also remains marginal, even though the management of village resources is constitutionally vested with the Grama Panchayat. Some temple lands (sacred groves) may be exempted from this and their control often lies with the local "pujari" or the temple authority. Women rarely find any representation in virtually all of the above arrangements. While there are many elected women Panchayat presidents (thanks to a positive discrimination policy), they largely remain proxy representatives of their male relatives.

Pressures on community lands in Tamil Nadu are particularly high. A policy that permits land owners to cultivate adjacent community lands has led to large scale encroachments which get legalised over time. These "bima" lands have gradually eaten into the communal lands leaving the landless with fewer and fewer alternative sources of biomass and grazing lands. Thus pressure on any available forest patches have increased substantially over the years.

This project had the explicit objective of building protocols for restoring natural coastal habitats in areas that were pre-dominantly non-forest. Involvement of the various stakeholders was therefore integral to the restoration component of the project. We were aware of the constraints within which the community mobilisation had to take place and therefore the strategy followed was limited to four specific areas:

1. Ensuring that the community as a whole was aware of the project, its objectives and broad activities. Further to ensure that there was a broad consensus in the communities regarding the proposed interventions.

2. Creating a representative body, the eco-development committee, from within the community that would become the one-point contact for all the activities to be undertaken. This body would need to have the explicit support of the elected representatives as well as the traditional leaders of the village.

3. Building capacities at the local level and at the level of the eco-development committee to ensure that regular activities such as watering, watching, care of saplings in the nursery, maintenance of records and monitoring would be conducted with minimal support from FERAL.

4. Creating an administrative and reporting structure that ensured the activities mentioned above took place independently of FERAL, yet were accounted for in a formal financial and administrative system.

Figure 7.1: Awareness activities were carried out continuously through the project in various forms. These included street plays (left), micro-planning sessions (right), meetings, workshops and hand on sessions even administrative procedures, such as the formation and functioning of restoration committees.

The subsequent sections provide details of the community mobilisation strategy and how it coped with the various challenges and ground realities.

7.2 Awareness Programmes

Strategies followed for raising levels of awareness among participating communities involved three major activities:

- road shows involving street plays and video screenings followed by discussions with community members
- prepration of posters and awareness materials which were distributed to stakeholders put up in prominent areas of the village, and
- a series of participatory discussions and planning exercises with the stakeholders which ensured that they were intimately aware of the proposed activities and ensured transparency.

These activities resulted in an overall dissemination of information about the project through the road shows. Apart from the obvious entertainment that the street plays provided, subsequent presentations made highlighted the issues of habitat destruction and its consequent losses to the communities. Members of the communities participated actively in these programmes and discussions and summaries of the “message” were often relayed by the participants on stage.

7.3 Capacity Building

Capacity building was a basic requirement for programme implementation. Stakeholders played an important role in the project both during the actual planting phase as well as during aftercare and maintenance of the saplings. Implementation of project activities covered three districts which resulted in a high reliance on the stakeholders. This in turn required that they were able to function independently

Figure 7.2: Internal capcity building was one of the first tasks taken up. This ensured we had trained nursery workers to build up the substantial stock of saplings required for the project. Some of these workers later trained women at the village nurseries.

of the field teams, even though the progress of the project was continuously monitored. Capacity building dealt with three specific aspects:

- nursery management including:
  - germination techniques
  - creation of seedling beds
  - nursery bags and
  - transportation of saplings to satellite or villages nurseries
- maintenance and protection of saplings once they had been planted and
- monitoring and record keeping of the planted saplings.

Training, both through formal workshops, as well as through hands on sessions was provided to the stakeholders on a continuous basis. Expertise from external agencies[10] was enlisted for some of the programmes.

7.4 Implementation Arrangements

Implementation of project activities was done through committees formed for the purpose. These committees comprised of representatives from elected Panchayats, women self help groups and traditional leaders. The function of the committees were as follows:

- identify an area to be set aside for restoration activities and protected as a restoration site
- assist in obtaining necessary permissions and clearances for conducting restoration activities on the selected area, including those from concerned government agencies
- participate in various planning session and evolve a restoration plan or microplan[11]for the said site. The microplan itself involved:

[10] Auroville Botanical gardens.
[11] See Annexure C.1 for a sample microplan.

  - mapping of the site
  - physical demarcation of the site
  - selection of suitable species after discussion with project staff
  - selection of suitable sources of water
  - demarcation of areas to be fenced
  - identification and demarcation of village nursery area including identification of water source for the same
  - mapping the same on a brown sheet/chart paper and finally
  - ratification of a map and accompanying note (formal microplan) prepared by the project staff incorporating the above details.

- hire necessary village staff for nursery maintenance, watering and watching
- hire labourers for the planting season
- issue contracts for activities such as fencing where applicable

Finally the committees undertook the overall protection and management of the site during and after the project period.

Substantial efforts in terms of training and capacity building through hand holding and regular monitoring was invested in the various committees. The project staff interacted with committee members on a regular basis and supported them for many of their functions, particularly during the initial periods.

7.5 Conclusion

The strategy for this project had a limited expectation from the local communities. Their involvement in the project ensured a broad acceptance of the objectives and subsequent activities. The arrangements made with the communities through the eco-development committee also ensured that many of the logistic requirements of the restoration such as organisation of material and labour, were met by the community. However the institutional setup does not ensure long term sustenance of project activities. While the eco-development committees provide the basic organisational framework and have the capacities to maintain the sites, they lack the financial support or resources to do so independently. Another area of concern is the lack of policy frameworks to provide protection to these sites. In the absence of such protection, it is just a matter of time that these site fall prey to the large scale modifications in land use taking place across the state.

Two simultaneous interventions are required to change this situation. 1) The size of sites needs to be expanded (where possible) so the usufructs and ecosystem services they provide are substantial and their continued protection by local communities is justifiable. This will also increase their ecological value. 2) Policy frameworks are brought into effect that help demarcate extent of representative habitat and prevent encroachments and deleterious landuse changes around them.

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Chapter 8 Restoration of Tropical Dry Evergreen Forests

P. Dilip Venugopal, Sunita Ram and M. Anbarashan

Contents

8.1 Introduction to Tropical Dry Evergreen Forests

Tropical dry evergreen forests (TDEF) are distributed at lower elevations along the Coromandel coast and inland. They comprise of small evergreen trees 9 to 12 m height that form a complete canopy of small and coriaceous-leaved evergreen with short boles and spreading crowns with some deciduous emergents. These forests do not have a marked differentiation of canopy layers (Champion and Seth, 1968). Floristically, these forests are characterised by a set of species, exclusively or mostly confined to this vegetation type (Parthasarathy et al., 2008; Meher-Homji, 1974; Champion and Seth, 1968).

The TDEF on the Coromandel coast of India, which occur as patches, are short-statured, largely three-layered, tree-dominated evergreen forests with a sparse and patchy ground flora (Parthasarathy et al., 2008; Venkateswaran and Parthasarathy, 2005). Described as *Acacia–Albizia amara* vegetation series and *Manilkara–Chloroxylon* series by Gadgil and Meher-Homji (1986). The different levels of disturbance in this highly populated coastal region over the years has lead to suggestions that the original vegetation may have changed over the years and that what we see today is a climax forests (Venkateswaran and Parthasarathy, 2005; Mani and Parthasarathy, 2006) or a forest taken over by opportunists and described more as a secondary forest (Daniels et al., 2007). Only about 4% to 5 % of the original TDEF patches exists today (Blanchflower, 2003; Wikramanayake, 2002; Meher-Homji, 1992).

Distribution

This unique forest type is found in India, Sri Lanka where they formerly covered about 80% of the Island (Blasco and Legris, 1972; Dittus, 1985) , northeastern Thailand (Bunyavejchewin, 1999), southwest China (Hongmao et al., 2002) in Asia, in Zambia, Tanzania and Ethiopian Highlands in Africa and in Antigua, British Guiana, Trinidad and Tobago, along the south coast of Jamaica (Kelly et al., 1988; Loveless and Asprey, 1957) and Bahamas in the neotropics (Parthasarathy et al., 2008; Smith and Vankat, 1992). In Sri Lanka they are often described as old secondary climax forests due to past disturbance (Dittus, 1985). This unique forest type is distributed on the eastern (Coromandel) coast of India (Parthasarathy and Sethi, 1997), where historically, the forest extended from Vishakapatnam to Ramanathapuram as a belt 30 to 50 km wide, bordered on one side by the Bay of Bengal and on the other by forests of increasing deciduous nature as one progressed inland (Blanchflower, 2003). At present in India, the majority of the remaining tropical dry evergreen forests occur in the form of small fragments of 'sacred groves' or 'temple forests', preserved due to local belief that resource extraction from these groves would bring upon them the wrath of the presiding deity (Parthasarathy and Karthikayen, 1997).

Environmental Characteristics

The form of vegetation in TDEFs is determined by the climatic pattern of the area (Blasco and Legris, 1972). The climate along the Coromandel coast is distinguished by its inconsistency especially in the rainfall patterns in terms of intensity, amount and distribution within and between years. The vegetation of the region have adapted to survive months or sometimes years of relative drought and short periods of intense rain, between 1000 - 1500 mm per year (Hunneyball, 2003). TDEFs have been reported from varied soil types including red ferruginous, with alluvial deposits; uniform alluvium over Cuddalore sandstone formation (Parthasarathy and Karthikayen, 1997; Blasco and Legris, 1972), alluvial sandy loam (Parthasarathy and Sethi, 1997), and red ferrallitic (Visalakshi, 1995).

Biotic Characteristics

Flora

The number of species recorded from the different sites, as available from published literature has been provided in Table 8.1. The number of species reported from the sacred groves in and around the project area such as Puthupet, Kuzhandaikuppam, Arasadikuppam, Oorani and Thirumanikuzhi gives us a clue to the species richness of this forest type which ranges from 30 woody species at Oorani to 54 woody species in Kuzhanthaikuppam and Thirumanikuzhi. Parthasarathy et al. (2008) report that the species richness across 75 sites of TDEFs range between 10 and 69 species. The dominant plant families that characterise this forest type includes Rubiaceae, Euphorbiaceae and Ebenaceae, consisting of species such as *Memecylon umbellatum*, *Pterospermum canescens* and *Garcinia spicata* (Venkateswaran and Parthasarathy, 2005). Other commonly occurring species include *Drypetes sepiara*, *Atalantia*

Table 8.1: Number of TDEF species recorded from different sites.

Site	Area	No. of species
Point Calimere	2400 ha	200 dicots; 317 flowering plants (Balasubramanian and Bole, 1993; Blasco and Legris, 1972).
Kuzhanthaikuppam	1.2 ha	54 (woody species $\geq$ 10 cm GBH, sites combined) (Parthasarathy and Karthikayen, 1997).
Thirumanikuzhi	1.6 ha	54 (woody species $\geq$ 10 cm GBH, sites combined) (Parthasarathy and Karthikayen, 1997).
Puthupet	14 ha	51 (woody species $\geq$ 10 cm GBH) (Parthasarathy and Sethi, 1997).
Arasadikuppam	1.5 ha	31 (woody species $\geq$ 10 cm GBH) (Venkateswaran and Parthasarathy, 2003).
Oorani	1.8 ha	30 (woody species $\geq$ 10 cm GBH) (Venkateswaran and Parthasarathy, 2003).

Figure 8.1: The Kothattai Sacred Grove near Chidambaram.

monophylla, *Tricalysia sphaerocarpa*, *Diospyros ebenum*, *Dalbergia paniculata* and *Syzygium cumini*. These forests also harbour a considerable diversity and density of lianas (Reddy and Parthasarathy, 2003) . Hunneyball (2003) points out that the variety of forms of the species occurring in the patches, has been reported to be a peculiarity of the TDEF flora. Although several of these forest patches are in proximity to each other, there seems to be considerable variety in the species composition across sites (Mani and Parthasarathy, 2006). About 46 – 68% of the species, recorded across all sites are evergreen in nature (Hunneyball, 2003). The forest structure varies based on environmental conditions and the extent of human interference (Hunneyball, 2003). In some locations they are of low stature, with the upper canopy generally not exceeding 10 m (Hunneyball, 2003). In the others the tree height was around 8 m (Parthasarathy and Karthikayen, 1997; Parthasarathy and Sethi, 1997).

Fauna

Nearly all research on TDEF have concentrated on the vegetation, a few highlight the animals found in TDEF patches. Blanchflower (2003) provides a checklist of animals which includes 36 species of mammals, 29 species of reptiles and about 80 species of birds.

Although the TDEF in India are present today as remnant forest patches, these fragments of vegetation play an important ecological role. They act as a repository of biological specimens, are a safe site for several plant and animal species that would have been lost otherwise. They could play an important role in maintaining the regional biodiversity by augmenting regional populations (Pither and Kellman, 2002) and provide plant specimens for recolonisation that help conservationists to strategise against species loss.

Management Status

Forests in India fall under one of several management regimes that differ in the strictness of protection and accessibility to local people for resource use. These categories include, Wildlife Sanctuaries, National Parks, Reserve Forests, and Community Forests (including sacred groves, forests under the control of the Panchayat). Majority of the TDEFs are managed primarily as sacred groves, the purview of which is with the local temple authorities and the Panchayat and a few patches come under the Reserve Forests network and is managed by the State Forest Department.

Sacred groves are patches of vegetation, ranging in size from a clump of few trees to a few hectares in area (Chandrakanth et al., 2004) that are protected by religious belief of local people (Khumbongmayum et al., 2005; Parthasarathy and Karthikayen, 1997). The nature of the religious cults associated with the sacred groves suggests that these cults date from the hunting age before man had settled down to raise livestock or till the land. The deities generally lie open to the sky, and are believed in many cases to be offended if a shelter is erected over them. They are always situated at a distance from any human settlement (Gadgil and Vartak, 1976).

Often, in populated areas, sacred sites conserve the only vegetation without radical human alteration. At the global level sacred groves have been reported from Asia (Yang et al., 2004; Hongmao et al., 2002) and Africa (Campbell, 2005). Although some supporting cultures have been weakened by modern influences, sacred groves are frequently more acceptable to local people than externally imposed conservation policies . There is increased international interest in religiously based restrictions on land and forest stand use. However, the extent to which so-called sacred groves represent earlier forest ecosystems, and their possible role in biodiversity conservation, are interrelated and complex in nature (Campbell, 2005).

Sacred grove forest sites throughout the world are important for the preservation of plant and animal species useful to local people (Wadley and Colfer, 2004). For example, sacred groves become refuges for plants, birds, mammals, and other forest-dwelling animals (Basu, 2000; Chandran and Hughes, 2000; Sinha, 1995), and people depend on them for various products used in everyday life (Burchett et al., 1999; Chandrashekara and Sankar, 1998). Sacred groves may thus serve both local resource needs and international conservation goals (Swamy et al., 2003; McWilliam, 2001; Decher, 1997a; Lebbie and Guries, 1995). In addition to pressure put on them from daily use, these forest patch habitats are fragile, and changes in traditional cultural and economical values may threaten their existence (Mishra et al., 2004). Byers et al. (2001a) found that the cutting of mature trees for timber, collection of fuel-wood and cattle grazing were mainly responsible for the community organisation and altering the botanical/floristic composition in sacred groves in northeast India. The increasing demand for land and wood and growing disrespect for traditional values are parallelled by increasing erosion of the forest edge, even in sacred forests. Examination of the contribution of the sacred forests to biodiversity conservation offers perspective on the sacred forests as a model for environmental protection. Thus the role of natural sacred sites, particularly sacred groves, is attracting increasing interest in international organisations and conservation organisations such as UNESCO, the WWF and has significant relevance for the implementation of article 8j of the Conservation of Biological Diversity which stresses more on the use of traditional wisdom and practises for conservation and sustainable use of biological diversity (Chandrashekara and Sankar, 1998).

Traditionally, sacred groves embody a rich repertoire of forest preservation practises and share characteristics with common property resource systems (Chandrakanth et al., 2004). In India the biodiversity and cultural value of sacred groves are well documented. Several studies have been carried out in India to document and assess the biological value and the biodiversity of the sacred groves located in Kerala (Chandrashekara and Sankar, 1998), Maharashtra (Gadgil and Vartak, 1976), Gujarat , northeast India (Khumbongmayum et al., 2005; Mishra et al., 2004; Jamir and Pandey, 2003) and Coromandel coast of Tamil Nadu (Venkateswaran and Parthasarathy, 2003; Parthasarathy and Sethi, 1997; Parthasarathy and Karthikayen, 1997).

Although such traditional community based resource management holds potential for preserving not only biodiversity and ecological functions, but also cultural diversity (Gadgil and Chandran, 1992; Gadgil and Vartak, 1976) the present changes in religious beliefs and rituals that are central to sacred grove preservation, protection through such traditional approaches alone has become ineffectual (Tiwari et al., 1998). Due to increasing scarcity of various natural resources, the old taboos are less effective and some sacred groves have been destroyed as a result (Chandrakanth et al., 1990).

Threats

Tropical forests throughout the world are disappearing or deteriorating at a very rapid pace. Among the most significant anthropogenic causes is the conversion of land use to agriculture, pasture, or urbanisation and selective logging. Natural factors also account for a large portion of tropical forest loss (Alvarado and Sandberg, 2001). Tropical deforestation is a major concern on several fronts. It is significant to global climate warming and regional climate change (Houghton et al., 2000); global losses in biotic diversity and net primary productivity (Vitousek et al., 1997); and threats to ecosystem services and other variable functions (Daily, 2000; Kremen et al., 2000)

The TDEF in India is distributed along the highly populated East coast of India. The increasing demand for land for human-related activities has increased the stress on these forests over the years. Specific threats include, pressures from increasing human populations bordering the forest patches leading to shrinkage in forest area, increased resource extraction including fuel wood and other forest products, and increased grazing pressures and in several highly disturbed patches conversion to monoculture plantations (Parthasarathy et al., 2008). Today, several of the remaining TDEF forests exist as sacred groves, preserved as a result of local religious beliefs. These have been managed well over the years without any formal legal protection due to strict adherence to these religious beliefs and cultural taboos over generations. In several of the moderately to highly disturbed sites, Parthasarathy et al. (2008) note that such traditional management systems do not work efficiently anymore given changes in the cultural beliefs and outlook of the people, especially of the younger generations.

Conservation

To preserve and sustain tropical forest ecosystems, it has become critical to find remedial solutions to ameliorate the deforestation and deterioration of these ecosystems (Alvarado and Sandberg, 2001). Species extinctions are an inadequate measure of biodiversity loss as they do not provide information about changes in the capacity of particular species to contribute to the functioning of an ecosystem (Luck et al., 2003). Thus basic and applied ecological research have a vital role to play in tropical forest conservation and the management of natural tropical forest is not possible without a better holistic understanding of how such forests actually work ecologically and interact with humans.

Several disturbance factors that are primarily anthropogenic in origin, have been shown to impact the composition and biodiversity of tropical forests (Parthasarathy et al., 2008; Sagar and Singh, 2005, 2003; Hansen et al., 2001; Valkenburg and Ketner, 1994; Primack and Miao, 1992). Thus an understanding of not only the ecological aspects, but socio-economic aspects need to be taken into consideration to counter threats to this forest type.

In this report we present a protocol for selection and prioritisation of the coastal ecosystems namely sand dunes and tropical dry evergreen forests for restoration. The specific objectives of the next few sections is to:

1. Develop a site selection criteria
2. Develop criteria to prioritise sites for restoration and plan restoration activities for these prioritised sites

8.2 Site selection for Restoration of Tropical Dry Evergreen Forests

Selection Criteria & Prioritisation

The protocol for selection and prioritisation, consisted of two hierarchical levels of the parameters. The first layer included the various social and administrative criteria based on which sites were selected 'in' or 'out' (See figure 8.2). The next level included data on spatial attributes, social aspects and ecological parameters based on which sites were identified.

Development of the site selection criteria was done by enlisting logistical, social, administrative and spatial parameters. These parameters were collated and a ranking matrix was developed . This involved providing a score for each of the data parameters. The scores were added for each site. The data parameters were attached to a spatial database to model the selection process on a GIS platform.

Scores were assigned to each of the above mentioned parameters based on decision rules. Details of parameter scores and the rules set for assigning scores have been provided in table 8.2. The various parameters were also give different weightages based on their importance (table 8.3).

At the second level to rank sites for prioritisation, spatial attributes, social aspects and ecological parameters were ranked and weighted (See figure 8.3). The data were collected on field through ecological assessments. A list of the parameters recorded on field is given below:

1. The spatial parameters include area of the patch, Perimeter, Perimeter/Area ratio, Distance from coast line. Of these parameters, the area of the patch was given the highest weightage.
2. Community participation received the second heighest weightage among all the parameters as this was an important aspect for the success of the initiative.

Figure 8.2: A model depicting the procedure for selection of sites at the first hierarchical layer, based on various parameters.

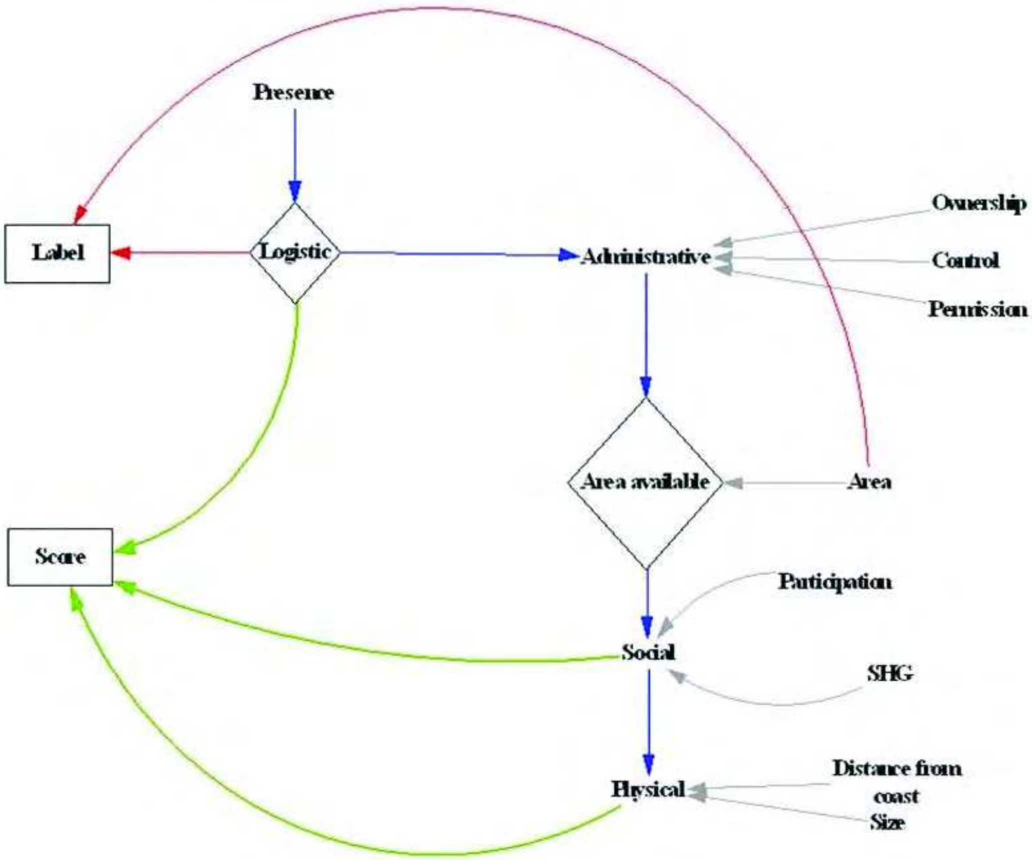


Table 8.2: Scores for different criteria for site selection.

Selection Criteria and rules where applicable	Scoring factor	Score
Logistical		
Presence of TDEF patch	Yes	1
Presence of a TDEF or a sand dune patch at site was a requirement	No	0
Administrative		
Land ownership	Temple	1
	Revenue land	0.5
	Patta	1
	Forest Dept	0.2
Ranking order favoured temple/putta lands because it is easier to get permissions and therefore forest areas areas were ranked lowest.		
Control	Temple	0.8
	Panchayat	1
	Private	0.5
	Forest Dept	0.1
	Temple endowment auth	0.2
	Fisheries Panchayat	0.2
Ranking order favoured Panchayats as they are democratically elected bodies. Privately or temple controlled areas are prone to unilateral decisions on removal of forest cover.		
Permission by controlling authority to take up restoration	Yes	1
	No	0.1
	Tentative, pending confirmation/ ratification by others	0.25
Area available for restoration	Yes	1
	No	0
This refers to the presence or absence of area to restore not the extent of the area itself.		
Social		
Community Participation	Yes	1
	No	0.1
Women SHG groups	Present	1
	Absent	0.9
Pressures on patches are from low intensity but continuous use/extraction by the local community. Their involvement and willingness to protect the patch was crucial. Having existing community based organisations facilitated mobilisation and routing work to persons below the poverty line and representing weaker sections.		
Physical attributes of the patch		
Size of Patch: Larger patches were assigned a higher score as probability of restoration success for larger patches will be greater)		1/ha
Distance from Coast (km): Given that the project objectives were limited to coastal and tsunami affected areas, this criteria has been included; sites further away from the coastline got a smaller score than those closer to the coast.	Inverse of distance	1/Distance from Sea

Figure 8.3: Methods used for final prioritisation of sites.

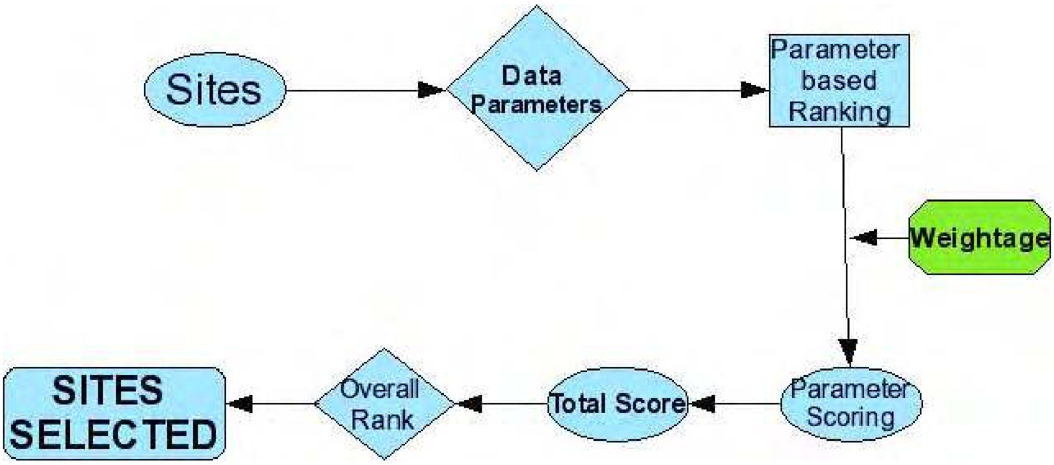


Table 8.3: Weighting factor given to criteria.

Data Parameter	Weightage provided
Area of the patch (Ha)	25
Perimeter (m)	1
Perimeter/Area ratio	2
Distance from Sea (Km)	1
Community participation	20
Average Canopy Contiguity (%)	1
Average canopy height (m)	1
Mean Number of seedlings	1
Mean Number of saplings	2
Mean Number of cut stems	2
Site Basal Area	1
Species richness (number of species)	4

3. Ecological parameters included average canopy contiguity, average canopy height, mean number of seedlings and saplings recorded, mean number of cut stems, mean number of stems above 10cm GBH recorded, basal area of the site and the number of tree species recorded. Data collection of ecological parameters has been discussed in detail in section 8.2.

Ecological Assessment of Tropical Dry Evergreen Forests

Existing literature on TDEF pertains mainly to climate (Blasco and Legris, 1973), edaphic (Blasco and Legris, 1973), ecological inventory of plant diversity (Blasco and Legris, 1973; Visalakshi, 1995; Parthasarathy and Sethi, 1997; Parthasarathy and Karthikayen, 1997; Reddy and Parthasarathy, 2003; Venkateswaran and Parthasarathy, 2003; Mani and Parthasarathy, 2005a), phonology (Balasubramanian and Bole, 1993) and tree population changes (Venkateswaran and Parthasarathy, 2005). These studies are restricted to individual or few sites, not extending across the entire range of distribution of TDEF. The administrative aspects of the existing TDEF patches, in terms of ownership and control, have also not been documented. There are very few studies documenting the effect of anthropogenic activities on TDEF remnants (see Venkateswaran and Parthasarathy (2003)). Consequently baseline information such as the spatial extent and distribution of the existing TDEF patches are still not available. Information such as the ecological status and pressures that threaten these patches, which would help in evaluating their conservation value, also are lacking. This section reports the ecological assessments that were undertaken as part of the site identification and site prioritisation exercises in detail.

Objectives

The broad objective of these ecological assessments was to devise a strategy for identification and prioritisation of TDEF patches for restoration, based on ecological, administrative and social data. To achieve this, the following activities were undertaken

- Categorisation of existing TDEF patches in terms of ownership and control.
- Collection of baseline ecological information on woody species diversity & richness, stand density, structural characteristics of the TDEF patches.
- Collect information on the levels of anthropogenic disturbances in the patches.

Methods

Survey of TDEF Patches Information on the presence and location the TDEF patches along the Coromandel coast in Kancheepuram, Villupuram, Cuddalore and Nagapattinam districts of Tamil Nadu and Union Territory of Pondicherry were determined from existing literature (Hunneyball, 2003), personal communication with other researchers and interviews with local people from different villages. For the purpose of this study, surveys were limited to within 25 km from the coast. Information on the ownership and control of the patches were collected, along with field mapping of the extent of the existing patches. Mapping of existing patches were done through extensive field surveys with a hand held GPS unit (Garmin 76, Garmin Ltd.). This was then projected on to a GIS platform and data were analysed using a combination of spatial software such as Arc View 3.2 (ESRI Inc.), Quantum GIS and GRASS. Detailed ecological assessments were conducted in thirteen sites that were short-listed for further prioritisation. Permissions for detailed work were not given in two of the sites and they had to be dropped from the list.

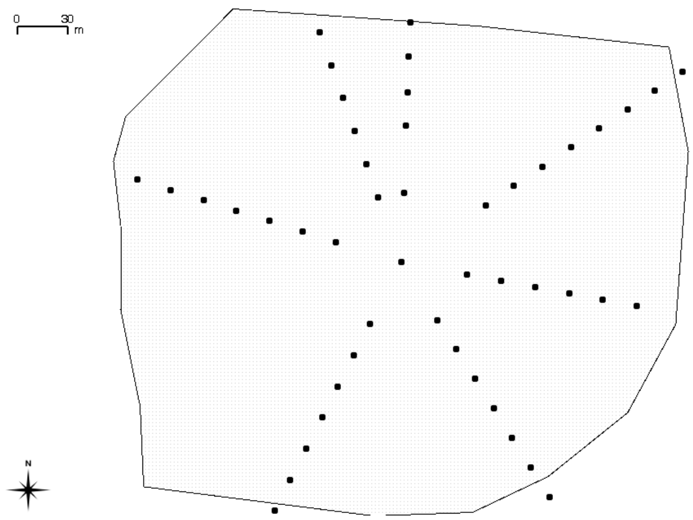
Data Collection Vegetation Sampling

Within each of the identified sites, sampling points were identified on the map by locating the geographic centroid of the patch using Arcview 3.1 and on field using a GPS. Transects radiating out from the centre to the edge of the patch, were laid and at approximately every twenty meters along the transect lines, quadrats of 10X10m size were laid for data collection. The angle for the transect was randomly decided in a manner such that each transect were placed at least 45 degrees from each other. In the event of a quadrat falling short of the edge, a point just inside the edge of the patch was identified and quadrat marked (see figure 8.4 for an example). For the purpose of this study, about 5 – 10% of the area of the site was sampled. The number of quadrats sampled was based on the size of the patch and logistics.

Data on existing vegetation collected within each of the quadrats is detailed below.

- *Recruitment and regeneration* was noted in terms of a) sapling count, where individuals up to 30 cm height from ground were counted and b) seedling count, where plants above 30cm height but less than 10cm girth at breast height were counted.

Figure 8.4: Placement of transects and sampling plots in S.Pudur.



- *Canopy height* was estimated visually by an observer on the ground. It was estimated by the same person each time to minimise variation in estimation. One member of the field group was approximately two meters tall, and was used as a visual tool to accurately estimate the average canopy height.

- *Canopy contiguity* – Canopy cover was measured using an 11cm diameter convex mirror, circular in shape and marked with a grid of 100 squares. The canopy cover measurement was the raw number of squares covered by canopy. In other words, it was equal to (100 - # sunny squares). These measurements were taken at breast height.

- Plant Species Diversity: All live trees ≥10 cm girth at breast height were identified and their girth measured at 1.3 m from ground level. In the case of trees with multiple stems, each stem was measured separately and basal area calculated.

The following parameters were also noted in each of the quadrats - Presence of lianas, invasives/exotics, evidence of felling/cut stems and leaf litter depth.

Analyses

Species richness, Diversity, and Basal area Species richness, diversity and basal area of all woody species $\geq$ 10 cm gbh in the 13 selected forest patches were determined. Species richness for each of the forest patch was determined as the number of species encountered within the quadrat sampled.

Basal Area

The basal area was calculated for each individual using the formula:

Basal area $= \frac{C^2}{4\times3.14}$

Where C= circumference or girth at breast height.

The Basal area was determined for

- each species in each quadrat

- each quadrat

Table 8.4: List of sites gradually cleared or reduced to cluster of trees around the temple.

Sno	Site	Panchayat	Block	Taluk	District
1	Pallavarayanatham	Pallavarayanatham	Annagramam	Annagramam	Cuddalore
2	Perunthottam	Perunthottam	Sirkali	Sirkali	Nagapattinam
3	Neithavasal	Keezhayoor	Sirkali	Sirkali	Nagapattinam
4	Varadharajapuram	Nepathour	Sirkali	Sirkali	Nagapattinam
5	Thirukattupalli	Thiruvengadu	Sirkali	Sirkali	Nagapattinam
6	Melaiyur	Melaiyur	Sirkali	Sirkali	Nagapattinam
7	Sikkal	Sikkal	Nagapattinam	Nagapattinam	Nagapattinam
8	Chavady	Poraiyar	Sembanarkoil	Tharangambadi	Nagapattinam
9	Karasur	Karasur		Pondicherry	Pondicherry
10	Sedurapet	Sedurapet		Pondicherry	Pondicherry
11	Kondimedu	Kondimedu		Pondicherry	Pondicherry
12	Poothurai	Poothurai	Vanur	Vanur	Villupuram
13	Vembanoor	Vembanoor	Chitamur	Cheyur	Villupuram
14	Irumbai	Irumbai	Vanur	Vanur	Villupuram
15	Thiruchitrambalam	Thiruchitrambalam	Vanur	Vanur	Villupuram
16	Palayarmadam	Palayarmadam	Chitamur	Cheyur	Villupuram
17	Komutichavady	Komutichavady	Vanur	Vanur	Villupuram
18	Kasipalayam	Pattanur	Vanur	Vanur	Villupuram
19	Pannakuppam	Cinna Babu Samuthiram	Kandamangalam	Villupuram	Villupuram
20	Killianur	Killanur	Vanur	Vanur	Villupuram

- each species irrespective of the quadrat
- each family in the forest patch

Results

Status of TDEF Sites A total of 76 TDEF patches were visited during the surveys, these comprised of 72 sacred groves and 4 Reserve Forests. Only sacred groves were included for the purpose of this study as forest department areas were out of the jurisdiction of this project. Of the 72 patches of sacred groves, 20 sites (table 8.4) have over the years been cleared or reduced to small clump of trees around the temple.

Ownership and Control All except one of the 76 sites visited fell under the ownership of the various Government Departments. Nepathour in Nagapattinam district is an exception and is currently owned by a private individual. While 4 sites were under the Reserve Forest network, the remaining 71 sites were on land belonging to the Revenue Department. The forms of control on the Revenue Department owned lands varied, with the local Panchayat, local Temple Committees and Government Departments such as the Temple Endowment Authority, controlling the activities in the groves.

It is important to note that the sites that have been either cleared or reduced were all either controlled locally by the Village Panchayats or the locally formed Temple Committees.

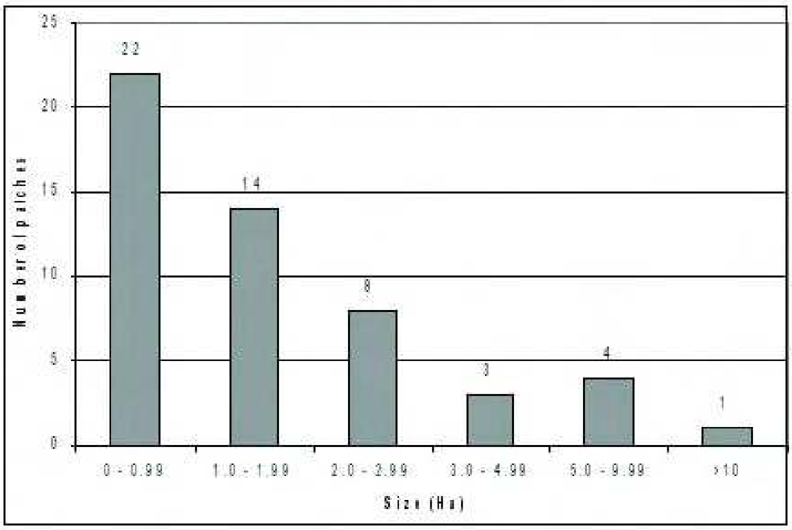
The current control regimes in 52 existing sacred groves has been provided in Table 8.5.

Size of Existing TDEF Sacred Groves The size of the existing TDEF sacred groves were deduced by mapping the perimeter of the patch and calculating the actual size characteristics such as area, perimeter, acreage and hectare. The mapping exercises and results presented below pertain only to the existing sacred groves and not the reserved forests.

Table 8.5: Status of control of TDEF sites visited.

Control	No of groves
Fisheries Panchayat	1
Local Temple Committee	25
Local Panchayat	22
Temple Endowment Authority, Govt of Tamil Nadu	3
In litigation, Private ownership	1
Total	52

Figure 8.5: Size frequency of existing sacred groves in Coromandel coast of Tamil Nadu



Area statistics in hectares are as follows. Number of sites: 52, mean area: 2.09, median area: 1.21, standard deviation: 2.93, standard error: 0.41, minimum area: 0.16 and maximum area: 17.32. About 42% of the sites (N=22) were less than 1 Ha in size and 69 % (N=36) were less than 2 Ha in size. Larger sites, above 5 Ha, formed only 9 % (N = 5) of the total sites (Figure 8.5).

Tree Species Diversity and Richness in the TDEF Patches A total of 58 woody species, including 54 tree species and 4 liana species were recorded across the 13 sites where surveys were conducted for the first level of prioritisation. These 58 species included 51 genera belonging to 29 families. The highest number of species was recorded in Suriyanpet (21 species), with the lowest species diversity being recorded in Kadapakkam (9 species).

Species such as *Memecylon umbellatum*, *Atalantia monophylla*, *Garcinia spicata*, *Borassus flabellifer*, *Glycosmis pentaphylla*, *Syzygium cumini* were commonly present in all the sites. Species of the genera *Streblus*, *Mitrephora*, *Alangium*, *Tricalysia*, *Cordia*, and *Chionanthus* were recorded only in some sites and were totally absent in others.

Tree density and Basal Area The number of stems recorded in the 10m x 10m quadrats, were higher in Kuzhadaikuppam, Sendarakillai and Omipper, while Ramapuram and S.Pudur had lower trees/quadrat (See Table 8.6). The basal area of these thirteen sites varied considerably with basal area of the individual sites being 5.93 m^2 at Konchikuppam to 24.44 m^2 in Tputhupalayam (table 8.6).

Table 8.6: Summary of stand density and basal area recorded at the sites.

S.No.	Site	Species richness	No. stems/plot	Total stems (no.)	Basal area (10X10m)
1	Kadapakkam	9	4.5	54	11.22
2	Konchikuppam	14	3.29	112	5.93
3	Kothattai	19	4.47	326	6.54
4	Kuzhandhaikuppam	17	6.63	179	11.78
5	Omiper	14	6.5	117	13.34
6	Panaiyur	12	4.64	65	4.45
7	Pooranankuppam	13	3.92	47	20.87
8	Ramapuram	11	3.92	102	10.08
9	S.Puddur	16	3.69	181	4.36
10	Sendrakillai	18	6.16	228	23.66
11	Suriyanpet	21	5.93	166	14.05
12	Tpudhupalayam	15	4.84	92	24.44
13	Vada Agaram	21 (4 unidentified)	4.81	125	10.69

Structural characteristics of sites: Canopy

Canopy Contiguity

The average canopy contiguity was significantly higher in sites Sendarakillai, Suriyanpet and Poornankuppam than in S.Pudur, Konjikuppam and Vadagaram (Figure 8.6 and Table 8.7)

Canopy height

The average canopy heights recorded per plot were significantly higher in Sendarakillai, Poornankuppam and Kuzhandaikuppam than in Kothattai, S.Pudur and Vadagaram (Figure 8.6 and Table 8.7).

Stand Structure

The number of stems recorded per plot was significantly higher in Omipper, Sendarakillai and Kuzhandaikuppam when compared to Vadagaram, Kothattai and Konjikuppam.

The structural parameters of each site were compared using the one way ANOVA.

Evidences of Resource extraction

Evidences of resource extraction in the form of cut stems recorded per plot was significantly higher in Vadagaram, Kothattai and Konjikuppam as compared to Sendarakillai, Kadapakkam and Ramapuram (see Figure 8.6 and Table 8.7).

Recruitment and Regeneration

The number of saplings per plot recorded varied across sites with significantly higher numbers recorded in Tputhupalayam, Kuzhandaikuppam and Sendarakillai than in Vadagaram, Omipper and Kothattai (Figure 8.6). The Z values for the same are presented in Table 8.7.

Results of the structural characteristics of the sites revealed that some of the sites such as Sendarakillai, T Puthupallayam and Kuzhandaikuppam are less disturbed, with taller canopy, higher canopy contiguity and higher basal area of stems. However, sites such as Vadagaram, Kothattai, S.Pudur, Kadappakam been more disturbed due to various anthropogenic pressures as the data suggests. These sites required immediate intervention in the form of protection and restoration efforts to prevent further destruction. Based on the results of the ecological assessments these sites were recommended for the immediate intervention in the form of restoration efforts.

Based on the final scores received by each site, during the second level of prioritisation, the top

Table 8.7: Statistically significant difference in forest structure of the sampled sites. For each of the measured variable the difference in Z values derived from the Kruskal Wallis one way anova denotes the significant difference in vegetation characteristic. Figures in Parenthesis denote Standard Error Values.

Site	Count	Seedlings/plot		No. Cut Stems/plot		Avg Canopy Height (m)		Avg Canopy Contiguity (%)	
		Mean	Z-Value	Mean	Z-Value	Mean	Z-Value	Mean	Z-Value
Kadappakam	12	17.33 (18.13)	-1.57	0.75 (3.17)	-3.23	2.6 (0.61)	-1.48	27.92 (9)	-1.93
Konjikuppam	34	62.35 (10.77)	1.9	16.09 (1.88)	2.63	2.8 (0.34)	-1.82	32.76 (5.35)	-2.78
Kothattai	71	21.92 (7.45)	-3.56	12.69 (1.3)	2.8	2.8 (0.24)	-3.43	40.76 (3.7)	-0.93
Kuzhanthaikuppam	27	69.89 (12.08)	2.94	6.96 (2.11)	-0.44	5.31 (0.38)	4.12	61.3 (6)	2.36
Omipper	18	55.89 (14.8)	1.52	7 (2.59)	-0.11	5.06 (0.47)	2.68	65.56 (7.35)	2.77
Panaiyur	14	21.93 (16.78)	-0.76	3.86 (2.93)	-1.16	3.08 (0.54)	-1.04	37.5 (8.33)	-1.24
Poornankuppam	12	73.5 (18.13)	0.65	8.75 (3.17)	0.01	7.1 (0.61)	4.6	70.42 (9)	2.68
Ramapuram	26	47.08 (12.31)	-0.15	3.35 (2.15)	-2.39	2.71 (0.4)	-1.68	41.73 (6.12)	-1.08
S.Pudur	49	53.73 (8.97)	-0.58	11.2 (1.57)	-0.52	2.29 (0.28)	-3.73	28.39 (4.45)	-4
Sendarakillai	36	56.5 (10.47)	2.39	1.83 (1.83)	-4.67	5.71 (0.33)	5.97	71.81 (5.2)	4.58
Suriyanpet	28	37.18 (11.87)	-0.2	4.04 (2.07)	-2.02	3.68 (0.37)	0.13	66.79 (5.89)	2.88
T.Puthupallayam	19	159.21 (14.41)	3.12	6.05 (2.52)	-0.9	4.33 (0.46)	1.65	52.37 (7.15)	0.57
Vadagaram	31	9.58 (11.28)	-3.75	28.35 (1.97)	7.12	2.97 (0.35)	-2.03	32.48 (5.6)	-1.98

Figure 8.6: Box plots showing average canopy contiguity recorded per plot at all sites (a) , average canopy heights recorded (b), number of stems cut per site (c) and number of seedlings recorded per plot (d). KDP-Kadapakkam, KKP-Konchikuppam, KOT-Kothattai, KKM-Kuzhandhaikuppam, OMI-Omiper, PAN-Panaiyur, POO-Pooranankuppam, PPL-TPudhupalayam, RAM-Ramapuram, SPD-S.Pudhur, SKL-Sendrakillai, SNP-Suriyanpet, VDM-Vada agaram.

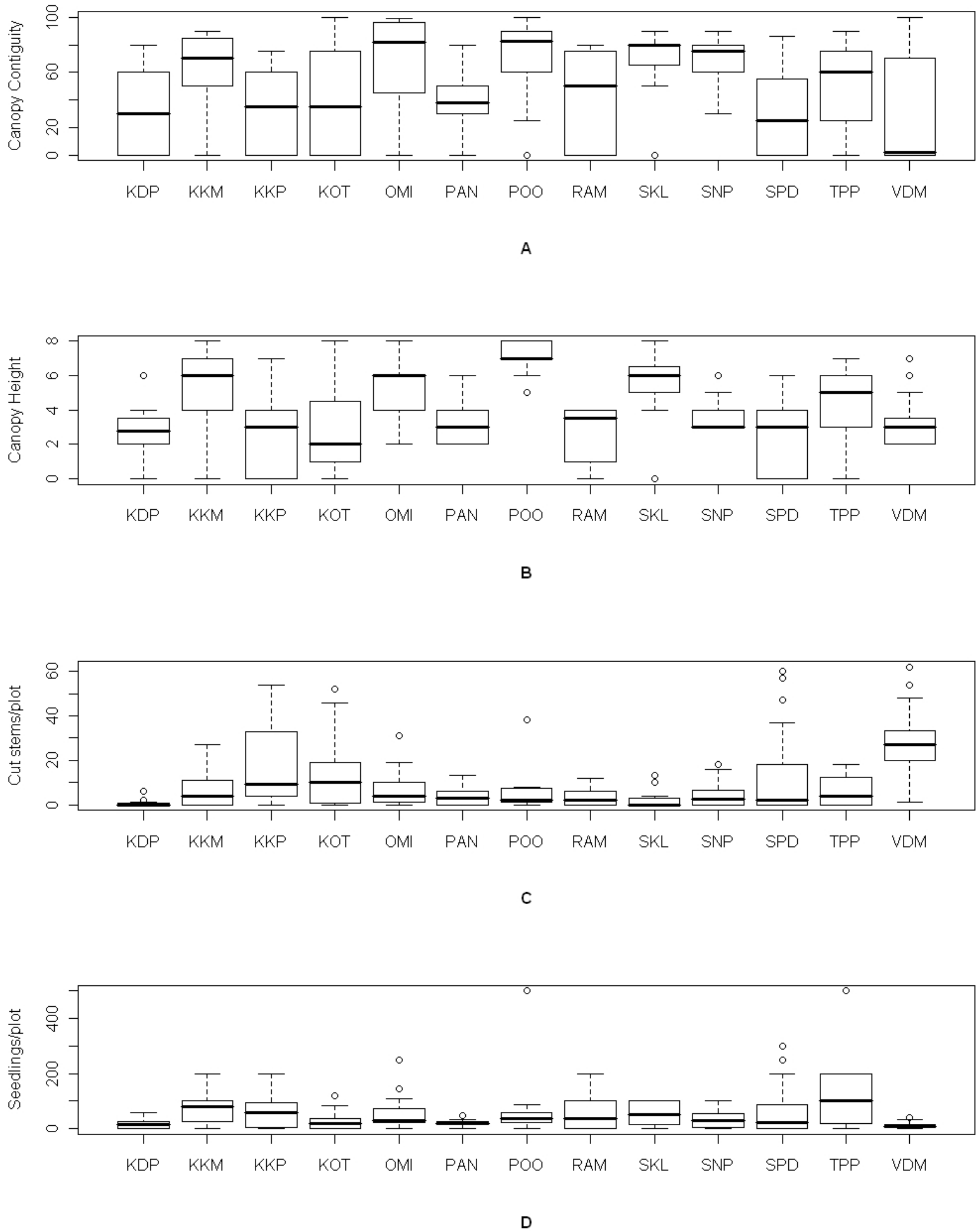


Table 8.8: Shortlisted TDEF sites.

Sl.No.	Site	Panchayat	District
1	Puthupet	Kizhputhupet	Villupuram
2	S.Pudur	Thondamanatham	Cuddalore
3	Periyamudaliyarchavadi	Kottakuppam	Villupuram
4	Vadaagaram	Marakanam	Villupuram
5	Kadapakkam	Kadapakkam	Kanjeepuram
6	Poornakuppam	Ariyankuppam	Puducherry
7	Kothattai	Kothattai	Cuddalore
8	Sentharakillai	Sentharakillai	Cuddalore
9	Konjikuppam	Kadampuliyur	Cuddalore
10	Ramapuram	Ramapuram	Cuddalore
11	Ommiper	Marakanam	Villupuram
12	Kuzhandaikuppam	Vennangupattu	Kanjeepuram
13	Suriyanpet	Kumalamkulam	Cuddalore
14	Panayur	Kadapakkam	Kanjeepuram
15	Tputhupalayam	Thirumanikuzhi	Cuddalore

Table 8.9: Selected TDEF sites and their area.

Name of Village	District	Area available for Restoration
Kothatai	Chidambaram	17.32 ha
S. Pudhur	Cuddalore	8.64 ha
Vadagaram	Villupuram	5.37 ha

3 ranking sites were selected. However, one of the site, Puthupet ranked third in the list had to be dropped as the sacred grove is controlled by many villages and the community participation for the restoration component was un-feasible. Instead site ranking fourth, namely Vadagaram, was chosen for taking up the restoration activities.

The final list of sites chosen for restoration were:

1. **Kothattai** located in Chidambaram Taluk of the Cuddalore district. This is the largest sacred grove patch along the Coromandel coast within 25 km from the coast and covers an area of 17.32 ha.

2. **S.Pudur** located in Cuddalore district covers an area of 8.64 ha is the second largest site that has been chosen for restoration.

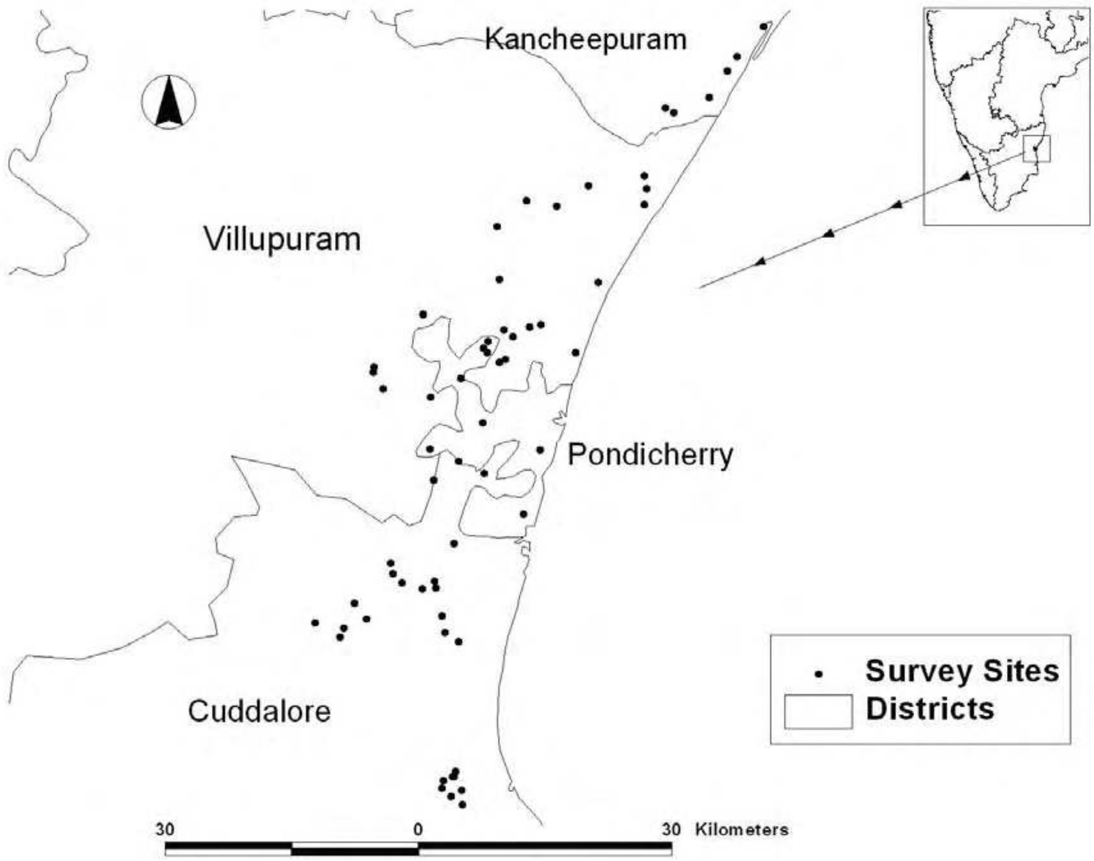
3. **Vadagaram** located in Vanur block of Villupuram district covering an area of 5.37 ha is the third site prioritised for restoration.

8.3 Planting Tropical Dry Evergreen Forests

Site Selection

Site selection for restoration was done by collating logistical, social, administrative and spatial parameters. Based on the results from the analysis of site selection parameters, three TDEF sites were identified for restoration out of the 77 villages surveyed (Annexure 1A: List of villages, which were surveyed). The details of these three TDEF sites are given in Table 8.9 below.

Figure 8.7: Map of sites surveyed.



Developing Restoration Plans for TDEF

Based on the analysis of environmental and social parameters, restoration plans for the three TDEF sites were completed. Maps describing the restoration plan for each of the site are presented below (Figure 8.10).

Ratification of restoration plans by the community at Microplanning sessions

The restoration plans were presented to Panchayat members and representatives from the community at a microplanning session held at each of three villages. During the session, proposed restoration plan for the respective TDEF patches were presented to leaders and representatives from the community and their views, suggestions and objections were recorded. The Panchayats were later given a copy (Annexure B.1) of the proceedings to formalise and ratify the activities as part of the restoration program prior to implementation.

At Vadagaram and Kothattai, the restoration plans were ratified with minor changes in the fencing plan and selection of species for planting. However, at S.Pudhur, the local cricket team strongly objected to the planting activity since the degraded TDEF patch was used as a cricket ground. Intervention from the Panchayat leaders assuring the cricket team alternate play ground did not help and subsequently, the restoration activity for this village was withdrawn.

Figure 8.8: The 15 TDEF sites receiving the highest ranks.

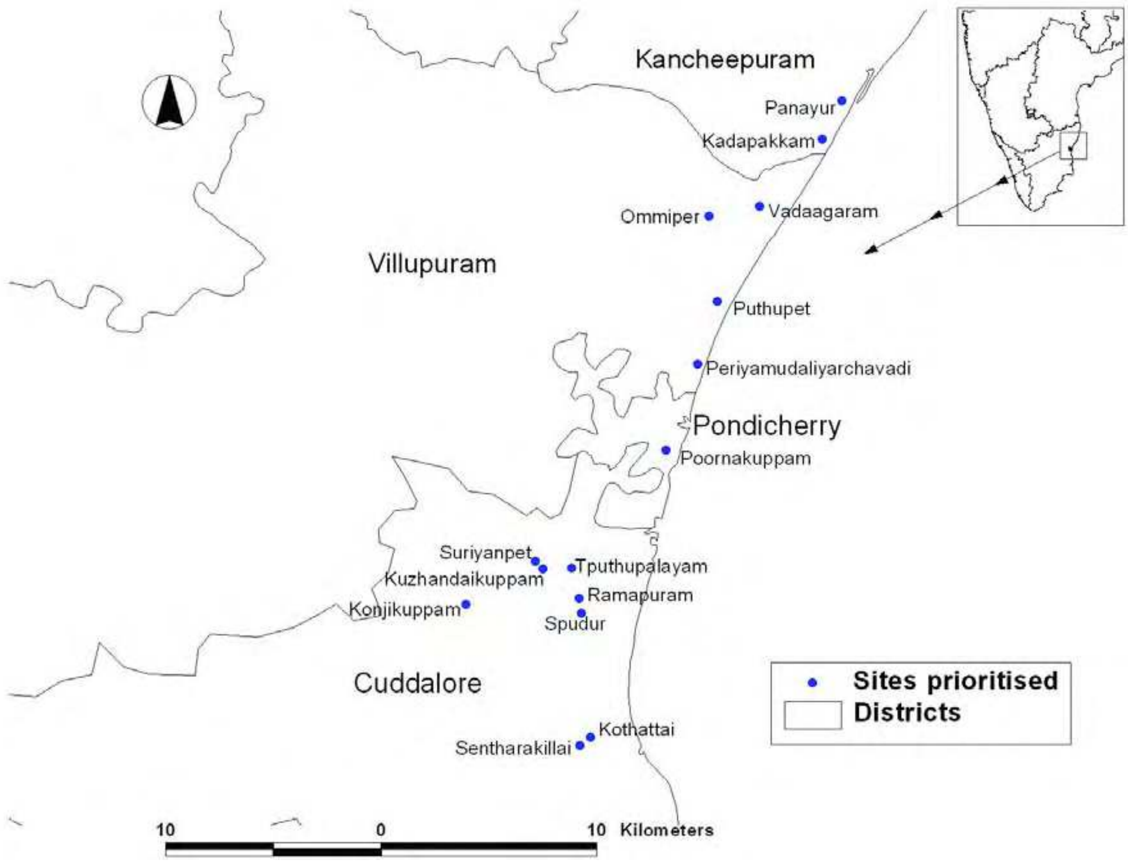


Table 8.10: Seedlings transported to TDEF sites. Note: mortality calculated from survival status taken just before planting on TDEF site.

Name of Village	Number of saplings at on-site nursery	Number of species	% Mortality
Vadagaram	2830	16	0.17 (5 nos)
Kothattai	5915	17	3.3 (196 nos)

Establishing on-site nurseries

TDEF saplings from the mother nursery at FERAL field office were transported to on-site nurseries established at Vadagaram and Kothattai. The saplings were kept for a month in these nurseries for hardening. Women from SHG groups in the village were hired for maintenance, watering and monitoring saplings in the on-site nurseries. The number of saplings transported to the selected sites is given below (Table 8.10).

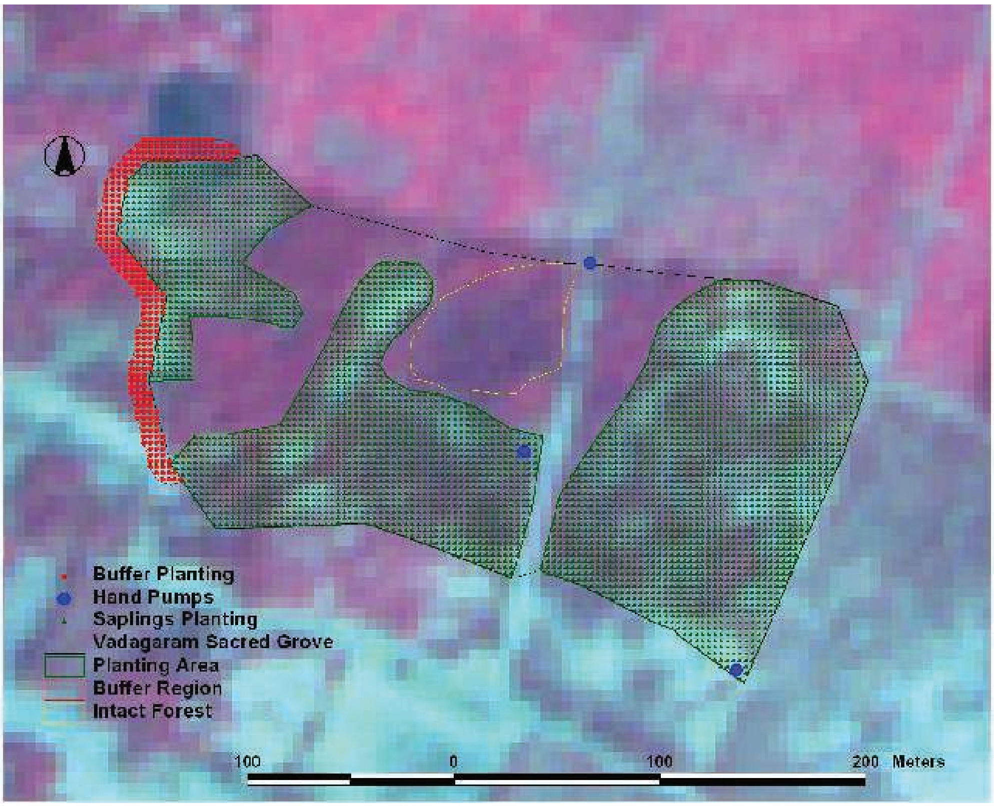
Restoration Activities

Pits and planting mixture

Depending on the number of saplings for planting, pits were first dug in rows in area demarcated for planting. The dimensions of the pits were approximately 1.5 cubic feet. Planting mixture, consisting of compost (farmyard manure) and coconut fibre, procured locally, was mixed in the ratio of 1:1 and filled in the pits before transplanting the saplings. The spacing between two pits, which was 1 metre, was

Figure 8.9: Restoration plans for the selected sites Vadagaram (top) and Kothattai (bottom).

Figure 8.10:



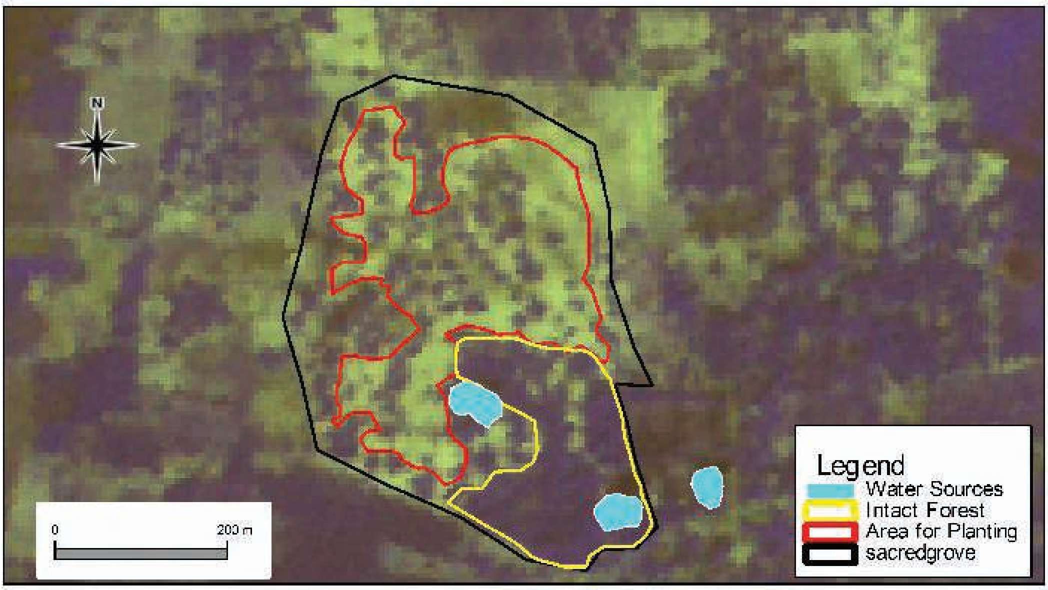


Figure 8.11: Planting at Kothattai.

Table 8.11: Number of species and individuals transplanted.

Name of village	Total number of TDEF saplings	Number of species
Vadagaram	2825	16
Kothattai	5719	18

decided based on the canopy cover and root spread of the selected TDEF species.

Planting

Saplings from the on-site nursery were shifted to the TDEF patch, poly bags were removed and saplings were transplanted into the pits. Care was taken to adequately mix the number of each species in every row. The empty poly bags were disposed off to solid waste collection centres in nearby towns. Total number of TDEF saplings planted at the two sites is given in table and the total number of each species in tables 8.11and 8.12.

Buffer area planting

In order to provide the community a source for fuel wood and timber, buffer areas around the TDEF patches were identified. In these areas, both in Vadagaram and Kothattai, the numbers and species planted are given below.

Labour for the planting activity

During the microplanning sessions, the village elders were informed that the planting activity will be carried out with the help of women (SHG members) within the village. The total number of labour days for each of the sites and the total number of actual days taken for planting activity is given in table 8.15.

Table 8.12: Numbers of species planted at Vadagram.

Sl.no	Species name	No. of saplings at on-site nursery	Mortality	No. of saplings planted on site
1	*Albizza amara*	82	0	82
2	*Bauhinia racemosa*	70	0	70
3	*Butea monosperma*	151	0	151
4	*Dalbergia paniculata*	129	0	129
5	*Dalbergia sissoo*	181	0	181
6	*Ehretia pubescens*	93	0	93
7	*Phyllanthus polyphyllus*	345	5	340
8	*Polyalthia suberosa*	133	0	133
9	*Pterospermum xylocarpui*	84	0	84
10	*Senna auriculata*	344	0	344
11	*Streblus asper*	44	0	44
12	*Syzygium cuminii*	194	0	194
13	*Terminalia bellerica*	128	0	128
14	*Wrightia tinctoria*	44	0	44
15	*Cardia mixia*	316	0	316
16	*Cassia fistula*	492	0	492
17	*Antidesma menasu*			
	Total	2830	5	2825

Table 8.13: Numbers of species planted at Kothattai.

Sl.no	Species name	No. of saplings at on-site nursery	Mortality	No. of saplings planted on site
1	*Albizza amara*	328	2	326
2	*Bauhinia racemosa*	280	0	280
3	*Butea monosperma*	457	3	454
4	*Dalbergia paniculata*	515	2	513
5	*Dalbergia sissoo*	579	18	561
6	*Ehretia pubescens*	317	1	316
7	*Phyllanthus polyphyllus*	1020	150	870
8	*Polyalthia suberosa*	133	0	133
9	*Pterospermum xylocarpum*	124	0	124
10	*Senna auriculata*	275	0	275
11	*Streblus asper*	176	0	176
12	*Syzygium cuminii*	622	17	605
13	*Terminalia bellerica*	143	2	141
14	*Wrightia tinctoria*	40	1	39
15	*Cardia mixia*	312	0	312
16	*Cassia fistula*	492	0	492
17	*Antidesma menasu*	102	0	102
	Total	5915	196	5719

Table 8.14: Composition of buffer area plantations.

Vadagaram	Kothattai
Tectona grandis (Teak) – 150	*Tectona grandis* (Teak) – 200
Azadiracta indica (Neem) – 150	*Azadiracta indica* (Neem) – 120
Khaya senegalensis (Kaya) – 200	*Khaya senegalensis* (Kaya) – 1222
	Tamarindus indica (Tamarind) - 300

Table 8.15: Details of employment generated from TDEF planting activities.

Activity	Vadagram	Kothattai	Total
Number of person days for digging pits	83	240	323
Number of SHG women employed for digging pits	0	180	180
Number of person days for planting	311	749	1060
Number of SHG members employed for planting	79	150	229
Number of days taken for the planting activity	7	13	20

Fencing

The specifications and area to be fenced off for the TDEF patches in Vadagaram and Kothattai were discussed with the community during the microplanning session.

At Vadagaram, the community undertook the responsibility of completing the fencing activity. The entire TDEF patch at Vadagaram was fenced off and the fencing plan is given in figure . At Kothattai, fencing work was given to a contractor identified and recommended by the Panchayat president. Areas prone to grazing were fenced (refer fencing plan given in figure 8.12) through this contract.

Watering and watching

Shallow wells (auger wells) were dug at Vadagaram (3 wells) and Kothattai (4 wells) to facilitate watering at the patches. 1.5 hp portable pumps were distributed to pump water from these wells. Women from SHG groups within the village were employed to water the saplings during the dry season. Watchmen hired from within the two villages helped to monitor the saplings and infrastructure set up at the TDEF sites.

Monitoring survival of saplings

A protocol for monitoring and analysing survival status of saplings at the TDEF sites has been developed (Annexure 3).

Constraints / lessons learnt

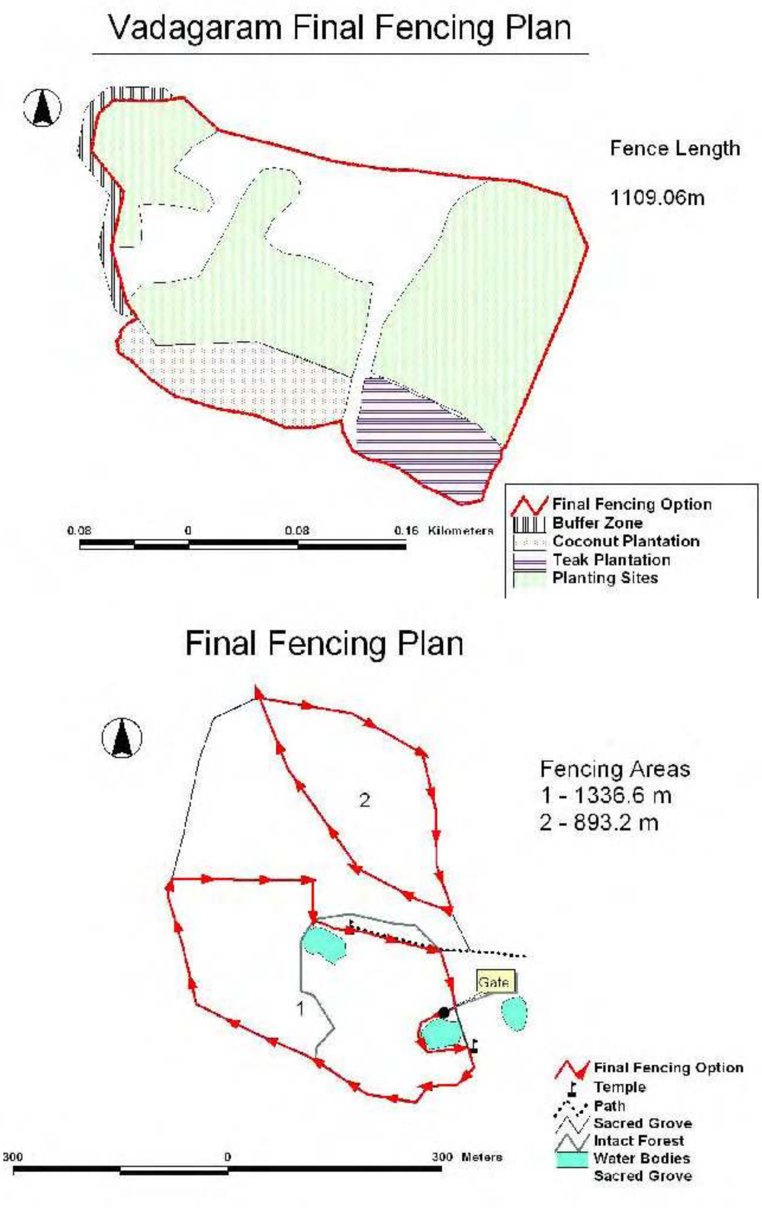
The team encountered several problems / constraints during the implementing of the restoration plans, which are mentioned below.

Organising labour, particularly women from SHG groups during the planting activity was a constraint. During the planting activity, there was heavy rain and most women were reluctant to work in those conditions.

The fencing activity was attractive to a few people in the community, who wanted to make the most of the contract. This became a deterrent in completing the fences on time. At Vadagaram, the community took up the responsibility of fencing and it took several meetings with the village leaders to negotiate the contract for the fencing activity. This delayed the fencing activity at Vadagaram, thereby exposing saplings on the periphery of the TDEF patch to grazing.

At Kothattai, a tender was floated for the fencing activity and was given to a contractor, who was identified and recommended by the village Panchayat president and had the lowest bid. This helped in getting the fences in place relatively faster when compared to Vadagaram. During the implementation,

Figure 8.12: Fencing plans for the TDEF sites, Vadagaram (top) and Kothattai (bottom).



it was found that a large number of pillars used for the fencing were not of good quality and the contractor was asked to replace them immediately. Approximately 200 such pillars were replaced at Kothattai.

Restoration activities could not be implemented at S.Pudur due to internal conflict in the village. Also, there was stiff resistance from local boys who used the clearing in the grove, as play ground. This suggests that all factions of the local community have to be involved in the implementation of restoration activity, a rather difficult task.

The cost of restoration was underestimated in the project proposal. Costs of labour (particularly for digging pits and watering), procurement of planting material, transport and fencing increased considerably. The saplings currently planted comprises higher percentage of deciduous species. This limitation arose due to the non - availability of seeds/sapling of slow growing evergreen species. Future restoration efforts should ensure adequate allocation of time and effort towards this as it was really short during the course of this project.

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Chapter 9 Stabilisation of Coastal Sand Dunes

P. Dilip Venugopal, R. S. Bhalla and M. Anbarashan

Contents

9.1 Introduction to Coastal Sand Dunes and Beaches

Vast tracts of India's coast consist of beaches and coastal sand dunes. These natural formations are among the most effective natural defences against storms, cyclones and tsunamis. Fishing communities rely on their presence and most of the coastal tourism industry advertises them as major attractions. What is often not realised is that these are dynamic and complex habitats, many of which are under threat. Coastal sand dunes depend on a constant supply of sand, which is often is obstructed by activities such as construction of sea walls and wind breaks along the coast or damming of rivers and choking off their natural supply of sediment to the coast.

Conservation of dunes thus involves both their stabilisation as well as ensuring a constant supply of sand. The project efforts were to identify sites along the coast with relatively un-disturbed dunes and to stabilise selected dune structures using a mix of native species.

Ecological Goods and Services of Coastal Sand Dunes

Coastal sand dunes perform a unique ecological function as a buffering mechanism for coastal erosion and deposition and protection against wave action, wind and tides (Mascarenhas and Jayakumar, 2007,

Figure 9.1: Sea walls and groynes spell doom for coastal sand dune systems.

(a) A sand deficient beach. *(b)* Groyne field.

2006; Mascarenhas, 1998; Arun et al., 1999; Dahm et al., 2005; Sanjeevi, 1996; Sridhar and Bhagya, 2007; Environmental Protection Agency, Queensland, a). They also provide a large range of goods and services to coastal communities. These include sites for boat landing, sales of fish, drying and repairing of nets and motors as well as ground water recharge (Bhalla, 2007). Additional uses of coastal sand dune vegetation are fodder, food and medicinal plants (Sridhar and Bhagya, 2007). Other functions of coastal sand dunes mentioned in literature are:

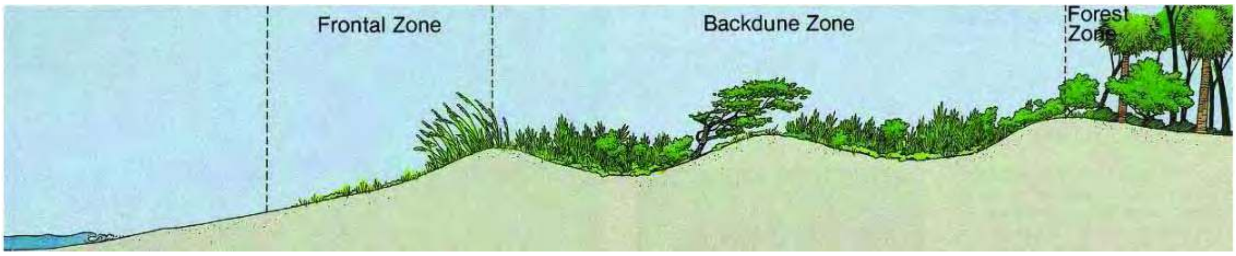
- Store house of sediments and nutrients and sources of beach nourishment
- Protection from storm surges, hurricanes and erosion
- Provide habitats for adapted plants, birds and mammals.
- Providing nesting site for sea turtle and birds.
- Arrest blowing sand and deflect wind upwards.
- Assist in the retention of fresh water
- Obstruct the ingress of saline marine water into the hinterland.
- Prevent loose sand from advancing inland on the coastal zone

Coastal dunes are among the few natural defences against the tsunami. While the role of vegetation or bio-shields is fiercely debated (see chapter 4), it is widely accepted that coastal sand dunes played an important role in protecting coastal communities against both the tsunami and storm surges (Bhalla, 2007; Mascarenhas and Jayakumar, 2007; Chatenoux and Peduzzi, 2007). Despite this, very few agencies involved in of coastal habitats along the Coromandel coast have considered beach and dunes a habitats that need to be conserved.

Changing this would require high levels of policy advocacy as many decisions related to modification of environmental flows, such as construction for sea walls and dams are being made at the state level. Various advocacy efforts are underway[12] but are yet to yield any results.

[12] For more details visit the CAN website: `http://www.slideshare.net/equitywatch/erosion-of-pondicherry-beaches`

Figure 9.2: The structure of a dune. (From M.J.Williams 2007).



Formation

Coastal sand dunes are formed as a consequence of sand deposition by waves, its transport inland by wind and stabilisation by vegetation. Thus, the direction and load of littoral drift and wind speed and direction play a key role and dunes recede and grow as they change. Tidal heights and storm surges can also affect coastal dunes which "eat" into them during storm surges and re-build during periods of calm. Thus dunes provide the very first protective barrier for a range of coastal hazards (Mascarenhas and Jayakumar, 2007; Dahm et al., 2005). The role of vegetation in dune formation is critical and is that of a wind trap and sand binder (Dahm et al., 2005). Vegetation growing on the berm is particularly hardy. Among the kinds of stress faced by plants at the frontal dune and berm are salt and sand spray, salt water flooding, heat, low nutrients, getting covered by sand and a mobile substratum (Mascarenhas, 1998). Vegetation on older dunes changes with a dominance of shrubs and small trees the further back one moves from the to the back dune to finally the forest zone.

There are three major structures that compose a dune system:

1. The berm "an accumulation of sand brought up by the waves on the beach at a point just above the highest high tide." Mascarenhas (1998).
2. The frontal zone, which is an accumulation of sand on and behind the berm - where prevailing winds and vegetation play a crucial role and
3. Back dunes which result from an accumulation of sand behind the frontal dune formation and can attain substantial heights and sustain a wider range of vegetation, from small shrubs and trees to large palms.

Depending on the amount of sand available, or beach nutrition, coastal dunes can grow landward with the newest dune facing the sea and older ones further back. Thus they are dynamic ecosystems depending on a regular supply of sand.

Assessment and Characterisation of the Study Area

Sanjeevi (1996) mapped the dune formations along the Coromandel coast and found that they exhibit a wide variation in morphology and landuse. Mascarenhas (1998) mapped beach profiles for various parts of the Goan coast and then again (with various authors) for parts of the Coromandel coast after the 2004 tsunami (Mascarenhas and Jayakumar, 2007; Mascarenhas, 2006; Mascarenhas and Jayakumar, 2006).

Zonation Vegetative cover on the coastal sand dunes, have been reported to generally consist of three zones –

Table 9.1: Characteristics of dunes in regions of the Coromandel coast.

Sl.	Region	Characteristic and use pre-tsunami. From Sanjeevi (1996)
1	Pulicat to North Madras	Well developed dunes, nearly 3m high, gently undulating and covered by vegetation (Casuarina spp.)
2	Madras City, Marina beach, Covlong, Mahabalipuram	Non undulating wide sandy beaches, nearly 1km wide at Marina.
3	South Madras, Tiruvanmaiyur	Major source of fresh water
4	South of Mahabalipuram	Dunes used for coconut and casuarina plantations.
5	Pondicherry and Porto Novo regions	Dunes not wide but well developed and 10m high.
6	Cauvery delta and Point Calimere region including Nagapattinam	One of the remarkable dune fields in the Coromandel coast, attributed to the sand supplied by Cauvery. Some dunes as far as 35km from Pt. Calimere are paleo-dunes indicating Holocene period coastlines. Used for agriculture, dunes cause blockage of drainage leading to flooding.

1. Pioneer zones with mainly herbaceous vegetative cover
2. Woodland or scrub zone, with secondary stabilising plants including shrubs, grasses and stunted trees
3. A coastal heath zone (forest) composed of low shrubs and stunted trees (Environmental Protection Agency, Queensland, a).

Such a zonation pattern along the Coromandel Coast, has been reported by Blasco and Legris (1972) from the Point Calimere region . However, this zone formation has probably been lost from many sites along the Coromandel coast due to various anthropogenic pressures. The ecological assessment carried out during this project has recorded about 30 species. A clear pattern of the vegetative zonation has been evident in South Pogainallur with binders such as *Spinifex littoreus* and *Ipomeae pes-caprae* (Ipomea) in the high tide line to slope region, herbaceous cover and members of Asteraceae, Poaceae in the berm and other stunted clumps and trees such as Pandanus (*Pandanus odoratissimus*) and *Borassus flabellifer* (Borasus palm or Palmyra) in the front dune to back dune regions.

Dunes cover large parts of the Coromandel coast (Sanjeevi, 1996) and vary in character and composition at different regions, from flat wide and non-undulating beaches to narrow by tall dune formation. These characteristics are summarised in table 9.1. Studies conducted post-tsunami documented changes in specific portions of the coast, particularly Nagapattinam (Mascarenhas and Jayakumar, 2006) and Parangipettai and highlight the role of dunes as natural defences (Mascarenhas and Jayakumar, 2007).

Species Composition and Richness

The composition of vegetation varies greatly in coastal dunes and is largely determined by the zone and therefore the nature of environmental conditions it has to cope with. Table 9.2 lists some of the plant species found in different zones. Arbuscular mycorrhizal fungi significantly contribute to the survival of

Table 9.2: Zones and species composition in Indian coastal sand dunes.

Sl.	Zone	Species composition	Species characteristics
1.	Berm and frontal dune	*Clerodendrum inerme, Cyperus orenius, Opuntia sp., Pandanus odoratissimus, Spinifex littoreus* and *Vitex trifolia* (Arun et al., 1999).	Deep rooted, salt talerant and spreading through suckers.
2.	Back dune	*Pongamia sp., Rhododendron, Pandanus sp.*	Shrubs and small trees. Deep routed, highly resistant to desiccation (waxy leaves), adapted to tapping moisture from morning dew.
3.	Forest zone	TDEF species	Dry evergreen and deciduous species, essentially those found in TDEF areas.

Table 9.3: Sand dune sites visited per district.

State/UT	District	No of Sites
Tamil Nadu	Kanchipuram	7
Tamil Nadu	Villupuram	12
Tamil Nadu	Nagapattinam	8
Pondicherry	Pondicherry	11
Pondicherry	Karaikal	8
	Total	40

plants under harsh conditions and development of plant community structure in dune systems (Arun et al., 1999).

Arun et al. (1999), found 14 leguminous species associated with coastal dunes in Karnataka. Among the dominant families associated with dunes in tropical areas are Asteraceae, Convolvulaceae, Poaceae and Leguminosae while Poaceae is the most common family in temperate regions. They also found indigenous tree species (*Tamarindus indica, Pongamia pinnata* and *Erythrina indica*) and a mangrove species *Derris triflorum* in their study area. Sridhar and Bhagya (2007) compiled a list of 154 species belonging to 108 genera and 41 families.

9.2 Site selection for Coastal Sand Dunes

A survey along the Coromandel coast in Tamil Nadu (Kanchipuram, Villupuram & Nagapattinam) and Pondicherry (Pondicherry & Karaikal) was conducted to identify potential sites for sand dune restoration. Data on the administrative (control & ownership), logistical (permission and area availability) and social parameters (community participation, women SHGs) were collected. The survey included discussions with village leaders and representative of the Panchayat. A total of 46 sites were visited, the details of which have been provided in table 9.3 below (also see figure 9.3).

Development of the site selection criteria was done by evaluating logistical, social, administrative and spatial parameters. These parameters were collated and a ranking matrix was developed to prioritise sites for restoration planting. This involved providing score for each of the data parameters. Finally, the scores were added up for each site to identify sites for restoration planting. The scores assigned to each of the above mentioned parameters have been provided in table 9.4.

Table 9.4: Weightage provided for the various data parameters, for prioritisation.

Data Parameter	Weightage provided
Area of the dune available (Ha)	25
Continued community participation	20
Presence of dune structure	5
Number of profile characters	1
Presence of dune vegetation	2
Number of zones vegetation recorded	1

After the first level of site selection, 5 sites were short listed (figure 9.3). They were

1. Angalammankuppam, Kanathur Panchayat, Kancheepuram District.
2. Panichamedu, Vanur Block, Villupuram District
3. Bommayarpalayam, Kottakuppam Panchayat, Villupuram District
4. South Pogainallur, Nagapattinam District
5. Karukkalacherry, Karaikal, Pondicherry

The availability of land and community participation were important factors limiting the choice of sites for sand dune restoration. Ownership of land along the coast by private people and developmental activities along the coast (in the form of buildings, industrial activities and tourism) reduced land available for sand dune restoration. The requirements of the fishermen in terms of space for fishing related activities had also to be taken in account. At the second level of prioritisation, spatial attributes, social aspects and ecological parameters were ranked and provided a weightage for the ranking of the sites. Data was collected through field surveys and parameters used for ranking of the sites were:

1. Spatial – Area of the dune available (Ha). Higher weightage was provided to the area of the dune available for taking up the restoration activities.
2. Social – Continued community participation also received a higher weightage.
3. Dune Structure – Presence of dune structure, the number of profile characteristics (berm, front dune, back dune etc) present. The rebuilding of the dune structure and its restoration was beyond the scope of this project, given the project duration and budgetary constraints. So higher weightage was provided to this parameter also. This was however documented via mapping of the sites. Some of the species planted and the sites there were planted at were selected on the basis of their role in sand harvesting.
4. Presence of vegetation in the dune and the number of zone in which vegetation was recorded.

The weight given to the various parameters is shown in table 9.4.

Finally detailed discussions with local communities were made and size of sites and ownership were determined.

The administrative control of the sand dune areas at the visited sites, rested predominantly with the local Panchayat (53%), followed by private land owners (30%). The local Panchayat in many of the villages involved the fishermen community. A break up of the administrative control has been provided in the figure 9.4.

Figure 9.3: Surveyed (left) and prioritised dune sites (right).

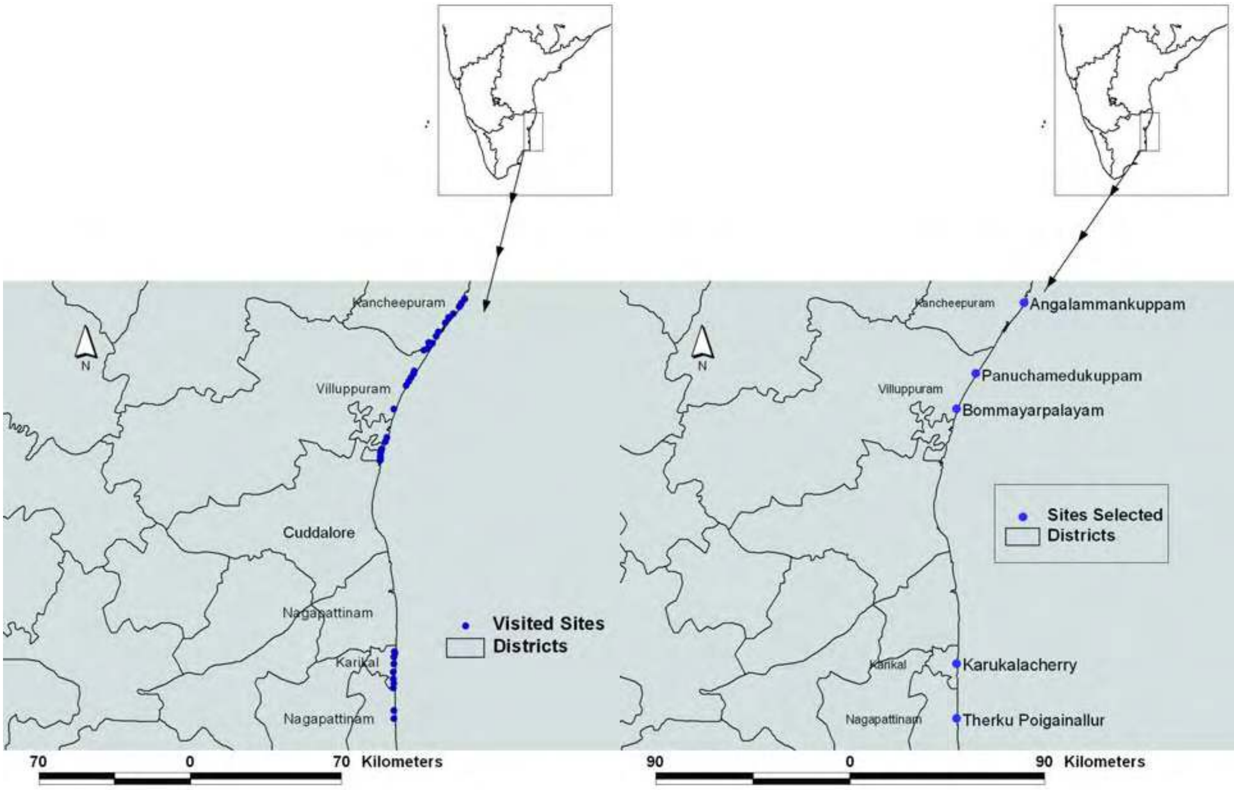


Table 9.5: Administrative information about coastal sand dune sites.

State/UT	District	No of Sites
Tamil Nadu	Kancheepuram	7
Tamil Nadu	Villupuram	12
Tamil Nadu	Nagapattinam	8
Pondicherry	Pondicherry	11
Pondicherry	Karaikal	8
	Total	46

Figure 9.4: Administrative control of dune sites.

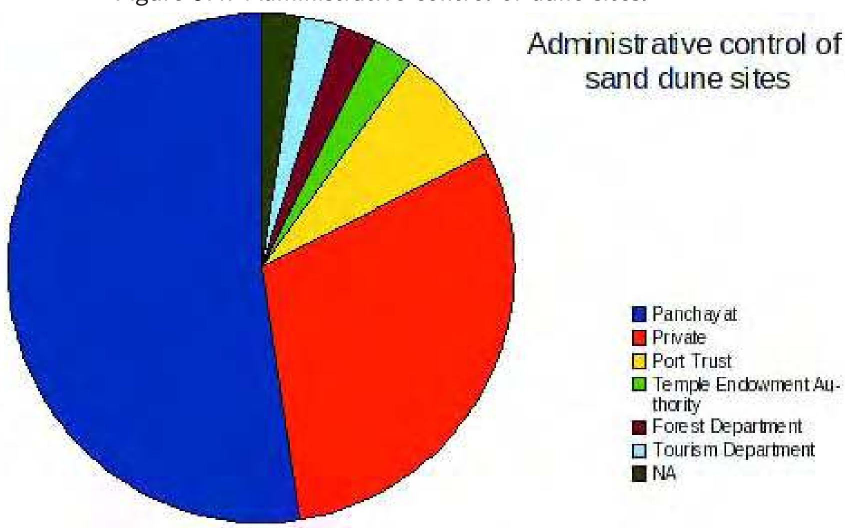


Table 9.6: Number of transects and plots laid per dune site.

Site	No of Transects	No of Plots
Karukkalacherry	11	131
South Pogainallur	2	84
Angalamman kuppam	4	33
Panichamedu	10	27

Ecological Assessments

The vegetative cover and patterns of zonation, were studied in four sites namely South Pogainallur, Karukkalacherry, Angalammankuppam and Panichamedu[13]. At each site, transects running inland, perpendicular to the coast line, till the back dune zone, were used for the vegetation sampling. At every fifth metre of the transect line, a circular plot of 2m radius was drawn and the occurrences of the dune vegetation were noted, along with notes on the zonation. Zonation was broadly classified as High Tide Line, Berm, Front Dune and Back dune. However, it has to be noted that the profile and the topography of these zones varied with sites. The transects were placed at equal distances from one another, at all the sites. The number of transects varied with each site, depending upon the length of the beach available for sampling. Similarly, the length of the transect line also, varied across sites because in some sites, the back dune portion was not available.

Dune Vegetation

The surveys conducted to document the vegetation in the dunes across the different sites recorded a total of 30 species across different zones. Site wise list of species documented at three sites has been provided in table 9.7[14].

Site specific details regarding the occurrence of vegetation across the different zones and the overall density has been provided below. 16 species including runners and herbaceous species were recorded in Karukkalacherry (table 9.8 while, 22 species were recorded in South Pogainallur (table 9.9). Species such as *Kyllinga triceps, Spinifex littoreus, Ipomea pes-caprae, Salicornia bracheata,* were found in the high tide line to slope region. Berm to front dune consisted of herbaceous species such as *Leucas diffusa, Gisekia Pharnaceoides, Phyllanthus virgatus, Tephrosia purpurea and Indegofera.* The front to back dune zone consisted of the coastal dune tree species, such as *Borassus* and the introduced *Casuarina*.

Location of Coastal Sand Dune Sites

Two sites, namely, South Pogainallur and Karukkalacherry, were finally selected from the shortlist (figure 9.5). These sites scored the highest in the various parameters used for ranking. Further details of the two sites follow.

[13]Only the high tide line to berm was sampled.

[14]Panichamedu was dropped from the analysis as the site was reduced to a narrow strip of beach with high levels of anthropogenic pressure.

Table 9.7: List of species recorded at the site.

Sl no	Species	South Pogainallur	Karukkalacherry	Angalammankuppam
1	*Anacardium occidentale*	1		
2	*Aristida setacea*	1		
3	*Azadirachta indica*	1		
4	*Boerhaevia diffusa*	1		
5	*Borassus flabellifer*	1		
6	*Calatrophis gigantea*	1	1	
7	*Canavalya rosea*	1	1	1
8	*Casuarina equisetifolia*	1	1	1
9	*Catharanthus roseus*		1	
10	*Cleome tenella*	1		
11	*Cyperus arenarius*	1		
12	*Euphorbia rosea*	1		
13	*Gisekia pharnaceoides*	1		1
14	*Glinus oppositifolius*			1
15	*Indigofera aspalathoides*	1		
16	*Ipomea pes-caprae*	1	1	1
17	*Kyllinga brevifolia*		1	
18	*Kyllinga triceps*	1		
19	*Leucas diffusa*	1		
20	*Oldenlandia caerulea*	1	1	
21	*Opuntia sp*		1	
22	*Pedalium murex*		1	
23	*Perotis indica*	1	1	
24	*Phyllanthus virgatus*	1		
25	*Prosopis juliflora (Sw.) DC.*		1	
26	*Salicornia brachiata*	1	1	
27	*Sesuvium portulacastrum*		1	
28	*Spinifex littoreus*	1	1	1
29	*Suaeda nudiflora*		1	
30	*Tephrosia purpurea*	1	1	
		22	16	6

Table 9.8: Species diversity and vegetative occurrence across different zones in Karukkalacherry coastal dune.

Sl no	Species	HTL-Berm	Berm-Front	Front-Back	Total Result
1	*Calatropis gigantea*		3	2	5
2	*Canavalya rosea*			4	4
3	*Casuarina equisetifolia*		2	14	16
4	*Catharanthus roseus*			1	1
5	*Ipomaea pes-caprae*	2		3	5
6	*Kyllinga brevifolia*	2	7	24	33
7	*Oldenlandia caerulea*			1	1
8	*Opuntia sp*		1		1
9	*Pedalium murex*			1	1
10	*Perotis indica*		1		1
11	*Prosopis juliflora (Sw.) DC.*			1	1
12	*Suaeda nudiflora*			1	1
13	*Tephrosia purpurea*			2	2
14	*Salicornia brachiata*			3	3
15	*Sesuvium portulacastrum*			1	1
16	*Spinifex littoreus*	4	7	5	16
					164

Table 9.9: Species Diversity and density in Southpoigainallur coastal dune.

Sl no	Species	HTL – Berm	Berm-Front	Front-Back	Total Result
1	*Anacardium occidentale*			3	3
2	*Aristida setacea*			1	1
3	*Azadirachta indica*			4	4
4	*Boerhaevia diffusa*			2	2
5	*Borassus flabellifer*		1	4	5
6	*Calatrophis gigantea*			1	1
7	*Canavalya rosea*			1	1
8	*Casuarina equisetifolia*	6	14	17	37
9	*Euphorbia rosea*			15	15
10	*Gisekia pharnaceoides*		7	35	42
11	*Perotis indica*			13	13
12	*Cyperus arenarius*			3	3
13	*Ipomea pes-caprae*	2			2
14	*Kyllinga triceps*	4	8	22	34
15	*Phyllanthus virgatus*		4	26	30
16	*Tephrosia purpurea*		7	13	20
17	*Salicornia brachiata*	2			2
18	*Leucas diffusa*		3	7	11
19	*Indigofera aspalathoides*		1	6	7
20	*Oldenlandia caerulea*			6	6
21	*Cleome tenella*			3	3
22	*Spinifex littoreus*	3	1	2	6
					248

HTL-high tide line, Berm-Front- Berm to Front dune, Front- Back- Front dune to back dune

Table 9.10: Species diversity in different zones in site Angalammankuppam.

Sl no	Species	Berm	Front dune	HTL	Total Result
1	Barren		6		6
2	*Canavalya rosea*		2		2
3	*Casuarina equisetifolia*		3		3
4	*Gisekia Pharnaceoides*	1	10	2	13
5	*Glinus oppositifolius*		3		3
6	*Ipomea pes-caprae*	2	1		3
7	*Spinifex littoreus*	1	7	2	10

South Pogainallur

South Pogainallur, located 5 Km South of Nagapattinam on the Nagai-Velankanni road is a village with predominantly agriculture as their main occupation. The sand dunes along the coast in this village is largely undisturbed as this is not a fishing village. Some areas of the dune have been planted with Casuarina by the Forest Department and the villagers too. An area of 2ha was provided by the Panchayat Leaders for restoration activity.

Karukkalacherry

Karukkalacherry settlement of Akkaravattam Revenue village in Karaikal region of the Pondicherry Union Territory was selected for restoration activities to be taken up. The dunes, found in the south-eastern portion of the village were taken for the restoration activities. There are about 275 households with a population of around 600 in the Karukkalacherry settlement. A distributary of Muliyar River and the estuarine region forms the northern boundary of the village.

9.3 Restoration

The goals for the restoration activities were to assist the recovery and stabilisation of the dunes. The objectives of the restoration activities taken up in the sites were:

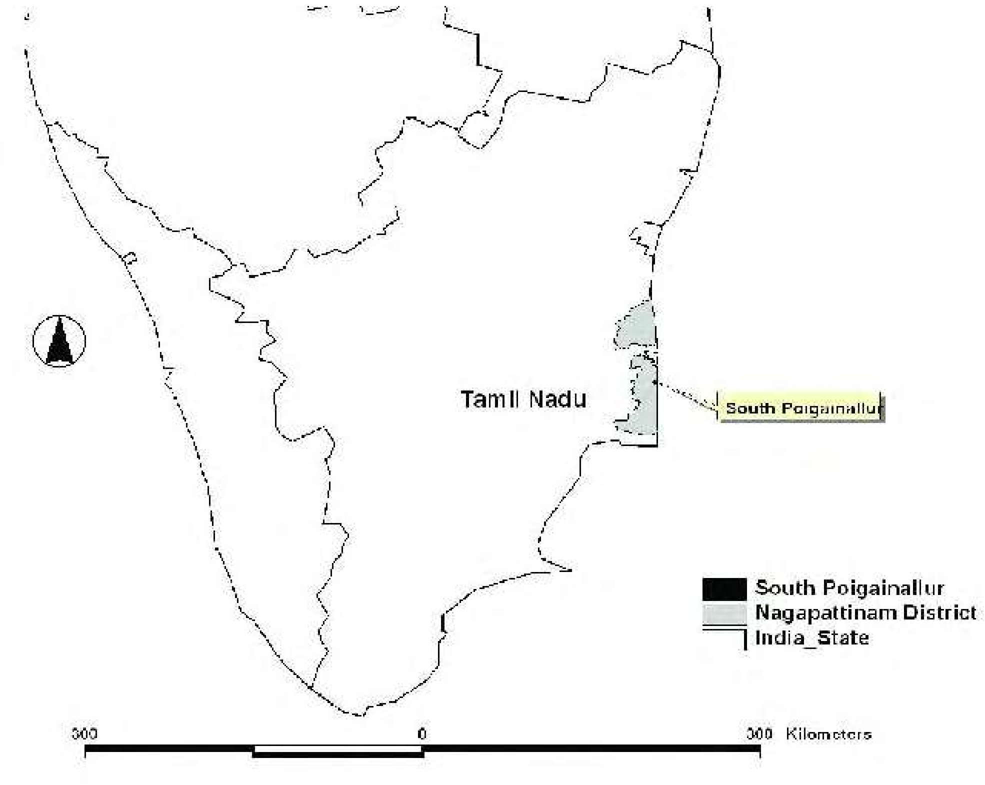
1. Dune stabilisation through planting
2. Sand harvesting through planting appropriate species at appropriate locations
3. Species enrichment planting in back dunes.
4. Providing protection from cattle grazing and fuel wood collection through fencing
5. Creating awareness among local village people through street play and distribution of posters and pamphlets.
6. Ensure community participation in restoration activities through involvement of local self group women for planting, watering and watching.
7. Creation of a committee comprised of representatives of the Panchayats, traditional leaders and representatives of women self help groups.

Restoration Plans

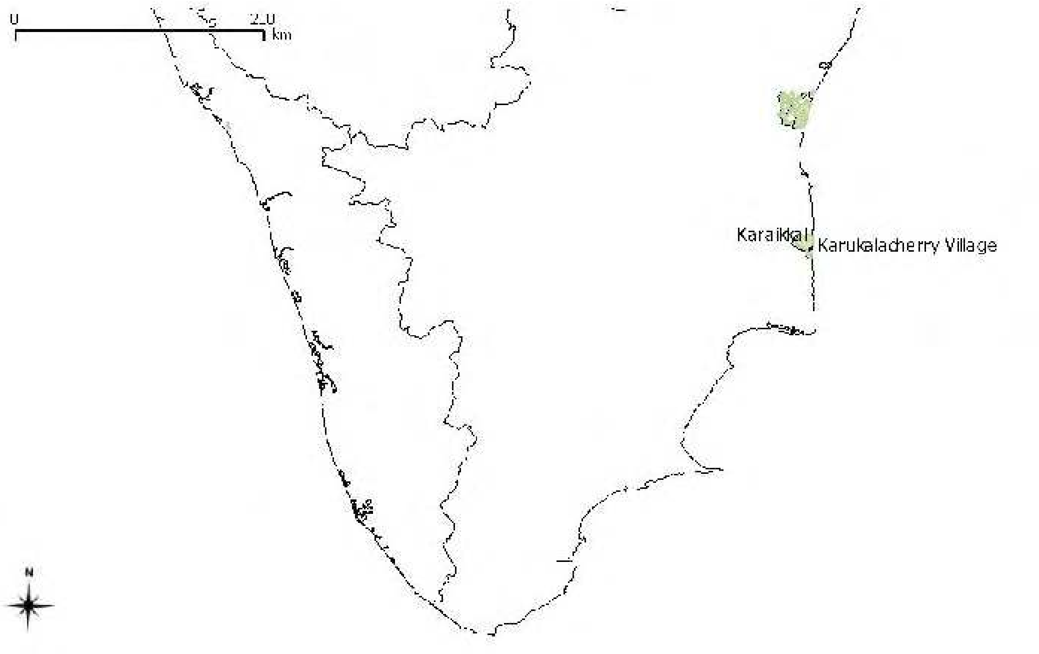
Preparation

Based on the analysis of environmental and social parameters, individual restoration plans for the two sand dune sites were completed. Maps describing the restoration plan for the selected sites are presented below.

Figure 9.5: Location of selected sites.

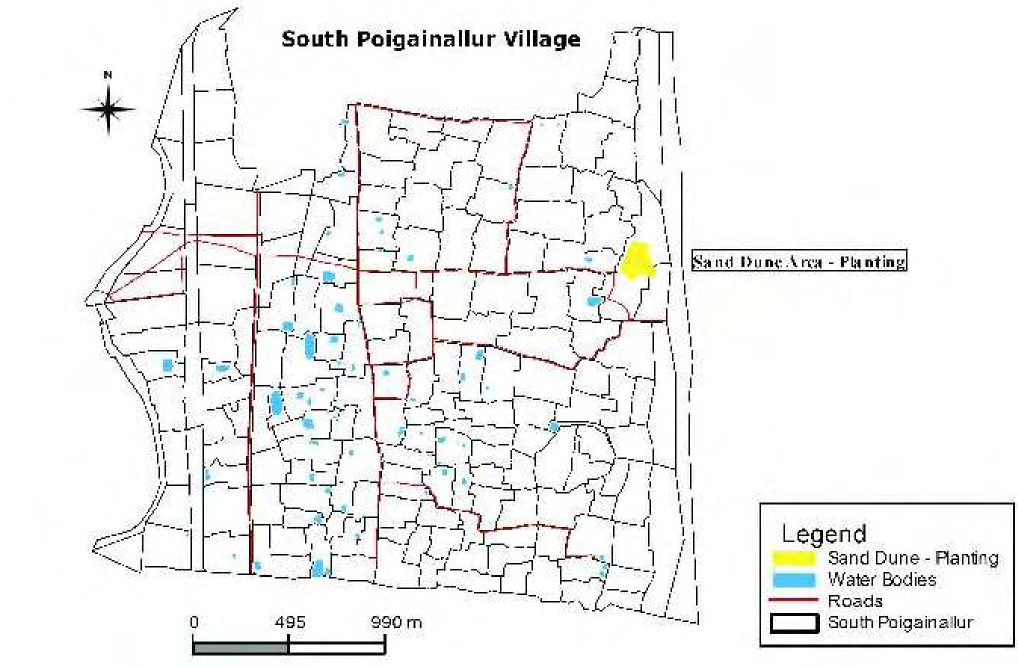


(a) South Pogainallur

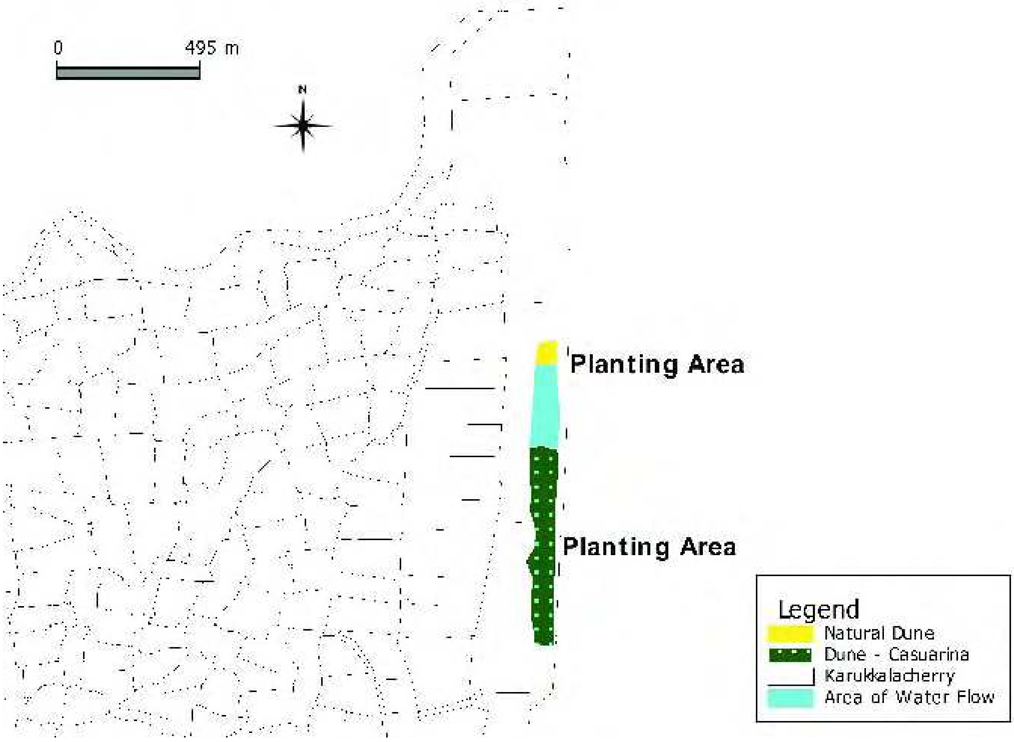


(b) Karukkalacherry

Figure 9.6: Maps of the Restoration plan for South Pogainallur.



(a) Location of site in S.Pogainallur



(b) Planting Plan.

Table 9.11: Number of saplings transported to site.

Name of Village	*Borassus flabellifer*	Saplings	Number of species
South Pogainallur	6500	462	3
Karukkalacherry	19000	8111	9

Ratification of Restoration Plans by the Community at Microplanning Sessions

The restoration plans were presented to Panchayat members and representatives from the community at a microplanning session held at each of three villages. During the session, proposed restoration plan for the respective sand dune patches were presented to the community and their views, suggestions and objections were recorded. The Panchayats were later given a copy of the proceedings to formalise and ratify the activities as part of the restoration program prior to implementation.

At both South Pogainallur and Karukkalacherry, the restoration plans were ratified by the community. However, at Karukkalacherry, the planting site was interspersed with Casuarina planting done by the Pondicherry Forest Department. Subsequently, discussions with the Forest Department were held and the planting as part of the UNDP-PTEI project was completed as a joint initiative. The Forest Department of Pondicherry donated sand dune saplings in two phases (5000 each) for the planting at Karukkalacherry too.

Establishing On-site Nursery

Sand dune saplings from the mother nursery at FERAL field office were transported to on-site nurseries established at South Pogainallur and Karukkalacherry. The saplings were kept for a month in these nurseries for hardening. Women from SHG groups in the village were hired for maintenance, watering and monitoring saplings in the on-site nurseries. The number of saplings transported to the selected sites is given below.

Forming Eco-restoration Committees

Prior to the planting activity (which was planned to begin immediately after the first Northeast rains), eco-restoration committees were formed in S. Pogainallur and Karukkalacherry. The eco-restoration committees comprised of the Panchayat leader, a village animator, watchman and at least 2 women from SHG groups. Men and women were equally represented in the committees. At Karukkalacherry, a rotation policy was adopted by the SHG federation to give employment opportunity for all the SHG members.

Restoration Activities

Pits and Planting Mixture

Depending on the number of saplings for planting, pits were first dug in rows in the sand dune patches. The dimension of the pits was approximately 1.5 cubic feet. Planting mixture, consisting of compost (farmyard manure) and coconut fibre, procured locally, was mixed in the ratio of 1:1 and filled in the pits before transplanting the saplings. The spacing between two pits, which was 1 metre for the saplings,

Table 9.12: Number of saplings and seeds planted.

Name of village	Total number of sand dune saplings	Number of species
Karukkalacherry	27111	9
Pogainallur	6962	3

Table 9.13: Planting statistics for coastal sand dunes.

Karukkalacherry			
Species	Saplings	Seeds/suckers	Source
Pongamia pinnata	1027		FERAL
Terminalia cadaba	64		FERAL
Borassus flabellifer		19000	FERAL
Spinifex littoreus		900	FERAL
Pandanus		1100	FERAL
Pongamia pinnata	4270		Forest Department of Pondicherry
Terminalia cadaba	100		Forest Department of Pondicherry
Azadiracta indica	340		Forest Department of Pondicherry
Albizia lebbek	150		Forest Department of Pondicherry
Thespesia populiana	160		Forest Department of Pondicherry
Total	6111	21000	27111
South Pogainallur			
Pongamia pinnata	416		
Terminalia cadaba	46		
Borassus flabellifer		6500	
Total	462	6500	6962
Grand Total	6573	27500	34073

was decided based on the canopy cover and root spread of the plants. Spinifex, a runner and Pandanus was planted at smaller intervals of 2 feet.

Planting

Saplings from the on-site nursery were shifted to the sand dune patch, poly bags were removed and saplings were transplanted into the pits. *Spinifex littoreus* and Pandanus were procured locally, primarily as cuttings, which were then planted at 2 feet distance. Borassus seeds were sown manually at a depth of approximately 1 foot below ground level. Care was taken to adequately mix the number of each species in each row. The empty poly bags were disposed off to solid waste collection centres in nearby towns. Total number of sand dune saplings and seeds planted at the two sites is given in table 9.12 and the species wise breakup with the source of planting material in table 9.13.

Labour for Planting

The total number of labour days for each of the sites and the total number of actual days taken for planting is given in the table 9.14. Most of the labour hired for the planting comprised of women who were members of self help groups in the village and who had representation in the eco-restoration committees.

Table 9.14: Labour utilised for the planting activity.

Name of village	Women SHG members	Men	Total
Karukkalacherry	286	10	296
South Pogainallur	63	4	67

Fencing

Fencing was required only at Karukkalacherry site due to high pressures of grazing. FERAL purchased fencing materials and the Forest Department took up the responsibility of fencing the planting area. At South Pogainallur, however, a need for fencing was not envisaged as there were no pressures from grazing.

Watering and Watching

At South Pogainallur, a 1.5 hp portable pump was provided and members from the eco-restoration committee water the plants from ponds near the site. At Karukkalacherry, the responsibility of the watering was handed over to the Forest Department.

Monitoring Survival

A monitoring protocol for analysing survival status at the sand dune sites has been developed and will be part of the regular monitoring for survival at the sites. The entire South Pogainallur site was taken up for monitoring owing to its small size.

9.4 Discussion

The two coastal sites Karukkalacherry and South Pogainallur were taken up comparison of dune vegetation. Among these two sites 16 species were enumerated in site Karukkalacherry and 22 species in site Pogainallur. The species composition varied across these two sites. Species such as *Kyllinga triceps, Spinifex littoreus, Ipomea pes-caprae, Salicornia bracheata*, were only found in the high tide line in both the sites.

Critical to the formation, stabilisation and post-storm recovery process is the presence of specialised dune plants e.g. *Spinifex littoreus and* Ipomea. These native plants are capable not only of maintaining dune stability but can also colonise patches of bare sand and quickly grow down an eroded dune face to help build up and restore the dune profile. Ipomea *and Spinifex littoreus* are very effective in long-term control of coastal erosion as they can grow to keep up with the movement of sand whereas rigid walls and structures are soon buried or undermined. *Spinifex (Spinifex littoreus)* is a native sand binding grass found on coastal foredunes throughout the region. *Spinifex littoreus* is one of the few plants able to colonise the seaward face of the foredune.

Kyllinga triceps is another native sand-binding grass species in both sites site Pogainallur and Karukkalacherry. In the second zone considered as a berm to front dune, primary stabilising plants consisting mainly of herbaceous species, were recorded. This zone composed of the herbaceous species like *Leucas diffusa, Gisekia Pharnaceoides, Phyllanthus virgatus, Tephrosia purpurea, Indegofera*, coastal tree species like *Borassus flabellifer* and the introduced *Casuarina equisitifolia*. The front to back dune zone composed of secondary stabilising plants consisting of shrubs, vines, stunted trees and a few associated herbs and grasses, recorded 20 plant species. Variation in vegetation zonation landward across coastal sand dunes is associated with decrease in the degree of exposure to salt spray, strong winds and sandblast, and with improvement in the nutrient status and moisture content of developing dune soils. Studies on the vegetative cover of dune ecosystems of India, have been very few. The occurrence of 13 leguminous plants from 12 different sites along coastal Karnataka has been reported by Arun et al. (1999). Other species included *Clerodendrum inerme, Cyperus orenius, Opuntia sp., Pandanus odoratissimus, Spinifex littoreus, Ipomeae pes-caprae and Vitex trifolia*. These species have also been used by farmers as fencing to withstand erosion.

Threats and Conservation

Coastal sand dunes are rapidly disappearing from both the East and West coast of India (Sanjeevi, 1996; Mascarenhas, 1998). This can be attributed to a range of anthropogenic interventions which have both direct and indirect impacts on the dunes (Mascarenhas, 1998; Martinez et al., 2006). Perhaps the most serious of these in the Coromandel coast is the development of sea walls and groynes which alter the nature of littoral drift and create a sand deficit to the North of the structure. Ironically, the very ecosystem that provided among the best defences against the tsunami are falling victim to projects carried out in the name of coastal defence.

The role of the sand dune ecosystems as natural barriers against calamities such as storm surges and Tsunami has been realised in countries such as Australia and New Zealand, where there programs have been developed for restoration of the sand dune ecosystem. However in Indian context, the importance of the dune ecosystem is yet to be realised and understood fully. On the contrary, extensive dune plantations have been undertaken along the entire Coromandel coast and the construction of permanent settlements, sea walls and groynes is leading to the disappearance of beaches (Bhalla, 2007). The impact of these plantations (consisting mainly of exotic species such as Casuarina) on the native coastal sand dune ecosystem is yet to be understood.

The importance of conservation of the sand dune ecosystems must be realised and restoration programs be developed. However, the availability of land and community participation are important factors limiting the choice of sites for sand dune restoration. Ownership of land along the coast by private people and developmental activities along the coast (in the form of buildings, industrial activities and tourism) would seriously hinder land available for sand dune restoration.

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Chapter 10 Restoration of Mangrove Habitats

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Contents

10.1 Introduction

Mangroves are among the most productive coastal ecosystems. There are a range of quantitative articles and reports on products such as fuel, timber, honey and other minor forest produce. Magrove ecosystems are also attributed with various functions and ecological services such as protection from waves and nurseries for commercially important fish (see Spaninks and van Beukering, 1997; Dwight, 2003; Moberg and Ronnback, 2003; Crona and Ronnback, 2007).

Mangrove forests along the East coast of India comprise nearly 57% of all mangrove wetlands in the country and the Sundarbans comprise over 75% of these. The protected forests of Pichavaram and Muttupet contribute the bulk of the area under mangroves along the Coromandel coast, however they contribute to a meagre 2.5% of the mangrove forest cover along the east coast and are classified as river dominated allochthonous types (Selvam, 2003). Pichavaram and Muttupet are fed by various

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distributaries of the Cauvery delta which flush these regions during the short North East monsoon. These mangroves differ fundamentally from the other mangrove systems on the East coast in terms of extended dry seasons and associated high salinity. The harsher environment in the mangroves of the Cauvery delta has resulted in a lower species diversity, with the dominant species being *Avicenna marina* (Selvam, 2003).

Mangroves are among the most threatened ecosystems in the world owing to high demographic pressures and alteration of freshwater and sediment inflows that nourish and maintain their environment. They have almost disappeared along the East coast of India, except in Bengal and continue to face a high levels of deforestation far exceeding the regrowth capability (Blasco et al., 2001). The rapid degradation and removal of mangroves is ascribed to a a variety of reasons including fuel and timber extraction, encroachments, brackish water aquaculture and land use change driven by high population densities.

There are a number of strong arguments in favour of restoring mangrove systems, most of which are centred around the range of ecological goods and services they offer (Spurgeon, 1999; Spaninks and van Beukering, 1997; Kathiresan and Bingham, 2001), their high ecological value (Macintosh et al., 2002) and in purely logistical in terms of "ease of restoration" (Yap, 2000). There are also some examples of community based restoration of magroves (Selvam et al., 2003; Spurgeon, 1999; Spaninks and van Beukering, 1997), although we are warned that in some cases, motives other than ecological restoration often lead to communities conserving such areas (Walters, 2004).

Mangrove forests of the Coromandel coast that lie outside the protected areas of Pichavaram and Muttupet are relegated to short strips of remnant vegetation in backwaters and estuaries dominated by *A.marina*. Most of these areas continue to degrade due to a range of anthropogenic pressures, from grazing to large scale conversions to shrimp farms. The bulk of these patches are around the backwaters of Parangipettai with other significant areas including the Ariyankuppam river mouth at Pondicherry and the Kollidam estuary. There have been various attempts at mangrove restoration taken up by the forest department as well as NGOs along the Coromandel coast. These got a fillip post the 2004 tsunami, when planting "bio-shields" became one of the preferred avenue for spending, regardless of their actual value as coastal defences (Chatenoux and Peduzzi, 2007; Bhalla, 2007; Kerr et al., 2006; Baird, 2006).

Restoration Sites

A total of seven potential sites were shortlisted based on their environmental parameters and the positive response from the communities. These were located in the areas described in Table 10.1. A total of 44 sites had been covered in an earlier prelimnary survey during which basic environmental parameters (water pH, salinity and turbidity) were measured along with the size of remnant mangrove patches, species composition and canopy height. .

10.2 Site Selection Protocols for Mangroves

We documented the various environmental parameters known to affect mangrove survival and growth across proposed sites. The study presented below compares the suitability of three of the shortlisted sites for restoration. While all these sites fell under the "permissible" levels of soil and water salinity

Table 10.1: Shortlisted mangrove sites.

Sl.	Name of Site	District	Whether work was done	Reason
1.	Cheyyur	Kancheepuram	No	Permission to work was withdrawn by the Panchayat after initial progress.
2.	Kollathur	Kancheepuram	Yes	The blockage of the outlet of the estuary led to a algal bloom which smothered the saplings planted in 7.03ha, followed by a drought which killed them. The same area was flooded after the first monsoon showers and re-planting could not be taken up.
3.	Tengathittu	Pondicherry	No	Permission was withdrawn just before planting was to commence.
4.	Murthykuppam	Pondicherry	No	Permission was withdrawn just before planting was to commence.
5.	Chunambar	Pondicherry	No	Permission was withdrawn just before planting was to commence.
6.	Malathirukazhipalayam	Cuddalore	Yes	Nearly 40,000 saplings from four species were planted in7.38 ha.

and pH there were significant differences between them. The sites where the final planting was done, however, had to be changed during the last few months of the project for reasons explained elsewhere in this report. The measurement of environmental parameters was done for the new sites as well (also see Gilman and Ellison (2007) for a brief discussion on restoration protocols).

Mangrove physiology, growth and placement can be affected by a variety of variables, including tides, water salinity, soil salinity, soil pH, available nutrients, and soil grain size (Ball and Farquhar, 1984a; Lovelock et al., 2004, 2006). Tides are important because they help determine where mangroves will grow based on how salt tolerant they are; mangroves grow best in soils with moderate soil salinity of about 25 ppt (parts per thousand) English et al. (1997). High salinity in general is often found to be the reason for stunted mangrove growth. High salinity decreases the rate of photosynthesis so with lower salinity and more light the net photosynthesis per unit leaf area increases and growth rate of the mangrove increases López-Hoffman et al. (2007). Soil pH affects the distribution of mangrove species because each species has a different tolerance for different pH levels Wakushima et al. (1994). Available nutrients determine how a mangrove will grow. Nitrogen and phosphorus are the most important nutrients when it comes to growth. Nitrogen is first taken up followed by phosphorus; once phosphorus is taken up photosynthetic rates increase tenfold. Grain size and composition of soil also affect mangroves. Mangroves tend to grow well in areas where their roots have ample places for attachment and seem to only do well in mud and very fine sand (Cardona and Botero, 1998). Also, soil composition and grain size determines porosity of the soil which ultimately influences soil salinity, water content, and amount of nutrients contained in the soil (clays and silts have higher concentrations of nutrients). As part of pilot demonstration of restoration plots, satellite imagery based site selection and preliminary field assessment for the identification of areas, were conducted.

Objectives of the Site Selection Process

1. To delineate the study area
2. To use satellite imageries for identification of potential sites
3. To document the environmental and ecological conditions at the sites within the study area The following questions were addressed as sub objectives
    a) Can sites for mangrove restoration be decided based on tidal influences, water & soil quality?
    b) How can the data on these variables inform species selection for restoration planting?

Site Locations

The sites chosen for this study were Chunambar, Madalapattu, and Ediyanthittu (Figure 10.1). Ediyanthittu and Madalapattu are found in the Villupuram and Cuddalore districts of Tamil Nadu state, while Chunambar is found in the Union Territory of Pondicherry. All three sites were coastal environments (estuaries with connection to the sea) with little or no existing mangrove growth. Chunambar had relatively new mangrove growth (planted previously), but mostly of one species, *R. apiculata*. Ediyanthittu is a wide estuary with some islands and relatively good space along the shore for planting mangrove seedlings. The islet has naturally established mangroves of Avicennia Sp. Rhizophora and Avicennia have also been planted in other parts of the site. Madalapattu currently does not contain mangroves. The study was conducted during May 15 – Jun 15 2007 and data were collected through site visits by boats and on foot.

Materials and Methods

Recent satellite images (IRS-P6 LISS IV) were purchased from the National Remote Sensing Agency, Govt. of India. The coastal areas of Tamil Nadu, along the Coromandel coast, including the districts of Villupuram, Pondicherry, Cuddalore & Nagapattinam districts were identified as the larger study area (figure 10.2). The tidal creeks and the river mouths were identified from the image and the preliminary ecological assessments were completed at these sites. Ecological assessments were conducted in three estuarine areas identified with the help of the satellite imageries.

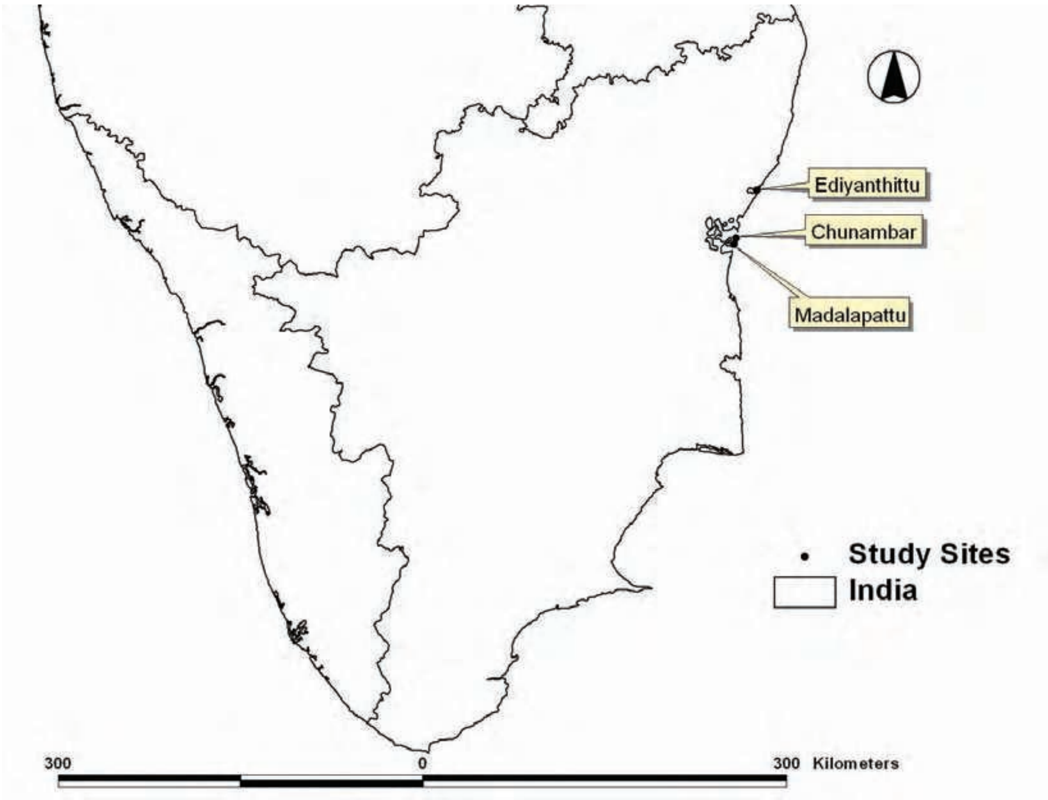
Sampling design

The satellite images were overlaid with square grids of equal dimensions and points within them were chosen for collecting the data (see figure 10.3 & 10.4 provided as examples for images of sites and sampling locations). The sampling design was generated using ArcView 3.2 (ESRI Systems Inc.)

Soil Sampling

At each of the mangrove sites soil samples, approximately half of a two litre bag, were taken based on random points placed on a satellite image of the area through the use of ArcView that were loaded onto a GPS unit.

Figure 10.1: Location of study sites along the Coromandel coast.



Soil Analysis

The pH of the soil samples was determined by adapting the method used by the Goddard Space and Flight Centre/NASA Laboratory Analysis (NASA, 2001). The samples were not exposed to air after collection and pH was the first parameter to be measured because exposure to the air could allow the sulphur in the soil to oxidise and artificially lower the pH of the sample. 20 grams of the sample was taken and mixed with 20 grams (millilitres) of distilled water and shaken for 30 seconds and allowed to sit for 3 minutes. That process of shaking and sitting was repeated for a total of 5 times then the solution was allowed to settle and the pH was taken from the clearer solution on top with a Waterproof pH Tester (2 Microprocessor-based Pocket pH Tester by Oakton). The same procedure was repeated for all samples.

Soil salinity was determined using a method developed by Primary Industries and Resources South Australia, and adapted to fit this project. Once the pH testing was done, the soil sample was allowed to dry and then 25 millilitres of the sample was taken and mixed with 125 millilitres of distilled water and shaken for 1 minute, then allowed to settle for 1 minute. A refractometer was used to measure the salinity of the clearer solution on top in parts per thousand (ppt).

Grain size and percentage composition of sand, silt, and clay in the samples was determined by first ensuring that the dried sample was devoid of clumps of soil and then the sample was sieved. First through a 0.5 mm sieve to separate out the sand grains, then the sand grains were weighed. The rest of the sample was sieved through a 0.063 mm sieve to separate out the silt from the clay. The silt and clay were each weighed separately. The weights were recorded and then percentages were determined for each sand, silt, and clay by dividing the weight of each by the total weight. The percentages were

Figure 10.2: An imagery of the Coromandel coast comprising the project area.

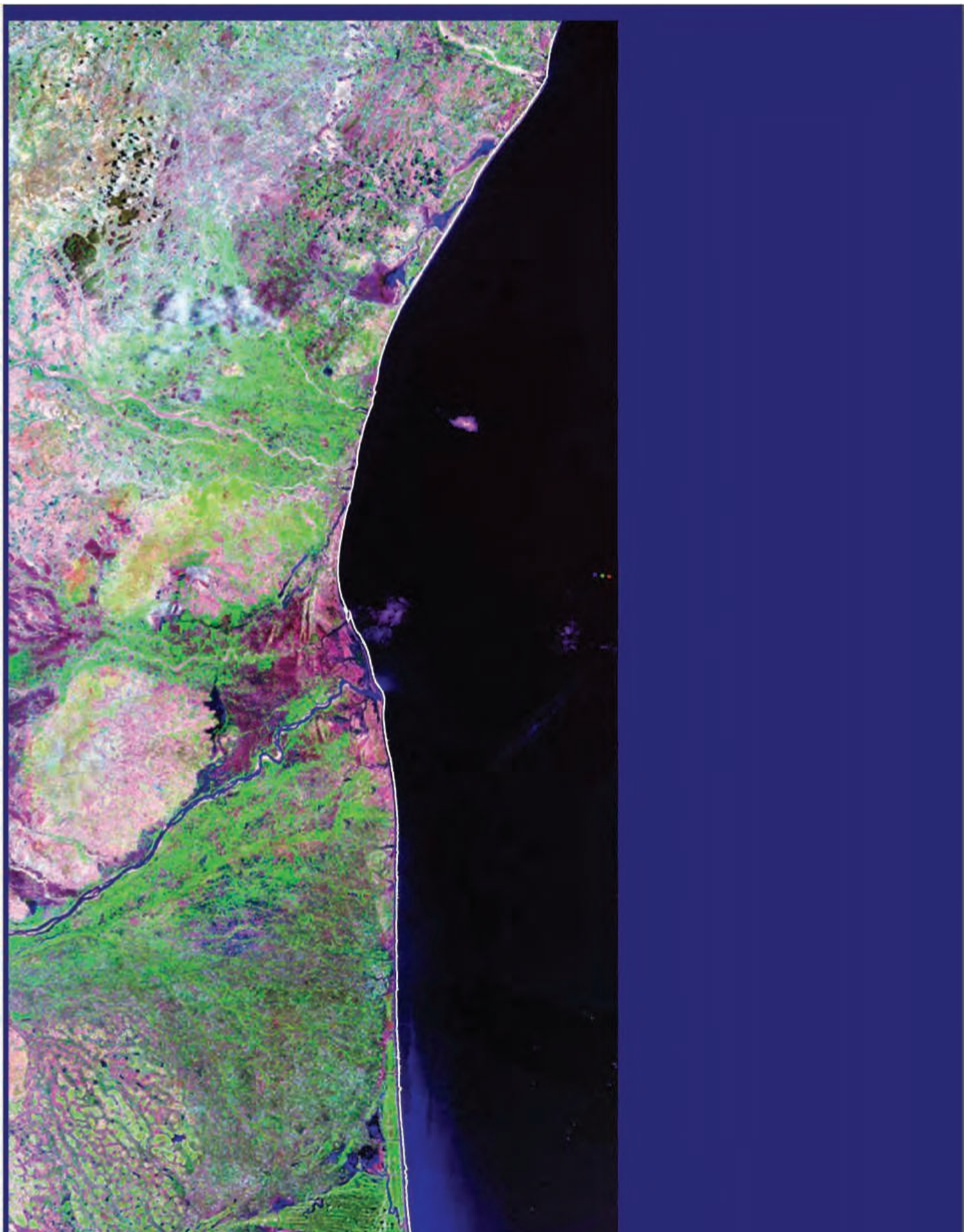


Figure 10.3: Chunambar. Sampling locations shown in green dots. It should be noted that some sampling locations were not feasibly accessible or were too far inland where no mangrove growth would occur, and were therefore not visited.

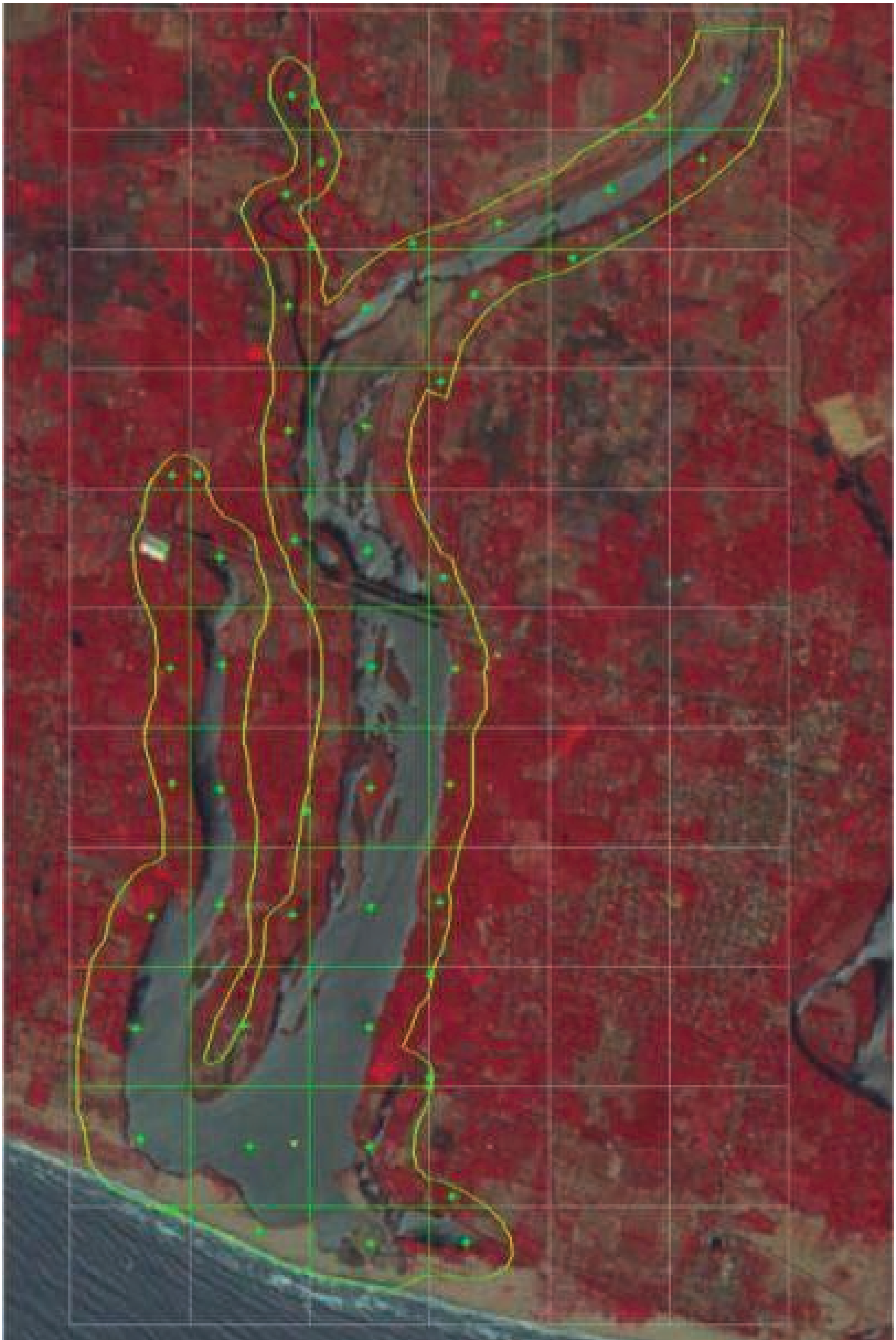


Figure 10.4: Madalapattu. Sampling locations shown in green dots. It should be noted that some sampling locations were not feasibly accessible or were too far inland where no mangrove growth would occur, and were therefore not visited.

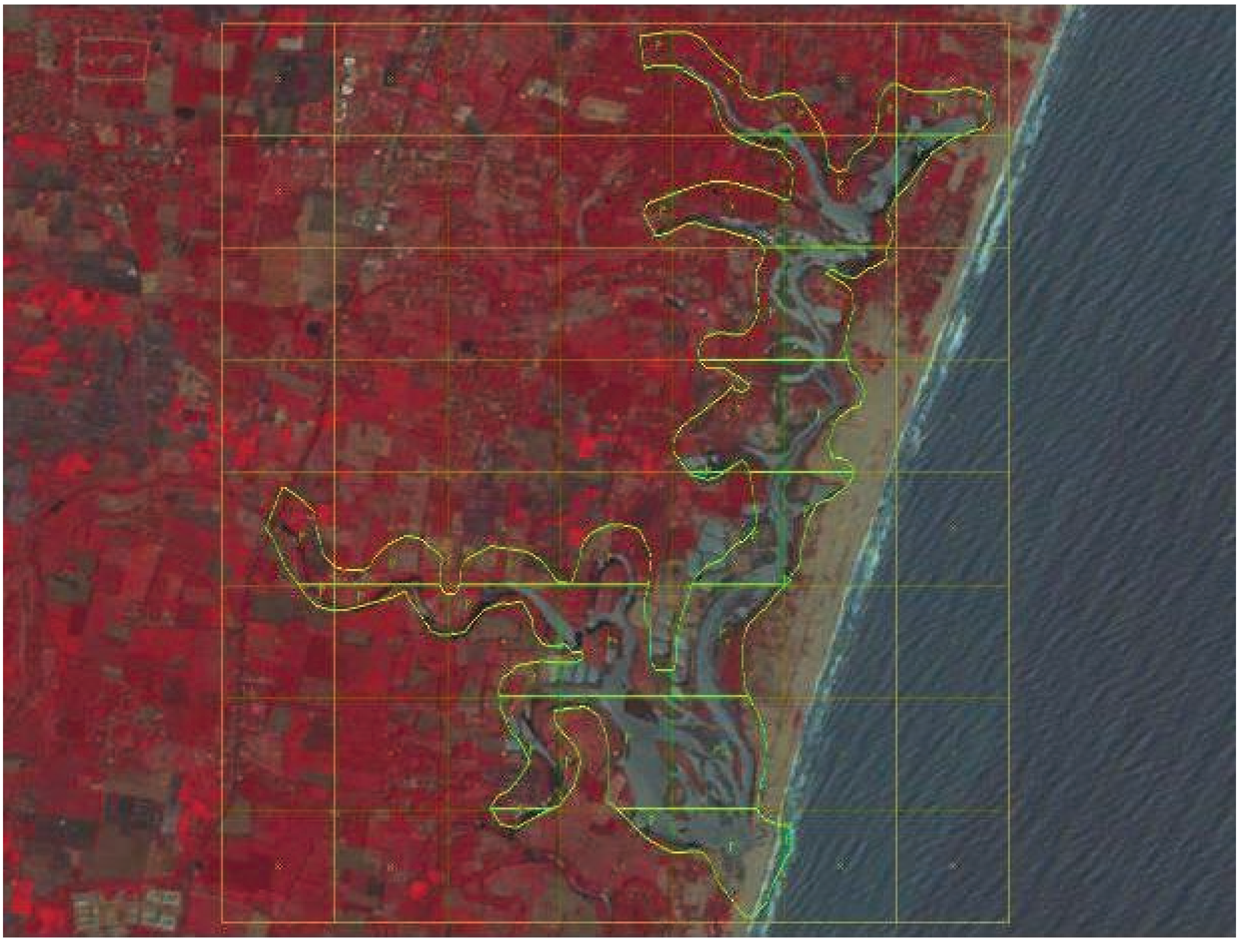


Table 10.2: Results of non-parametric ANOVA.
* - Significant Regular Test: Medians significantly different if z-value > 1.9600
Bonferroni Test: Medians significantly different if z-value > 2.3940

Site	Count	Mean	SError	Z-Value
Chunambar	24	7.66	9.28E-002	-2.2487
Ediyanthittu	15	8.31	0.12	4.2937
Madalapattu	34	7.74	7.80E-002	-1.3602

Soil_PH	Chunambar	Ediyanthittu	Madalapattu
Chunambar	0.0000	4.1554*	0.7730
Ediyanthittu	4.1554*	0.0000	3.7476*
Madalapattu	0.7730	3.7476*	0.0000

also recorded and the soil type was identified. This process was repeated for each sample.

Water Analysis

The salinity of the water was taken at each soil collection and tide measurement site. To do this, a refractometer was taken on field along with a 100 millilitre beaker to collect a water sample and distilled water to recalibrate the refractometer after each reading. The salinity was recorded in ppt.

The pH of the water was taken with the same pH meter used to measure the pH of the soil. A 100 millilitre beaker was used to collect a water sample and then the meter was used to determine the pH.

Analyses

Data analyses were carried out in statistical software NCSS (2000). Screening of data for normality distribution revealed that the assumptions of normality required for a parametric test, were not met by water pH and water salinity. Hence the Kruskal-Wallis One-Way ANOVA was used to compare all the data parameters across sites. The results of the soil and water quality analysis were exported to a GIS platform for further analysis of the spatial patterns observed.

Results

Soil

The non-parametric ANOVA revealed that the soil pH values were significantly different across sites (Figure 10.6) and that the soil pH at Ediyanthittu was significantly higher compared to Chunambar and Madalapattu (Table 10.2).

The multiple-comparison Z-value test showed that soil pH values were not significantly different between Madalapattu and Chunambar. However soil pH of Ediyanthittu was significantly greater than these two sites. The results from the multiple comparison Z-value tests were also concurrent, with none of the values at each site significantly different from other sites.

The sites composed of varying soil types and composition. It was found that Chunambar contained high percentage of samples with the soil composition being sandy loam. However, in Madalapattu higher percent of clay was observed (Figure 10.5).

The distribution of the sampling locations at each of the sites have been provided in the maps as Appendix 1, along with the values for the various water and soil parameters.

Table 10.3: Results of tests for soil salinity.
Kruskal-Wallis Multiple-Comparison Z-Value test.
Regular Test: Medians significantly different if z-value > 1.9600
Bonferroni Test: Medians significantly different if z-value > 2.3940

Site	Count	Mean	SE	Z-Value
Chunambar	24	6.67	0.6416	1.2981
Ediyanthittu	7	6.2	1.1881	0.6454
Madalapattu	34	5.54	0.5391	-1.6549

Soil_Salinity	Chunambar	Ediyanthittu	Madalapattu
Chunambar	0.0000	0.0467	1.5300
Ediyanthittu	0.0467	0.0000	1.0311
Madalapattu	1.5300	1.0311	0.0000

Figure 10.5: Soil composition in site.

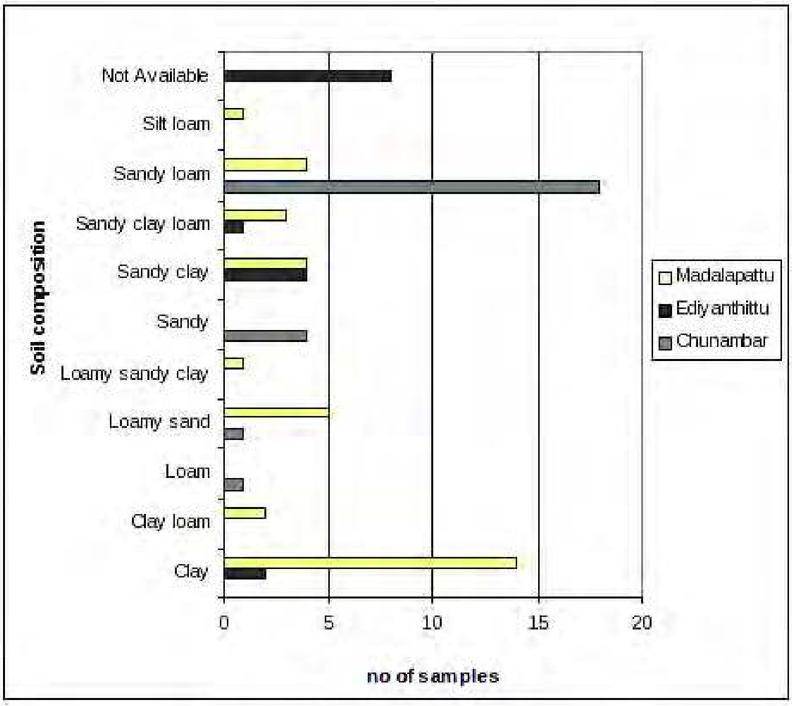


Table 10.4: Water pH was significantly different across the sites, with the values being lower in Chunambar, when compared to Ediyanthittu and Madalapattu.
Kruskal-Wallis Multiple-Comparison Z-Value Test
* - Significant Regular Test: Medians significantly different if z-value > 1.9600
Bonferroni Test: Medians significantly different if z-value > 2.3940

Site	Count	Mean	Serror	Z-Value
Chunambar	24	7.9083	3.54E-002	-6.1317
Ediyanthittu	13	8.2923	4.81E-002	3.4422
Madalapattu	29	8.2345	3.22E-002	3.1847

Water_PH	Chunambar	Ediyanthittu	Madalapattu
Chunambar	0	5.4453*	5.2825*
Ediyanthittu	5.4453*	0	1.25
Madalapattu	5.2825*	1.25	0

Table 10.5: Water salinity was significantly lower in Madalapattu when compared to Chunambar and Ediyanthittu.
Kruskal-Wallis Multiple-Comparison Z-Value Test
* - Significant
Regular Test: Medians significantly different if z-value > 1.9600
Bonferroni Test: Medians significantly different if z-value > 2.3940

Site	Count	Mean	S Error	Z-Value
Chunambar	24	36.7917	0.7993	3.7857
Ediyanthittu	14	39.2143	1.0465	4.0328
Madalapattu	29	20.4138	0.7271	-6.9726

Water Salinity	Chunambar	Ediyanthittu	Madalapattu
Chunambar	0	1.01	5.8044*
Ediyanthittu	1.01	0	5.9701*
Madalapattu	5.8044*	5.9701*	0

Water

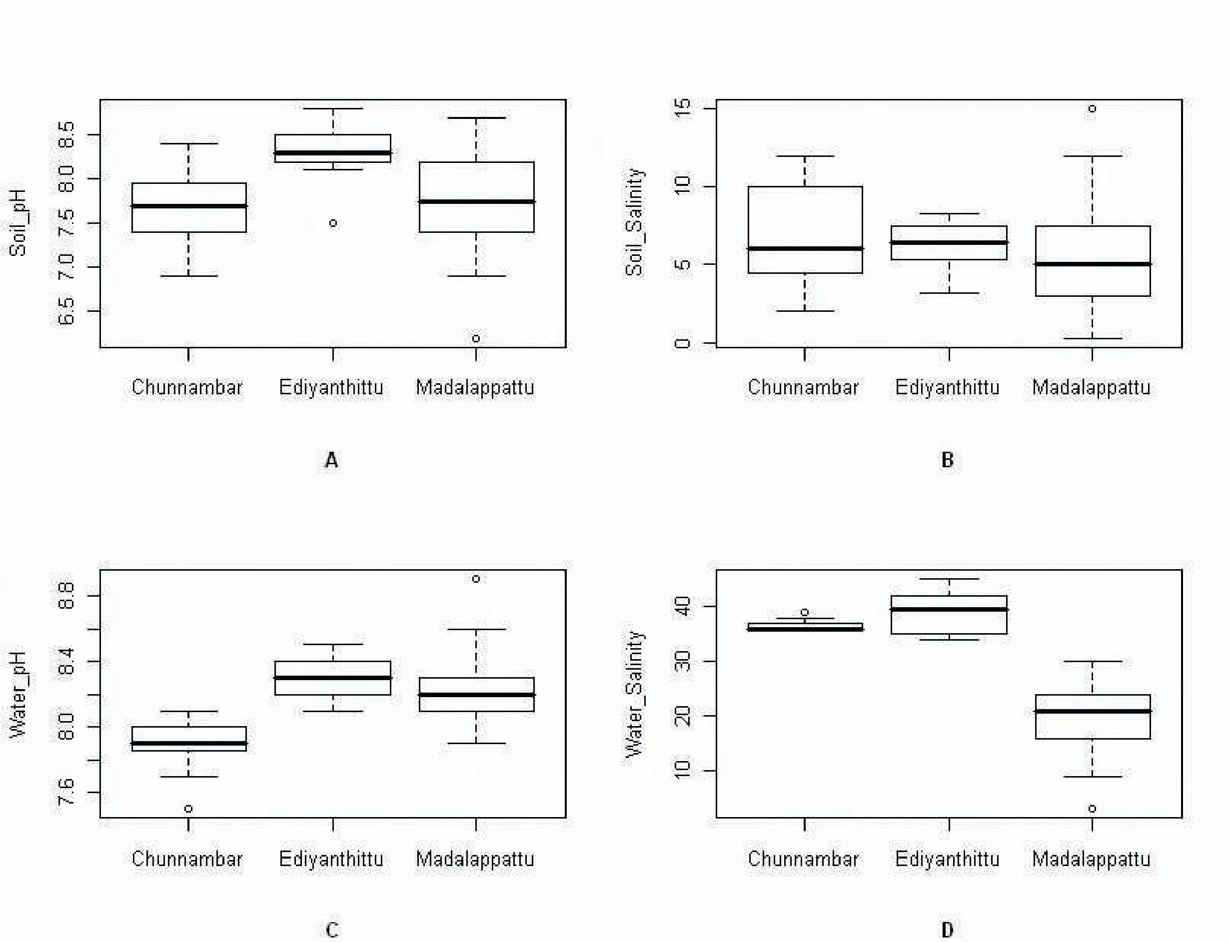
Water pH was significantly different across the sites, with the values being lower in Chunambar, when compared to Ediyanthittu and Madalapattu. The water pH values in Chunambar were significantly lesser than Ediyanthittu and Madalapattu. However, there was no significant difference between Ediyanthittu and Madalapattu.

Water salinity was significantly lower in Madalapattu when compared to Chunambar and Ediyanthittu (Figure 10.6). However Chunambar and Ediyanthittu were not significantly different.

Discussion

Salinity of 15 ppt (parts per thousand) has been found to be optimal for the growth of seedlings of *R. apiculata*, while higher salinity levels (35-40 ppt) were found to reduce the growth rate (Kathiresan and Thangam, 1990). Areas with lesser soil salinity showed higher growth rates of *R. apiculata* (Kathiresan et al., 1994). *R. apiculata* establishes successfully in the intertidal estuarine areas having high level of potassium salts, as they induce growth effectively (Kathiresan et al., 1994). Higher levels of nitrate and phosphate also help in increasing the growth rate (Lovelock et al., 2006). As the salinity level increases, shoot height, growth, and leaf area are reduced, thus seedling's growth is best enhanced under low saline conditions; especially during monsoon months (Kathiresan and Thangam, 1990). *R.*

Figure 10.6: Box plots showing results of water and soil salinity and pH across sites.



apiculata is tolerant to the conditions in the lower intertidal zones, which are characterised by higher tidal inundation, water levels (therefore rich in nutrient levels), and lower oxygen availability (Ibid). Hypersalinity had been shown to induce stunted growth of *Avicennia marina* stands, reduced biomass in hydroponically grown *Bruguera gymnorrhiza*, and caused denaturing of terminal buds in *Rhizophora mangle* seedlings (Selvam et al., 1991). In hypersaline soils, the mangrove uses most of its energy excreting salt instead of growing (Koch, 1997). If the topography of the land changes and flushing events are at a minimum, a hypersalinity induced environment occurs and mangrove growth will be stunted or completely replaced by salt marsh (Kathiresan and Bingham, 2001).

After analysing the data and looking at results for the various sites, Ediyanthittu and Madalapattu seem to be better sites for planting mangrove seedlings in terms of water and soil salinity amounts. The mode was taken (Ediyanthittu N = 15; Madalapattu N = 34) and the water salinity results were 35 and 24, and soil salinity results being 6.2 and 5 respectively. Water salinity result for Chunambar (N= 26) was 36. Although Chunambar had slightly higher salinity, it could also be a potential site for mangrove planting. Different mangrove species do well in varied salinity amounts and various species can be contained in a stand along the tidal gradient, as salinity varies along the gradient (Kathiresan and Bingham, 2001). The "true" mangrove species, Avicennia and Rhizophora tolerate higher salinity, *Rhizophora mucronata* seedlings do better in salinity of 30, *R. apiculata* do better at 15, and *Sonneratia alba* grows in waters between 5 and 50. All seedlings need relatively low salinity but as they grow their tolerance to salinity has been reported to increase (Kathiresan and Bingham, 2001). It is important to note that this study was conducted during the hottest and driest months of the year so the influx of fresh water was minimal and therefore salinity levels were probably at their highest levels.

The pH has also been shown to have an effect on the growth of mangroves. Overall it has been found that mangroves achieve maximum root growth at an acidic pH of 6 and maximum shoot growth at an alkaline pH of 10. Anything lower than 6 retards mangrove seedling growth and is a cause of mangrove death (Kathiresan and Thangam, 1990). The water pH for Chunambar, Madalapattu, and Ediyanthittu were found to be (7.9, 8.0), (8.1), (8.2, 8.3) respectively[17]. Soil pH was found to be (8.0), (7.4, 7.9, 8.2), (8.5) respectively. Water and soil pH in terms of maximum growth for the mangrove seedlings, shows overall the Chunambar and Madalapattu sites allow for more root growth with their slightly lower pH values, which could be beneficial in terms of gaining nutrients from the soil. Ediyanthittu offers a slightly more alkaline pH and would be better for shoot growth and overall height of the mangroves. However, for a healthy stand of trees, both in terms of root growth and shoot growth, all three sites offer a relatively neutral pH and should induce a good root and shoot growth because none of the sites have extreme pH values.

Soil type is important in determining mangrove growth. Studies have found that mangroves prefer mud and fine-grained sand substrates. They have been, however, found in many different types of substrates such as peat, silt, and even rock and coral. Soil type also influences flooding condition of an area (Leonor and Pablo, 1998). Sandy loams are permeable, but have a low porosity as the grains are of many different sizes subjected to rhombic packing, in which the grains fill spaces. Clay loams tend not to be permeable and have a higher porosity as the grains are of similar shape and subject to cubic packing allowing water to move between the grains. The data for the study sites show that Chunambar soil is a sandy loam, Madalapattu soil ranges from sandy loam to clay loam, and Ediyanthittu soil is

[17] The Malathirukazhipalayam site had a water and soil pH of 8.8 which is within the acceptable limits.

sandy clay loam. Reviewing the results for the soil types for each site, mangrove seedlings would do well at any of the sites based on the fact that all the sites are sandy loams, the visual observation of the samples from the sites shows that sand is fine-grained, and mangroves have been found to grown in many substrates. The range of soil types for Madalapattu, as opposed to one general type, could be due to the fact that sediment loading is different in that area as opposed to Chunambar and Ediyanthittu as the marine and fluvial activities could be different (Ramanthan, 1997).

Nutrient loading, such as Nitrogen, Phosphorus, and Potassium (N, P, K) are important in mangrove growth as well. It has been shown that areas where there is little N and P input trees tend to be limited in growth. The presence of N and P greatly increase the number of shoots, but P does on a larger scale (Lovelock et al., 2004). Growth in mangroves is initially enhanced by N and then by P, with N enhancing the production of new leaves and P enhancing the number of leaves and the rate of shoot elongation (Ibid). K can be important in some regions and has been shown to enhance the growth of *R. apiculata* (Kathiresan and Bingham, 2001). In one study, it was found that K values were less in the mangrove soils than in the estuarine soils and it was thought that the mangroves were taking up K from the soil to use for osmoregulartory actions (Kathiresan et al., 1994). Soil analysis for this project for N, P, K values has yet to be completed, but based on readings, the southeast coast of India appears to be a good place to plant mangroves post-monsoon because there are high nutrient concentrations and low salinity concentrations causing the mangrove seedlings to grow 5 times as much and produce 4 times as many leaves than in the dry season (Kathiresan and Bingham, 2001).

Conclusion

Through literature review, salinity, pH, soil composition, and nutrients were determined to be the best indicators of the success of mangrove seedlings, when planted. All three sites surveyed were found to be potential sites for planting mangrove seedlings of common mangrove species such as *Excoecaria agallocha, Bruguera sps, Sonneratia alba, Avicennia officinalis, A. marina, Rhizophora apiculata*, and *R. mucronata*. Each site offers tolerable salinity level, neutral pH, and a sandy loam soil texture, all of which indicate the potential for good mangrove seedling growth of common mangrove species. Given that the survey was conducted in summer, observed salinity levels were slightly higher than during monsoon and post-monsoon. Planting of the seedlings was scheduled around monsoon time in which the seedlings would grow the most and develop the most leaves. This was done so seedlings are established enough to withstand higher salinity in the succeeding summer. However, lack of information on the tide levels and its effects on the soil and water parameters, nutrient content analysis of the soil, are limitations of this study.

10.3 Restoration

The goals of the restoration for mangrove systems were as follows. To remove exotic weeds, mainly *Prosopis sp*. from the planting site, restore tidal movements through digging of channels, to plant locally available propagules as well as those from other parts of the coast and to provide adequate protection to the saplings from grazing and encroachments of sites. In order to achieve this a process of short listing sites was followed as described above which was followed by intensive awareness campaigns. These included street plays, a series of meetings with representatives of Panchayats, women SHGs and traditional leaders and formation of a restoration committee which ratified micro-plans for each village. This process took between six and nine months for each site. Permissions were sought from respective government authorities once the community representatives showed interest and willingness to participate in the restoration programmes. The procurement of permissions was and remains one of the most difficult process in the entire preparatory phase for restoration.

Restoration Plans

Detailed plans of activities were evolved for each restoration site (see Annexure F.1 for an example). These were based on joint field visits with the restoration committees incorporated specific spatial information about where different activities would take place. The restoration plans formed the basis for budgeting and calculations pertaining to amount of fencing, channel digging, clearance of Prosopis, planting areas and spacing and species choice. Rates and conditions for hiring of labour and awarding of contracts for the various activities (as per UNDP financial guidelines) were also part of this process.

Restoration plans were prepared for the sites at Kollathur, Tengathittu, Chunambar, Murthykuppam and Malathirukazhipalayam. Restoration activities were carried out at Kollathur and Malathirukazhipalayam while community mobilisation activities including awareness generation and formation of restoration committees was done at all these sites.

Restoration Activities

A summary of the restoration activities carried out is provided in table 10.6. Details of species composition have been provided in Annexure F.3.

The restoration activities covered six areas of work which are described below.

Protection of the Planting Sites Through Fencing

There are two basic reasons why fencing needs to be a component of restoration attempts.

1. It ensures that the restoration sites are clearly demarcated and thereby prevents encroachments.
2. It stops or greatly restricts grazing and trampling of sites by cattle.

Bamboo panels or "padal" as they are called in Tamil, were erected in Kollathur while cement pillars and barbed wire posts were erected at Malathirukazhipalayam.

Transportation of Saplings

Transportation of saplings is one of the major causes of mortality. This is because saplings raised in fresh water at the nursery are exposed to a number of highly strenuous conditions.

Saplings Imported from Kerala Owing to the importation of large amounts of saplings (about 50,000 per load) we were not able to "bag" them immediately on arrival. Instead we transferred them to flooded beds with polythene bases immediately after arrival. This was done for two reasons. We expected a high mortality given that the saplings had been "on the road" for over 14 hours, not including the time taken for loading them from the beds at the agricultural university of Kerala to the lorry itself. Transferring them to beds minimised the time taken to re-introduce them to suitable conditions. Further it reduced the costs of wastage which would have occurred if they had died after transferring to

Table 10.6: Summary of restoration activities carried out at mangrove sites.

Sl.	Activity	Details	Comments
Kollathur			
1.	Fencing	1363 metres	Bamboo fence was erected as threat from cattle was not considered serious.
2.	Transportation of saplings	30,000	Saplings were transported to site and kept in a enclosure for planting over the next few days.
3.	Planting	25,080 saplings in 7.035ha.	208 women days (SHG members) and 22 man days of work spread over 6 working days.
4.	Protection and maintenance	Watchman/animator hired	Details here
Malathirukazhipalayam			
1.	Removal of Prosopis	5 ha.	A backhoe was used to clear Prosopis. The uprooted bushes were removed by the villagers for use as fuelwood.
2.	Digging of channels	8,891 m	The back-hoe dug large channels where feasible which were sectioned and deepened by locally hired labour.
3.	Collection of propagules locally	14,143 nos.	Propagules of *R.mucronata* species were collected from locally available stock. Note that these areas are not under the forest dept.
4.	Transport of saplings from nursery	Species 6	A total of 35,000 saplings were transported to the site for planting.
5.	Planting	39,359 saplings planted in 7.38ha.	Members of women SHGs were employed for 276 women days and 111 man days for sectioning and levelling spread over 16 days.
6.	Protection and maintenance	Watchman/animator hired	1 watchman and 1 animator.
7.	Fencing	960 metres	Cement pillars with barbed wire erected.
8.	TDEF planting	400 plants	Saplings of 8 species were transferred from nursery and planted.

bags. Finally, given that the saplings were earmarked for planting soon after their arrival from Kerala, it made more sense to leave them in beds than to transfer them to bags and shorty transplant them again. However, we did transfer saplings that were not planted to bags for long term storage and growth.

Saplings Transported from the Mother Nursery to the Sites These were uprooted from the beds and transported in wet sacks to the sites. They were thus subject to two major stresses:

1. Uprooting from beds causing some damage to their roots.

2. Exposure and desiccation while transportation.

In order to minimise this stress additional care was taken while removing saplings from their beds and removal of all except apical foliage so that transpiration rates were minimised.

Collection of Locally Available Propagules

This was limited to the Malathirukazhipalayam site where there were substantial numbers of flowering mangroves comprising almost exclusively of *Rhizophora apiculata*. Participants from the villages were encouraged to collect propagules from the surface of the water or from the trees prior to their falling. Given that these were collected locally, they were better adapted to the local conditions and showed considerably higher survival than those transported from the mother nursery to the site. Note that we actively discouraged the removal of established saplings for transplanting to minimise any damage to established stock.

Removal of *Prosopis juliflora* and Digging of Channels

Prosopis juliflora is an invasive alien species deliberately introduced to Tamil Nadu by the Forest Department in the 1970's . The purpose of the introduction was to generate biomass to meet local fuel requirements in the highly degraded and barren parts of the state. The tree has been seen both as an ecological threat as well as an important local resource for communitiesGeesing et al. (2004); Pasiecznik et al. (2001). The ability of *Prosopis juliflora* to survive in saline environments and its thorny and woody nature make it a common invasive in mangrove habitat and a difficult plant to remove.

We utilised back hoe machines to remove Prosopis from planting areas along the Malathirukazhipalayam site. Apart from removal of the weed, this also served to create depressions in the ground which were later joined to create channels that linked to the main river. Thus we were able to extend the planting area inland. Manual labour was used to level the area prior to planting and to section the channels so that soil would not slide back in. In this way a total area of 5 ha was cleared of Prosopis and over 8 km of channels were dug.

Planting of Propagules and Saplings

The final activity, which involved women from the self help groups in the villages, was the planting of saplings and propagules that were collected locally. Teams of women assisted by a few male labourers for carrying saplings and sectioning channels where needed planted about 40,000 saplings over 16 days at Malathirukazhipalayam and 25,000 saplings over 6 days at Kollathur.

10.4 Conclusion

The mangrove restoration component of this project built upon earlier work done by FERAL and the considerable volume of literature available on the subject. Among the contributions that this experience has made to restoration strategies for mangroves are:

- Nursery costs can be considerably reduced if saplings are planted in beds rather than bags. The costs of per sapling (including transport) procured from Kerala, kept in beds for over 4 months and re-planted is less than Rs.5. This can climb to over Rs.25/- for saplings kept in bags. However it needs to be noted that only young saplings can be kept in beds and they have to be moved to bags after they are about 4 to 6 months old.
- Mortality during transportation of saplings can be greatly reduced by de-foliating saplings, taking extreme care that roots are not damaged during removal from beds, and transporting them during evenings or night to reduce heat stress.
- Environmental parameters play a fundamental role the survival of saplings. This is probably why locally available planting material fares much better than that brought from other areas. In our sites, local material had survivals exceeding 80% while that of saplings brought from nurseries was about 25%[18]. We found that even though the environmental parameters for all our sites were within the range specified in literature, insufficient tidal movements can cause very high mortality due to desiccation or flooding.
- Algal growth and blooms are an important cause for mangrove mortality as they smother the younger saplings. The impact of algae can be reduced by building barriers at the mouth of the channels.
- Areas under mangroves can be greatly increased by digging channels along the river. Removal of Prosopis can often be pooled with channel digging. Heavy machinery is required for most Prosopis removal while manual labour is more efficient in levelling and sectioning channels prior to planting.
- Investment in fencing is important, both to protect the saplings from grazing and trampling as well as to demarcate areas and prevent their encroachment.

Prelimnary surveys of backwater areas along the Coromandel coast suggest there are large tracts suitable for mangrove restoration. However many of these areas are under intense pressure for conversion into shrimp farms. The role of communities and local leaders in protecting their habitats is a key to successful interventions in non-forest areas under mangroves. This however requires sufficient time and efforts in awareness generation and mobilisation which must be incorporated in the design of restoration programmes in the future.

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Chapter 11 Monitoring Protocols for Habitat Restoration

Aditya Gangadharan and Srinivas. V

Contents

11.1 Why Monitor?

Monitoring of restored sites is essential to assess the success or failure of restoration initiatives. The degree of success or failure can be assessed through measuring a variety of variables that can be measured. The choice of the particular measurements to make depends on the short and long term aims of the restoration intervention, the particular stage that the project is in and logistical constraints. Regardless of the criteria chosen, monitoring requires the use of appropriate methodologies and protocols, regular data collection, appropriate analysis and a strong feedback mechanism to put the results to use. Further, monitoring is required over both the short and long term. Felfili (1995) stresses the need to establish permanent plots and monitor restoration success over both the short and long term. "Short" and "long" depend on the characteristics of the ecosystem being restored; for small scale mangrove restoration projects, for example, 3-5 years of monitoring is standard to establish success but up to 10 years may be required (Field, 1998).

Short term monitoring tends to focus on structural characteristics of the restored ecosystem, such as survival and growth of planted saplings. These are often carried out at short intervals in time. Through regular monitoring, areas of poor plant survival can be replanted if necessary. More importantly, regular monitoring can help identify the factors affecting plant performance, such as local environmental characteristics and local level planting protocols. This can allow course corrections and remedial measures to be taken relatively quickly. Short term processes can test and validate the local level protocols used in the restoration effort.

Long term monitoring involves monitoring both structural as well as functional (ecosystem) characteristics, and is essential in managing biodiversity (Margules et al., 1996). It is particularly important when restoration efforts are geared towards restoring an ecosystem to its historic trajectory. Thus, commonly measured characteristics include species composition, soil structure and ecological processes (Field, 1998). Measurement of ecological processes is particularly important (Simenstad et al., 2006); however, they require large investments in effort and money, and therefore structural measurements are more common. The data from long term monitoring studies can be compared with other such studies, and performance can be compared. Thus, it can help refine the fundamental processes followed in restoring the ecosystem. In the longer term, vegetation dynamics can be measured (Sukumar et al., 1998, 1992) and hence contribute to conservation and management of the area (Lwanga et al., 2000).

Both short and long term monitoring are important components of adaptive management. Monitoring helps in the identification of cause and effect relationships (Dallmeier and Comiskey, 1998). Restoration is most useful to scientific understanding when a restoration activity is treated as an experimental and learning platform, and incorporates the core scientific processes of developing and testing hypotheses, drawing appropriate inferences from the data collected and incorporating these into future activities (Simenstad et al., 2006).

The major goal of this project was to develop and validate restoration protocols for the three types of habitats covered. Several attempts have been made in the past in developing and applying such protocols in India. Yet, critical monitoring and scientific evaluation of such attempts are rare, and their dissemination is limited. This has often resulted in confusion, lack of information and slow progress in restoration activities. Scientific monitoring is therefore a critical aspect of this project. Given the time constraints associated with the project activities, the project focused on short term indicators of restoration success.

11.2 Methods for Monitoring Vegetation

Monitoring methodologies followed must be scientifically valid to ensure that correct inferences are drawn from studies. The basic concepts underlying vegetation sampling are reviewed below. Explanations are derived from Krebs (1989), Kershaw (1985), Avery and Burkhart (2002) and Williams et al. (2002).

Plot Sampling

Sampling is a method by which information is gained about a population without having to measure the variable of interest for each individual. For small populations, it may be possible to measure the variable for all individuals, i.e. carry out a complete enumeration or census. However, for larger populations for which a census is not possible, the variable is measured for a random sample drawn from the population of interest. This is then used as an estimate of the variable for the entire population. The overall objective of any sampling based system is to obtain an accurate estimate of the parameter of interest while minimising the uncertainty (variance/ standard error) associated with this estimate.

For vegetation studies, plot sampling is the most commonly used method. Plot sampling involves dividing the area of interest into equal sized plots, selecting a random subset of these plots, detecting all individuals of interest within these selected plots, measuring the variable of interest for all these individuals and then using this sample to estimate the variable for the entire population. Plot sampling is ideal for vegetation surveys since all individuals in the plots can be detected with sufficient search effort, unlike in animal populations where individuals may be mobile.

Sampling needs to be carried out following certain rules to ensure valid inferences from the sample. The principles fundamental to sampling are replication, randomisation and control of variance. Replication of sampling units (plots) refers to the sampling of several plots. This is necessary for a good estimate of the variation in the population characteristics over space. Replication is important for valid variance estimates. Randomisation refers to the random (probability based) selection of sampling units, rather than ad-hoc selection. Much of the statistical theory used in estimating the variables of interest depends on the assumption of random selection of sampling units. Control of variance is necessary for meaningful estimates. Variance estimates need to be realistic, but should not overestimate the uncertainty in the parameter of interest. Several methods exist to control variance, including increasing sample size, stratification and changing sampler geometry and orientation.

Sampling Design

The design of the sampling framework is of paramount importance to valid estimates. The design must ensure that the fundamental assumptions of plot sampling are satisfied. Simple random sampling is the fundamental design, where every plot has an equal probability of being sampled, and this probability is independent of any other sampling unit being selected. This is often accomplished by numbering each sampling unit, and picking n of these at random. Sampling may be carried out with or without replacement, although in many ecological circumstances is normally without replacement. In this, each sampling unit is allowed to appear in the sample only once. The arithmetic mean of the samples is calculated and is taken as an estimate of the population mean:

Systematic sampling is another survey design that is widely practised. In this, the first sampling unit is chosen at random; thereafter, they are placed at uniform distances throughout the study area. Systematic sampling allows for easier logistics while carrying out surveys over relatively large areas; it also provides for a more even coverage of the study area. However, it may bias estimates if there are periodic patterns in the population that coincide with the sampling units. Further, variance estimates may be biased when they are calculated using standard statistical methodology, which assumes simple random sampling.

Stratified sampling is carried out when populations can be divided into discrete groups or strata based on relevant ecological characteristics (for example, dividing a survey region into strata based on habitat type). Within each of these strata, sampling is then carried out in either a random or systematic fashion. These stratum specific estimates can then be combined to get an overall estimate for the study site. Although the overall parameter estimate will be similar to that of an unstratified design, the variance can be decreased if a large amount of the variance exists between different groups. In addition to these, there are other sampling designs such as stratified sampling, cluster sampling and adaptive sampling.

Sampler Shape, Size and Effort

Sampler geometry and size can be varied according to the purposes of the study and prevailing conventions. Often, standard shapes and sizes are used for specific taxonomic groups, such as $1m^2$

square plots for herbs. Using such plots makes it easier to compare the results to other studies. However, in general terms, a shape and size must be chosen such that it leads to the highest precision in the results (ie, least uncertainty in the parameter estimate). In terms of shape, any shape is possible. The two important factors to weigh in this decision are edge effects and habitat heterogeneity. Edge effects occur when there is uncertainty over whether a particular plant falls inside or outside a plot; if such plants tend to be systematically included or excluded, then this will bias results. If edge effects are important, then a shape with a lower edge to area ratio would be preferable to one with a large ratio. So a square shape would be preferable to a rectangular shape, for example. However rectangular strips often can capture more habitat heterogeneity, since longer plots tend to cover more patches. This can often lead to more precise results and higher sample sizes, since organisms also tend to be distributed patchily. Ultimately, therefore, plots shape is decided by the system under study. Plot size is another factor; this is often calculated using formulae based on the principle of minimising variance as well as the cost of surveying. The other major factor in designing surveys is to decide the amount of effort to put into sampling. This is calculated through formulae that depend on the principle of estimating the number of samples required for a desired optimal level of precision. In ecological studies, coefficients of variation of 10-15% are usually desirable.

11.3 Monitoring Design and Methodology

Nursery Monitoring

Monitoring of the performance of planting material was initiated at the nursery itself. This was largely because the administration of the nurseries, both within the FERAL campus as well as the sites, depended on a constant flow of information. Monitoring largely involved tracking of inputs during the planting/bagging stage and of sapling survival and size when they were moved to the site nurseries or planting sites.

Given that nursery monitoring was closely tied with administration, particularly financial inputs, many of the parameters were not "ecological" but of a logistic nature. We used registers to track the following:

1. Number of labourers (mostly SHG women) hired for different activities. These activities included preparation of beds, soil mixtures, transplanting of seedlings into nursery bags, watering and shifting of bags at regular intervals.

2. Number of loads of red soil, compost and top-soil for bags.

3. Growth of saplings in terms of height.

4. Survival prior to shipping.

Details of growth and survival were tracked across species.

Site Monitoring

Once saplings were transplanted at the sites, their survival and growth was monitored at regular intervals. In addition to the planted vegetation, naturally occurring vegetation was also identified and monitored. This was however restricted to the TDEF sites since other sites did not have remnant natural vegetation.

Table 11.1: Number of sampling plots laid out per site.

Sl.No.	Name of Site	Type of habitat	Number of plots
1.	Vadagram	TDEF	11
2.	Kothattai	TDEF	20
3.	Karukkalacherry	CSD	17
4.	South Pogainallur	CSD	Entire site was measured.

Figure 11.1: All plants in the plots were tagged.

For TDEF, 20mX20m randomly placed plots covering 20% of the planted area were sampled for each site. The total number of plots laid out at the various sites are summarised in table 11.1.

Data was collected immediately after planting for TDEF followed by another round at the end of summer. Coastal sand dune sites were sampled once a month, however sampling at Karukkalacherry was suspended after two rounds[19]. Mangroves were sampled once a month after planting, this was at the end of the project period. It is extremely important that monitoring efforts are sustained for at least another two years, during which the saplings are likely to establish themselves.

Both biological data pertaining to the plants as well as relevant environmental data were collected. For all ecosystems, plant survival and growth were the major dependent variables. Plant survival was measured as a factor variable, with death recorded as 0 and survival as 1. Heights of surviving plants were measured using a ruler. In addition to these, the following variables were measured for existing trees on TDEF plots: girth at breast height (GBH) and canopy cover. GBH was measured using a tape measure and canopy cover was recorded using a densitometer. Soil pH, EC, available nitrogen, carbon and phosphates were measured for all ecosystems. In addition, watering frequency was measured for TDEF and high tide line for CSD.

[19]The concerned local officer objected to the monitoring.

Analytical Methods

Survival will be estimated for each time interval between sampling occasions. Survival at each sampling occasion ts will be calculated as the percentage of plants that were alive at ts-1 that had survived up to ts. Overall survival will be estimated as the percentage of plants planted at to that are alive at the final sampling occasion. Variance will be analytically estimated for both these parameters.

Linear regression will be used to investigate the role of environmental covariates in determining survival and growth of planted vegetation. For each ecosystem, regressions for survival and growth will be separately carried out against the covariates that were expected to impact them. Covariates used in these regressions will include soil and watering frequency for TDEF, soil for mangroves and soil and high tide line for CSD. We propose to use a forward selection process in choosing the covariates to include in the final model, and select models using the AIC (Akaikes Information Criterion; Burnham and Anderson 1998) score. AIC balances increasing model complexity through the addition of covariates against the better fit to the data such these covariates may bring. The model with the lowest value of AIC will be considered the 'best' model. Survival will be modelled using the binomial distribution and growth using a normal distribution. All analysis will be carried out using R statistical software.

11.4 Conclusion

Monitoring of activities in restoration projects serves a number of fundamental requirements that help measure performance of efforts and investments. Among these are the ability of projects to use adaptive management strategies which can be a crucial component of restoration projects which depend on a high level of community involvement and face a number of implementation related constraints. Perhaps the most important need for scientific and well designed monitoring frameworks is to ensure that each restoration effort builds upon previous experience and contributes to the field. Being able to determine the causal factors in the success or failure of a restoration project is the basis on which succeeding efforts can be made more effective. Unfortunately however, monitoring requires substantial investments of time and effort and usually needs to continue well after project implementation itself. Few agencies supporting restoration work are able to grasp its importance and a vast number of restoration projects fail to contribute their learning to the practice and science of ecological restoration.

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Part IV

Annexure

Annexure A Introduction and Background

A.1 Proceedings of experience sharing workshops

Experience sharing workshop on sand dune restoration at Nagapattinam, 7th February 2008

Mr. Thirunavukarasu, Wildlife Warden, Nagapattinam was the chief guest. Mr. Manivannan (Councilor), Mr. Balakrishnan (President) and Mr. Arivazhagan (Vice President) South Poingainallur, Mr. Balan (Panchayat member), Karukalacherry were special guests. SHG members and community representatives from South Poigainallur and Karukalcherry were participants in the workshop.

After the welcome address by FERAL, a short film titled 'Sea of Changes' by UNDP was presented. The film covered restoration activities in South Poigainallur as well. Mr. Chandrasheran, Field Coordinator, FERAL presented the restoration activities followed by an address by Mr. Thirunavukarasu, Wildlife Warden, Nagapattinam (photograph showing the wildlife warden delivering the address).

Mr. Thirunavukarasu stressed on the need to protect coastal ecosystems and also presented activities taken up by the forest department to this effect.

Mr. Balakrishnan, President, South Poigainallur spoke in length on the importance of sand dune in his village and shared with the participants how it saved the lives of many during the December 2004 Tsunami. A final vote of thanks was given by a staff from FERAL.

Experience sharing workshop on TDEF restoration at Pondicherry, 13th February 2008

Mr. Dhanraj (President), Mr. Ramalingam (Former President), Vadagaram and Mr. Thangapandiyan (President) Kothattai were the special guests. SHG members and community representatives from Vadagaram and Kothattai were participants in the workshop. Mr. Santo, Technical Consultant from Aurvoville Botanical Garden, Auroville also attended the workshop.

After the welcome address by FERAL, a Mr. Selvaganeshan, Senior Field Assistant, FERAL presented the restoration activities carried out in Vadagaram and Kothattai.

This was followed by a technical presentation by Mr. Anbarasen, Botanist, FERAL on importance of TDEF vegetation and the ways the community could protect them. Mr. Jayaraman (Former President), Vadagaram spoke about the importance of protecting forests and thanked the community at Vadagaram for their cooperation during the activity. This was followed by a vote of thanks by Mr. R.S. Bhalla (Project Head, UNDP-PTEI). Restoration protocols and vulnerability mapping A detailed coastal restoration protocol document has been prepared and is submitted as a separate report. Similarly, vulnerability mapping along the Coromandel Coast is submitted as a separate report.

Figure A.1: Experience sharing workshops. On left, the workshop held at Nagapattinam where the Wildlife Warden was the chief guest and made the inaugural address. On right, the workshop held at Pondicherry. Both workshops were attended by representatives of the Gram Panchayats, members of the restoration committees and traditional village leaders. Representatives from the Auroville Botanical Gardens participated in the workshop held at Pondicherry. Short presentations on the achievements at the different sites were made by the committe members.

A.2 Nursery raising of coastal species at mother nursery, FERAL field office

Dilip Venugopal

Background

Raising of coastal species saplings in mother nursery was a part of the establishment of pilot demonstration sites for restoration of native coastal habitats - an output of the UNDP-PTEI Phase II. The mother nursery at the FERAL field office in Morattandi, was the store house of the basic stockpile for the saplings of coastal species. These saplings were later transported to satellite nurseries in the villages or directly to the sites selected for restoration. The mother nursery was the controlled site where adequate care and protection for the sapings was ensured for the proper raising and survival. Various techniques and experiments for the successful raising of these plants were also developed and implemented at the mother nursery.

Setting up of the Mother Nursery

The FERAL field office, supported a mother nursery, where more than 90000 saplings of TDEF and sand dunes and more than 200,000 mangrove propagules were raised. The physical infrastructure includee leased land for nursery raising, fencing, watering facilities, soil beds, etc.

Training by Auroville Botanical Garden and streamlining of process

The Auroville Botanical Gardens (ABG), which has been involved in the raising of tropical dry evergreen forest saplings,provided technical assistance in raising the saplings at the FERAL mother nursery. (For an introduction to the activities by ABG see `http://www.auroville.org/environment/botanical_garden/introduction.htm`. Experts from the ABG have been providing their inputs towards various elements of successful nursery raising and maintenance, including

- Development of program and establishment of nursery.
- Identification of species to be raised in the nursery.
- Training for Feral Staff: general introduction, bag filling and transplantation
- Seed preparation for particular species, prior to germination.
- Germination techniques for various species.
- Maintenance and after care training including weeding and pest control.

Mother nursery maintenance

Soil Mixture The soil mixture plays an important role in germination, root establishment, nutrient supply and growth of the saplings. So it is vital to have a good mixture of soil for successful raising of saplings in nursery conditions, both on nursery beds and polythene packets. The soil mixture should comprise of 2 measures of top soil, 2 measures of farm manure and 1 measure of red soil. The top soil is first spread onto the ground, on top of which manure is spread. Add the red soil and mix well together.

The top soil, being rich in organic matter, aids in better growth of the saplings and the addition of manure is also for the same purpose. The red soil helps in binding the soil mixture well, such that the root holding is firm. Also, the soil pack being tightly bound helps in easy transplanting and transportation of saplings. It has to be ensured that the soil & manure are free of plastics and other solid waste. Weeds and other plants will have to be regularly removed from the mixture. In case of the soil being lumpy, it must be spread as a layer/bed of 10 cm, sprinkled with water and left for a day. This helps in loosening the clumps and they can be simply broken down by just physically moving them with a spade. The soil mixture can then be packed in polythene bags.

Alternative soil mixture is a mix of red soil, farm manure and sand, with similar proportions of each. Though this mixture contains lesser nutrients compared to the one provided earlier, top soil sometimes can be difficult to obtain, especially in large quantities. Silt washed along streams can also be used in the place of red soil, for binding the mixture well.

Filling soil into polythene bags Good quality polythene bags with higher micron size should be used for longevity and to endure handling and transportation. The dimensions of these polythene bags could be 5" X 8" or 5" X 10" depending on the species to be planted. The polythene bags could be made to order or purchased. The polythene bags should be stored in a place away from direct sunlight. Two holes acting as outlets for excessive water are made at about 2 inches from the base of the bag. The bottom edges are folded inwards, to prevent breakage. The soil mixture is filled gradually, with regular thumping of the bag on to the ground, for proper packing. Soil is filled up to the brim of the polythene cover. It is important to fill the packet completely without which the packets tend to crease and fold. This curtails even spread of water and also weakens the polythene at the creases. Also, after watering, the soil binds together, thereby reducing in quantity in the bag. Water the bags a day prior to the placing of saplings within them. The polythene bags filled with sand have to be handled carefully and should not be lifted by handling them at the top. This breaks the stitching along the rim. Handle them by placing your hand around the entire bag or by holding the base of the packet on your palm.

Figure A.2: The correct mix of red soil, topsoil and good quality compost is necessary to ensure high seedling survival and growth. It is equally important that the bags are not packed too tightly.

Transplanting/Planting Seedlings

Shifting saplings from nursery beds The size of the seedlings/saplings to be transplanted has to be considered beforehand. A shovel must be used to pull the saplings from the bed, without damaging the roots. The saplings must then be placed in a bucket of water and if the roots are long, then it can be clipped to fit the saplings into polythene bags. However, some species get affected by this process. If there is an exuberant growth of leaves in the saplings to be replanted, then the leaves may also be clipped. This would ensure that the nutrients would be utilised for the growth and establishment of the roots.

Placing saplings in polybags A hole is made is made in the soil within the polybag, with a stick or finger and the seedling is placed into the hole with the root being placed as deep as possible. The roots must be spread in the hole and the soil around the hole be compacted well. This would ensure that there are no air pockets around the hole. Air pockets loosen the soil and affect binding and therefore the root establishment. Care is needed while planting because the fine roots can be broken easily. The process of transplantation should preferably be done earlier in the morning and in the evening, to reduce heat stress on the saplings.

Germination Techniques

Auroville Botanical Garden trained the SHG women at the mother nursery on germination techniques for various species. Techniques for Butea monosperma has been provided as an example below.

Procurement of seeds

Seeds and saplings for TDEF and sand dunes were purchased through private entrepreneurs or ABG. A small number of mangrove propagules were collected from forest department areas like Muthupet

Figure A.3: SHG women planting saplings from seedling beds into bags.

Figure A.4: The sequence of activities from procuring seeds to their treatment and planting.

(a) Seed collection.

(b) Extraction of the seed.

(c) Soaking the seeds.

(d) Sowing in nursery bags.

Figure A.5: Unloading the saplings and transportaion to the nursery.

mangrove area. The largest number (more than a lakh) was purchased from Kerala Agricultural University, thereby increasing the costs of transport and raising of saplings (photograph-unloading mangrove propagules from Kerala at the mother nursery).

Problems faced

Outbreak of pests *Phyllanthus polyphyllus* had an outbreak of a defoliating green caterpillar (the tobacco cutworm or *Spodoptera litura*), devouring the leaves. Periodic treatment with ash however, controlled the caterpillar and the saplings remained healthy, with a mortality of 0.53% (N=1685).

The mangrove sapling, Avicennia marina, in the germination bed, had a pest outbreak, the caterpillar were found under the leaf or attached to the stem, feeding on the leaves. About 60% (N=7500), saplings were found to have been affected. The leaves were observed to turn brown and crumpled. Careful monitoring of manual picking of caterpillars and their eggs was carried out. The use of pesticides might have a residual effect, so were avoided as much as possible. Use of neem extraction and neem with aziderachtin, the chemical insecticide were used as well.

Another major attack was that of mites on *Thespesia populiana*, which destroyed approximately 2000 saplings. All these were burnt and disposed as a preventive measure to prevent spread of mites onto other saplings. *Thespesia populiana* saplings were raised through seedlings again and did well later on.

Other problems faced: Some of the other problems that we faced were that of logistics including maintaining quality of soil and manure and sourcing SHG women for work at the nursery, particularly when the National Rural Employment Guarantee Act was implemented in Morattandi.

Figure A.6: The tobacco cutworm

Nursery Establishment & Maintenance – General Pointers Half of the nursery area should be in full sun to give maximum growth rates for many species. All species need to be hardened off for at least 1 month prior to replanting.

Water Usage 1 litre /day 10 seedlings per day, thus 1m.sq per 10,000 seedlings per day

Water points No further than 50m apart, better if only 30m. All seedlings to be watered with rose, this would prevent damage to the saplings due to force of the water.

Shade Area 75% shade net for transplanting seedlings 50% shade net for some seedlings for 3 months or canopy of mature trees.

Germination Shed With fibreglass roof, seedling trays raised off the ground and protected from ants by channels around table supports

Germination Area 50% shade, seedling beds, surface level raised above ground level to prevent water logging in heavy rains.

Concrete Beds Useful to prevent root penetration of plastic bags and viral infections spreading. 1 X 10m with 75 cm path between each bed. Holding capacity of beds is 100 plants/sq.m

Soil Bins Lids to keep sifted soil dry during rainy season

Good access for transport To move seedlings around nursery and for pick up of seedlings.

Annexure B Administrative Arrangements

B.1 Draft of agreement made with eco-restoration committee

Roles and Responsibilities of the Eco-Restoration Committees

Panchayat Leaders:

Activities:

- Permissions for planting and restoration work through consultations with the village committee
- Develop rules for protection of the area restored (plants, fences, etc)
- Crucial Link between the Project Team and the village community
- Monitoring of activities of the rest of the members in the Eco-Restoration Committee

SHG Women at On-Site Nursery

Activities:

- Watering of Saplings: Two times, once in the morning and once in the evening
- Weeding: Checking and removing weeds in the polybags must be done on a daily basis
- Reporting: Saplings that are dead should be removed from the beds and reported immediately to the Village Animator

Wages:

- The SHG Women (2) will be paid wages of Rs 60/day
- They will have to sign the Daily Attendance Register
- The payment will be made by FERAL Field Assistant or Junior Accountant on a weekly basis on Saturdays
- This activity will continue until the planting on site takes place

Watcher

Activities:

- The watcher has to have a close eye on the saplings at the On-Site Nursery and prevent the saplings from theft, damage and grazing
- After the planting of Saplings on site, the watcher has the responsibility of preventing grazing and damage and has to visit the site on a daily basis
- The watcher also must take care of the infrastructure set up at the village including hand pumps and fencing

Salary:

- The Watcher will be paid Rs 1200/- month as a salary
- The salary will be paid at the end of each month by FERAL Field Assistant or Junior Accountant

Village Animator:

Activities:

- The Village Animator has to monitor activities specific to survival status of plants at the on-site nursery, planting on site, survival of plants on site after planting
- Bi-weekly reports has to be submitted to FERAL Field Assistant
- The Village Animator has to maintain daily register for the SHG Women as well has the village level staff

Salary:

- The Village Animator will be paid Rs 2500/- month as a salary
- The salary will be paid at the end of each month by FERAL Field Assistant or Junior Accountant

Annexure C Community Involvement

C.1 Sample micro-plan document

Report of the Micro planning program at Vadagaram

Vadagram is a small village neighbouring the Marakannam Reserve Forest about 3 kilometres South of Marakannam town. The village has one of the three tropical dry evergreen (TDEF) sites selected for restoration under the UNDP Post Tsunami Environment Initiative Phase 2. The TDEF site at Vadagaram is a 'highly disturbed'. Its control of the forest patch lies with the village 'Panchayat' and principal causes of disturbance are grazing, fuel wood collection and annual festivals. This site was selected due to its size (just over 5 hectares) and eagerness of the communities to restore and protect it. This short report covers the micro planning workshop held at Vadagram through which the restoration plan was discussed and formalised.

The micro-planning workshop was held with village representatives on the 3rd of October 2007 and was able to finalise the restoration plan and related logistic and management issues. These include area for planting, species composition, fencing plans, community contribution and management. Each of these issues were discussed in detail and consensus regarding the same was achieved within the committee. This will form the basis of the contract with the committee. This meeting was attended by village leaders, representative of the women groups and members of the FERAL team.

Planting area

After surveying and mapping the selected TDEF patch at Vadagram , a plan for the area to be planted was developed. Plantation of selected species will be carried out for 36912.85 sq m of the 5.37 hector forest patch (Figure C.1). This has been discussed with and agreed on by the village representatives.

Species to be planted

The plantation plan comprises of approximately 3100 saplings of 25 species as shown in Table .

There was a strong objection raised by the villagers towards planting of Hardwickia binnata (vernacular: "aacha"). The reasons given by the community were superstitious in nature (the tree is said to attract ghosts).

Buffer zone

Plantation of a buffer of 2237.02m^2 around the TDEF patch was proposed by FERAL. This will serve to protect the forest as well as benefit the village.

Figure C.1: The total area to be planted, including buffer is approximately 39,150 sq m and indicated by the grey shading.

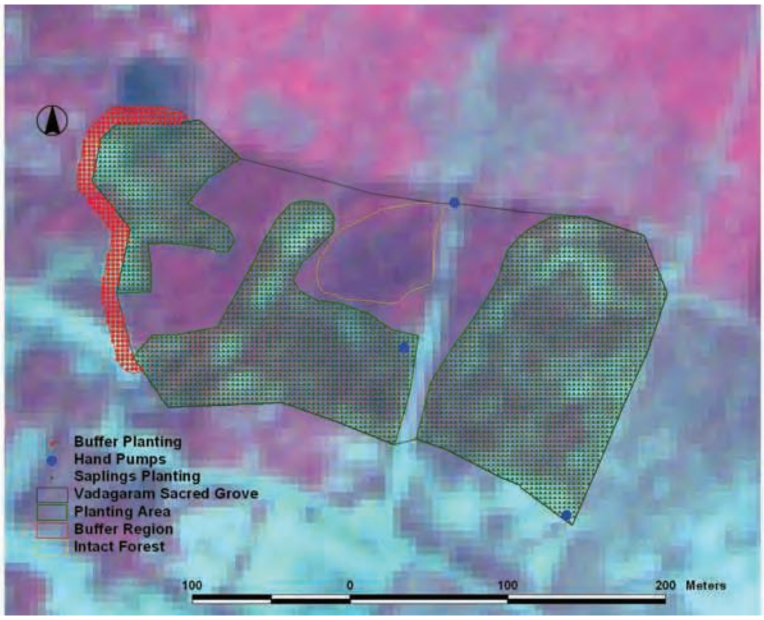


Table C.1: List of species and numbers to be planted.

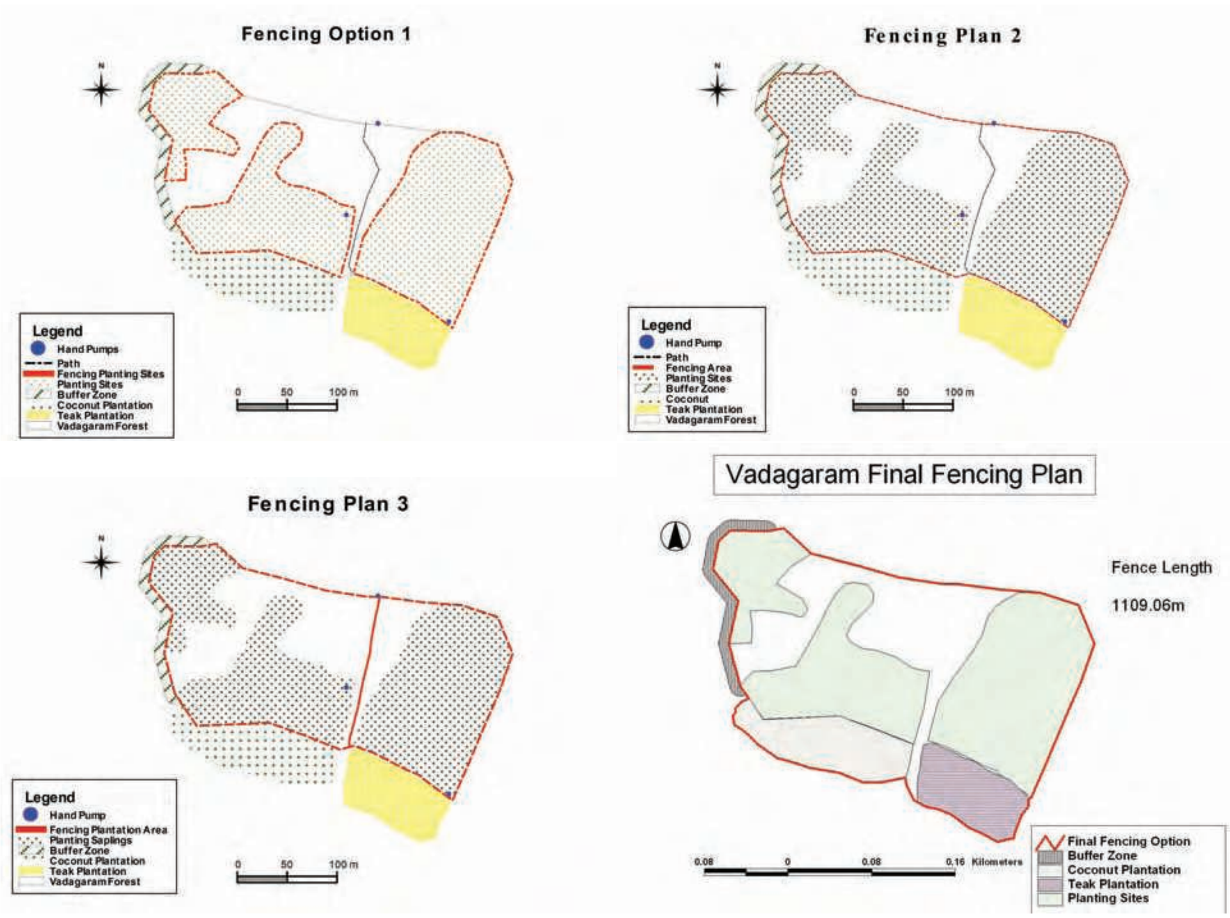
Sno	Species	Number of saplings
1	*Albizzia amara*	82
2	*Atalantia monophylla*	326
3	*Bauhinia racemosa*	70
4	*Butea monosperma*	151
5	*Causina glauca*	27
6	*Chloroxylon swetienia*	12
7	*Dalbergia sissoo*	181
8	*Dolicandrone falcata*	40
9	*Ehretia pubescens*	93
10	*Eugenia bracteata*	57
11	*Glycosmis mauritiana*	18
12	*Mimosops elengi*	77
13	*Murraya paniculata*	75
14	*Ochna obtusata*	66
15	*Phyllanthus polyphyllus*	345
16	*Polyalthia suberosa*	266
17	*Pterocarpus marsupium*	23
18	*Pterospermum suberifolium*	165
19	*Pterospermum xylocarpum*	84
20	*Senna auriculata*	225
21	*Streblus asper*	44
22	*Sygyzium cuminii*	194
23	*Terminalia bellerica*	128
24	*Walsura trifoliata*	286
25	*Wrightia tinctoria*	44
	Total	3078

The plan was accepted and 'Teak', 'Khaya' and 'Neem' were the trees specifically suggested for this zone. In addition they have requested that the buffer zone be extended through the coconut and teak plantations which are community owned and were earlier part of the TDEF patch, depending on the availability of saplings and space within these existing plantations.

Fencing plan

Of the three fencing plans prepared, the second and third were presented to the village representatives for approval (Figure C.2):

Figure C.2: Various fencing options presented to the community and the final plan after negotiation and discussion.



Out of the various methods for fencing suggested by FERAL, concrete beams with barbed wire was the one favored by the village. This however will be confirmed after reviewing the budget for fencing with UNDP, Chennai. The community has agreed to contribute Rs.20,000 towards this fencing.

Fence Costing

the estimates for material to be considered were made after thorougher inquiries and those of the lowest price were selected. This was finalized based on discussion with UNDP on the additional costs involved in fencing (Tables C.3 and C.2).

Table C.2: Costs of fencing materials as discussed with the restoration committee at Vadagram.

Item	Cost / Running Foot
Barbwire 12 gauge	2.28
Barbwire 14 gauge	1.45
Bamboo Padal	5.00
Thorn Fence	25.50
	Cost / 7 feet (individual)
Casuarina Pole Wet	26.67
Casuarina Pole Dry	23.81
Stone	119.00

Protection and maintenance

The village representatives have offered to give FERAL a letter of agreement, to protect and maintain the fenced off region. In addition they intend to fine those individuals who misuse this area for grazing cattle, fire wood, etc. This includes taking on the responsibility for solid waste management within the region and protecting the site during festivals.

Employing SHG members

Members of existing self help groups from the village have been employed to maintain the on site nursery. This will continue for subsequent plantation and monitoring of the saplings.

Table C.3: Costs of fencing as discussed with the committee at Vadagram.

	Fencing Area	Perimeter (m)	Perimeter Feet	No of poles required/10 feet	Barbwire Fencing 12' & Wet poles	Barbwire Fencing 12' Dry poles	Barbwire Fencing 14' Wet poles	Barbwire Fencing 14' Dry poles	Barbwire Fencing 12' Stone
PLAN 1	1	542.23	1779	178	16912.95	16404.16	12483.24	11974.45	33338.46
	2	406.42	1333.4	133	12676.63	12295.28	9356.47	8975.12	24987.92
	3	580.49	1904.5	190	18106.08	17561.39	13363.88	12819.19	35690.33
					47695.67	46260.83	35203.59	33768.75	94016.71
PLAN 2	East	595	1952.09	195.00	18552.97	17995.27	13692.26	13134.56	36557.32
	West	742	2434.40	244.00	23158.78	22460.94	17097.12	16399.28	45687.30
					41711.75	40456.21	30789.38	29533.84	82244.62
PLAN 3	Entire	1026.31	3367.15	337.00	32019.10	31055.28	23634.89	22671.07	63134.31
FINAL PLAN	Entire+plantations	1109.06	3638.64	368.00	34702.84	33650.36	25642.63	24590.15	68680.28
	Fencing Area	Perimeter (m)	Perimeter Feet	No of poles required/10 feet	Barbwire Fencing 14' Stone	Bamboo Padal	Thorn Fence	Barbwire 12' Cement Pole	Barbwire 14' cement Pole
PLAN 1	1	542.23	1779	178	28908.75	8895.00	45364.50	31737.36	27307.65
	2	406.42	1333.4	133	21667.75	6667.00	34001.70	23787.86	20467.69
	3	580.49	1904.5	190	30948.13	9522.50	48564.75	33976.28	29234.08
					81524.63	25084.50	127930.95	89501.50	77009.42
PLAN 2	East	595	1952.09	195.00	31696.61	9760.47	49778.40	34802.32	29941.61
	West	742	2434.40	244.00	0.00	12172.00	52753.45	43491.30	37429.64
PLAN 3	Entire	1026.31	3367.15	337.00	54750.10	16835.75	85862.33	60101.31	51717.10
FINAL PLAN	Entire+plantations	1109.06	3638.64	368.00	59620.07	18193.19	92785.24	65368.28	56308.07

Annexure D Restoration of Tropical Dry Evergreen Forests

D.1 List of villages where prelimnary surveys were undertaken for TDEF

1. Urani
2. Vadaagaram
3. Vennankupattu
4. Kadapakkam
5. Vembanoor
6. Panaiyur
7. Omiper
8. Thalakanikuppam
9. Kumalam - 1
10. Kumalam – 2
11. Saniyachikuppam
12. Nagari
13. Kadagampattu
14. Silikaripalayam
15. Mangalam
16. Kumaramangalam
17. Krishnavaram
18. T.Moorthikuppam
19. Alamarthukuppam
20. Thothacherry
21. Komuttuchavady
22. Katarampakkam
23. Kilianur
24. Kumalampattu
25. Thiruchitrambalam
26. Poothurai
27. Kasipalayam
28. Velazhankuppam
29. Irumbai
30. Pannakuppam
31. Ramanathapuram
32. Ramapuram
33. Karasur
34. Sooriyanpettai
35. Periyamuthalichavady
36. Setharapattu
37. Varakalpattu
38. Thirumaikuzhi
39. T.Pudhupalayam Restoration Plans
40. Vandhikuppam
41. Kuzhanthaikuppam
42. Pudhupalayam
43. .Kochikuppam
44. Arasadikuppam
45. Pudur
46. Siliminathanpettai
47. Palavathunam
48. Pethankuppam
49. Ramapuram
50. S.pudur
51. Thanadamanatham
52. Kothattai
53. Chinnakomatti
54. Periyakomatti
55. Sendharakillai
56. Sambandam
57. Mutlure
58. Vallam
59. Kizhboovanagiri
60. Perunthottam
61. Meliure
62. Neithavasal

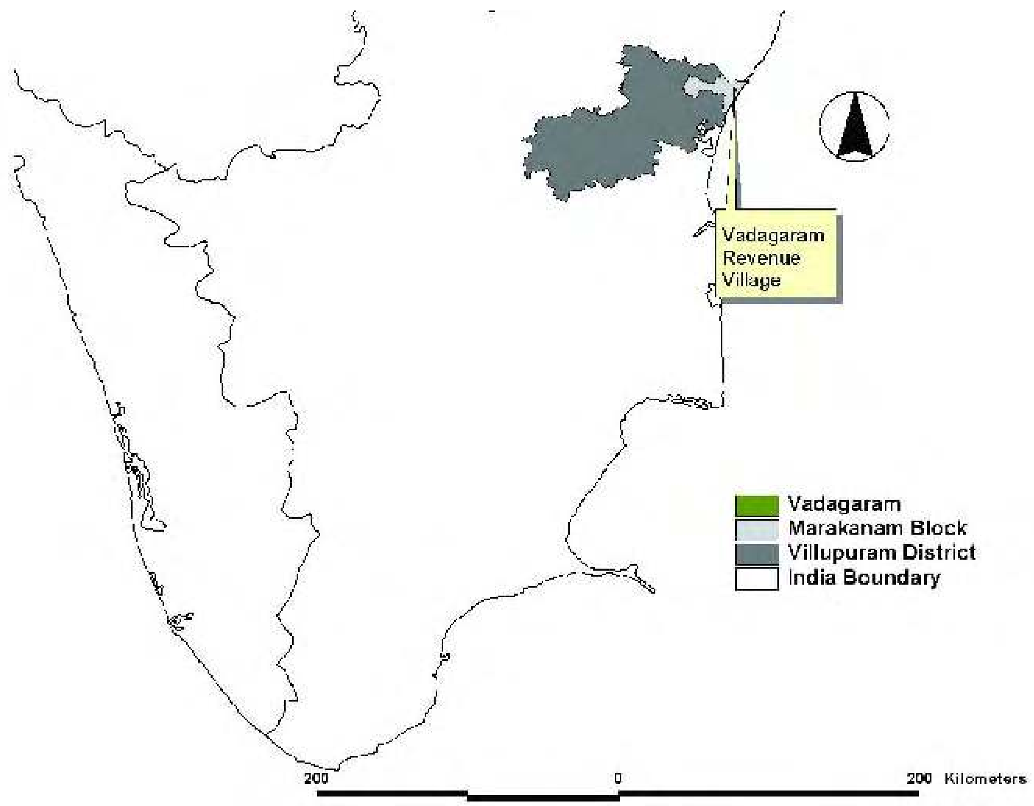
63. Vedharajapuram
64. Nepathure
65. Thirukattukolai
66. Melaperumpalam
67. Chavadi
68. Irumbai tank
69. Periyakattupalayam
70. Poornakuppam
71. Ulagapuram
72. Alambara
73. Kilputhupet
74. Thethakudi North
75. Thethakudi South
76. Sikkal
77. Manapattu

D.2 Selected Restoration Sites

Vadagaram

Vadagaram village is located approximately 3 Kilometres South of Marakannam town. The village has one of the two tropical dry evergreen forest (TDEF) sites selected for restoration.

Figure D.1: Location of Vadagram TDEF site.

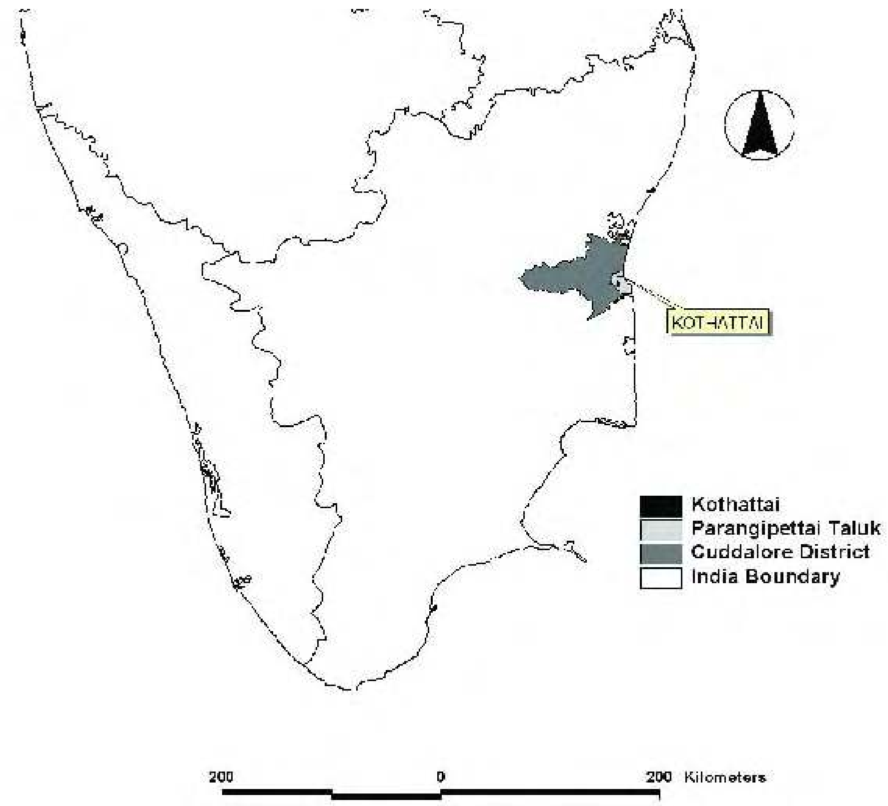


The TDEF patch at Vadagaram is 'highly disturbed' (sparse TDEF vegetation and low canopy cover). The Village Panchayat controls the forest patch and the temple authorities help in its maintenance. The principal causes of disturbance are grazing, fuel wood collection and annual temple festivals. This site was selected due to its size (just over 5 hectares) and eagerness of the communities to restore and protect it.

Kothattai

Kothattai, located approximately 12 kilometers north of Chidambaram town, has a large forest patch with an area of 17.32 hectares. The forest is highly disturbed and is under the control of the Temple Endowment Committee. The principal causes of disturbance are grazing and annual temple festivals. This site was selected due to its size and eagerness of the temple endowment department and the local community to restore and protect it.

Figure D.2: Location of Kothattai, TDEF site.



Annexure E Stabilisation of Coastal Sand Dunes

E.1 List of villages where prelimnary survey was held for coastal sand dunes

1. Achikadu
2. Allambara
3. Boomayarpalaym
4. Kunimedu
5. Paramankenni
6. Panichamedu @ Keelpettai
7. Muttukadu
8. Muttukaduchanthiram
9. Vembanoor
10. Panniyur chinnakuppam
11. Panniyurkuppam
12. Sikkanakuppam
13. Mugaiure
14. Thenpattinam
15. Vadapattinam
16. Angalammankuppam
17. Kudalure (Chinnakuppam)
18. Kudalure (Periyakuppam)
19. Kottakadu
20. Mudhaliyarkuppam
21. Manapattu
22. Pudhukuppam
23. Vambapet
24. Echankadu
25. Narambai
26. Moorthy Pudhukuppam
27. Devanampattinam
28. Keelavanjor
29. Melavanjor
30. Kizhiur
31. Pattinacherry
32. T.R.Pattinam
33. Karukalacherry
34. Kottucherry
35. Kallikuppam
36. Mandapathur
37. Vadakupoigainallure
38. South Poigainallur

Annexure F Restoration of Mangrove Habitats

F.1 Restoration of Mangrove Habitats in the Pondicherry Region

This proposal was submitted to the Forest Department of Pondicherry for consideration.

Overview of the document

This document presents the plan of action for three potential restoration sites in Pondicherry by FERAL in close collaboration with the Forest Department of Pondicherry. The document comprises of the following sections:

1. FERAL and Pondicherry Forest Department

   The working relationship between FERAL and the Forests department during and post project phase.

2. Site selection

   The procedure followed to prioritise sites which included various discussions with local communities, environmental monitoring and inventories of existing mangrove vegetation.

3. Micro-planning

   The process of identifying the specific activities and their location along with the stakeholders and officials from the Forest Department

4. Community mobilisation

   How local participation and support for long term protection of the planted areas will be ensured through awareness generation and interactions between community members and institutional stakeholders.

5. Administrative procedures to be adopted

   Measures and mechanisms adopted by FERAL to ensure transparency and accountability at all stages of implementation.

FERAL and Pondicherry Forest Department

The mangrove restoration activities to be conducted in Pondicherry will be in close consultation and collaboration with the forest department. After completion of planting and fencing activity, the sites will be formally handed over to the department for after care and maintenance. Additionally the forest department will be involved in: Selection of sites so that they fall under its jurisdiction and can therefore be protected well beyond the life span of the project. Ratification of the work plans at each site. Involvement in awareness generation through conducting meetings and workshop and participating in other awareness events conducted by FERAL.

Site Selection

The selection of sites for mangrove restoration in the Pondicherry region was a two stage process. The forest department had earmarked various regions suitable for mangrove restoration. These areas were visited and mapped using GPS units. Subsequently, meetings were organised with local communities to gauge the importance of these areas to them in terms of resources and their willingness to contribute to the process of restoration through planting and protection. During these field visits, measurements of environmental conditions were made to ensure that the physical and chemical properties of the water and soil were suitable for mangroves. Additionally, inventories were made of existing mangrove vegetation which was a good indicator of site suitability and types of pressures that limited natural regeneration. Details of the same have been provided in the appendix.

Micro Planning

All local and institutional stakeholders were met after the initial surveys to gauge the current levels of interest in the areas earmarked for restoration. These meetings included participatory mapping exercises and field visits with the stakeholders which resulted in: A GPS based track of the areas considered suitable for planting. A resource map showing areas of resource use and land use. A map of existing plantations and restoration efforts if any. Clear understanding of the jurisdiction of various institutional players, in this case, regions which were protected by the forest department opposed to revenue lands.

These micro-plans will be further developed at the FERAL office and presented to the stakeholders along with various measurements corresponding to types of activities and areas to be covered. Once the maps have been ratified by the concerned representatives and officers they will serve as a basis for the activities.

Community mobilisation

Two levels of community mobilisation are planned. The first will comprise of street plays conducted at each by a professional troupe which will be combined with distribution of posters and notices in Tamil. This will be followed by organising workshops wherein the forest department officials and resource persons interacted with the communities and discussed issues and strategies for conservation of mangroves and the benefits to local communities. The role of local stakeholders in the protection and maintenance of the plantations will also be discussed. One of the unique features of this proposal is the long term protection of the restoration sites through the involvement of the forest department. The department has its own mechanisms and processes for involving local communities in protection and maintenance of the areas which are expected to take over after the project activities are completed.

Administrative Procedures

The administrative protocols developed by FERAL with regards to implementation of restoration activities will be followed. This protocol has been whetted by the UNDP and its consultants and have been presented in the appendix. Additionally, the forest department will be consulted at each stage of the implementation. The latter mechanism is to ensure the following: Areas covered by the restoration are within the jurisdiction of the forest department. Quality of interventions is per the standards expected by the department. Facilities and expertise of the department are made use of at all stages of the project. This will include staff equipment and materials.

Budget details

As detailed out in the introduction and background section, FERAL is already in partnership with the UNDP tsunami initiative as part of the UNTRS. Funds needed for this initiative on mangrove restoration with the support of the Pondicherry forest department will flow out of the exiting partnership between UNDP and FERAL.

F.2 Planting Plans

Various maps of the project area were prepared as a pre-requisite to the planting plan. These included remote sensing based analysis which enabled us to identify likely habitats for restoration. Subsequently a baseline of data was collated from various sources and geo-referenced and digitised. Finally, various field surveys were undertaken and GPS units and sight levels were used to build localised high resolution maps for planning and measurements. One such detailed plan for an area of Pondicherry is presented below.

Tengathittu

Tengathittu is a deltaic island just South of the Pondicherry town. The Pondicherry harbour and fishing jetty are located at Tengathittu. The Ariyankuppam river, a distributary of Tambrabarani drains into the Bay of Bengal at this location, creating a suitable habitat for mangroves. While the major channel from Ariyankuppam has a fairly large mangrove patch, areas around Tengathittu only have remnant mangroves which are under high stress from grazing and garbage dumping.

Proposed Plan

A micro plan was drawn up with the forest department and local communities after conducting a number of surveys on field. These included a resource mapping exercise and detailed surveys of the proposed site wherein areas for fencing were marked and mapped with a GPS.

Proposed Plan

Based on the mapping exercise the following statistics emerged:

- Total area to be covered = 1.85 hectares. Assuming a spacing of 1 metres between saplings, the total number of saplings earmarked for the site would be 18,500.

Figure F.1: Remnant mangrove patches in Tengathittu. Garbage dumping is one of the major problems here which can be addressed by fencing off the planting sites.

Figure F.2: A cadastral map of Tengathittu overlayed on a Quickbird satellite imagery (made available by the Pacific Disaster Centre).

- Total length of fencing = 745 metres.
- Prosopis removal through use of machinery where possible and labour where not.
- Areas used for waste dumping require to be cleared prior to planting.
- A letter from the Panchayat President for a go-ahead and formal permissions from the Forest Department.

F.3 List and number of species planted at mangrove sites

Kollathur

Melathirukazhipalayam

Figure F.3: Resource map of Tengathittu.

Figure F.4: Planting area (green) and fencing area (red).

Table F.1: List of species planted at Kollathur.

Sl.No	Species Name	Total Numbers Planted
1	Avicennia marina	3000
2	Rhizhophora mucronata	11700
3	Rhizhophora apiculata	4280
4	Bruguera cylindrica	5500
5	Bruguera gymnorhiza	600
Total		25080

Table F.2: List of species (Mangrove and TDEF) planted at Melathirukazhipalayam.

Sl.No	Species Name	Total Numbers Planted
2	*Rhizhophora apiculata*	7000
3	*Rhizhophora mucronata*	26894
4	*Bruguera gymnorhiza*	4500
5	*Bruguera cylindrica*	965
Total		39359

Sl.No.	Local Name	Scientific Name	No.
1	Auosthi	*Polyalthia suerosa*	50
2	Eeati	*Dalbergies sisso*	50
3	Kattuaavaram	*Senna siamea*	20
4	Kattuvagai	*Albizia lebbek*	30
5	Poovarasu	*Thespesia populnea*	50
6	Achaa	*Hardwickia pinnata*	100
7	Mukusali	*Cordia mixia*	50
8	Sarkarai Pazham	*Holoptelia integifolia*	50
Total			400

About FERAL

The Foundation for Ecological Research, Advocacy and Learning (FERAL), is a non-profit trust founded in July 1997. FERAL comprises of a small team working on various aspects of applied research on ecological and environmental issues. The key areas of work include conservation, ecological restoration, environmental and natural resource management and training and capacity building in these areas.

Visit the FERAL web page, `http://www.feralindia.org`, for more information about ongoing activities and projects.