The Conservation of Mangroves in Kerala: Economic and Ecological Linkages

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Project proposal

1. Project number	:	KFRI 487/2005
2. Title of the project	:	The Conservation of Mangroves in Kerala: Economic and Ecological Linkages
3. Objective	:	a) To study the socioeconomic and ecological systems of mangrove forests and their linkages for its conservation. b) To identify the important values of mangrove ecosystem
4. Expected outcome	:	The results of the study would be useful for the policy makers to develop suitable strategies and action plans for mangroves and to prepare a perspective plan for these fragile ecosystems. The study will generate information on the socioeconomic system and identify the values of the mangrove ecosystem.
5. Date of commencement	:	April 2005
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7. Funding agency	:	KSCSTE Plan Grants
8. Project team		
Principal Investigator	:	Dr. P. K. Muraleedharan
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ABSTRACT

Mangroves provide many ecological, environmental and socioeconomic benefits to mankind. However, biodiversity rich mangrove ecosystems are fast declining world over. Presently, in Kerala, the extent of undisturbed mangroves is reduced to just 150 hectares mostly distributed in Ernakulum, Kannur and Kozhikode Districts, but potential area comes to around 1670 hectares. The vegetation has diminished in its extent drastically and has acquired a threatened status in Kerala.

More than 80 per cent of the mangrove lands in Kerala (potential and existing) are under private ownership; the land left with government agencies is very meager. The mangroves in the State are threatened with unprecedented destruction, which includes commercial exploitation of raw materials, land reclamation for agriculture, aquaculture and housing. There have been significant changes in the traditional and present uses of resources within the mangrove system, which have implications on its depletion.

The respondent perception on the *benefits derived from mangroves* highlighted forestry products and seafood as the most important direct benefits. This is indicative of the fact that respondents give more weightage to the direct economic benefits of the ecosystem. On social *and environmental problems* associated with mangroves' health problems, low agricultural productivity and water pollution were highlighted.

The traditional mangrove ecosystem was by and large, self contained following subsistence production, but now it is closely related to the market. The changing land use has drastically affected the mangrove ecosystem. The high returns from high tech aquaculture especially shrimp farming has led to rather quick transformation of the mangrove lands. Many people sold out their mangrove lands to big investors not realizing its environmental and social values. Decline in area under mangrove ecosystem continues in an unconcealed manner due to increase of population, industrialization and implementation of developmental activities. Mangrove afforestation initiative is yet to make a successful leap in the State. Socially, afforestation programme would be benefiting people living in coastal areas in terms of protection, environmental services and support for livelihood.

1. INTRODUCTION

Natural systems all over the world are subjected to various intensities of anthropogenic pressures, largely due to alarming increase in population growth. As current population level shows an increasing trend, pressures on natural areas must be expected to grow. This would affect all ecosystems, particularly some marginal ecosystems like the mangrove more seriously. Mangroves are salt tolerant plants of tropical and subtropical inter-tidal regions of the world. The specific regions where these plants occur are termed as 'mangrove ecosystems'. These are highly productive but extremely sensitive and fragile. Besides mangroves, the ecosystem also harbors other plant and animal species. These unique plant communities occur in a habitat created by the confluence of rivers, backwaters and sea. By virtue of the prolific aerial and underground rhizomorphs they form a very effective soil binding geotextile. This provides incredibly sound anchorage which enables the plants to withstand the waves. As the abode of rich biodiversity, their role in the sustainability of seafood species and shoreline stability, economic standing and the survival of selected communities and in the context of the predicted scenarios of global warming and sea level rise, conservation of mangrove vegetation is very important (Deshmukh, 1991).

The tropical wetland ecosystems including mangroves are known to provide a number of ecological services and economic benefits. However, as noted by Barbier (1994), there were not so many attempts to carry out economic analysis of the contribution of these wetlands, especially those systems, which are located in the developing countries. Since then case studies were executed in a few developing regions such as Thailand (Sathirathai, 1997), Indonesia (Ruitenbeek, 1994), and Mexico (Barbier and Strand, 1998). The coastal wetlands and mangroves in the tropical countries are highly productive ecosystems and they generate a number of direct and indirect goods and services. These include products like timber, fuel wood, honey and wax, fish, fish fingerlings, forages etc., and services like flood control, erosion control, storm surge protection, shoreline protection, ground water recharge, nutrient recycling, micro climate regulation, ozone layer stabilisation, recreation, etc (Ruitenbeek, 1994). An important

function of mangrove forests is the provision of food and shelter for large and varied groups of fish and shellfish. Mangroves also provide a buffer between land and shallow sea, preventing erosion of the land and saves life during cyclones or storm surges. Mangrove swamps are also the natural sewage treatment plants. Tiner (1985) divided major wetland values into three broad categories. They are: (a) Fish and Wildlife Values (comprising fish and shellfish habitat, waterfowl and other birds habitat, furbearer and other wildlife habitat, and endangered plant and animal habitat); (b) Environmental Quality Values (comprising values derived from water quality maintenance (pollution filter, sediment removal, oxygen production, nutrient recycling, and chemical and nutrient absorption), aquatic productivity, microclimate regulator functions, and ozone layer maintenance function); and (c) Socioeconomic values of wetlands (comprising values from flood control, wave damage protection, erosion control, groundwater recharge and water supply, timber and other natural products, livestock grazing, fish and shell fish, hunting and trapping, recreation, aesthetics, and education and scientific research).

In Kerala, mangrove forests that once occupied about 700 km^2, have now dwindled to 17 km^2. As in many other parts of the world, the vegetation has diminished in its extent drastically and has acquired a 'threatened' status in Kerala (Basha, 1991, 1992). Most of the mangroves areas (89%) in Kerala are owned by private owners of whom some live within the system. In addition to owners, some people who live outside the system also depend on the mangroves for their livelihood. Both the owners as well as dependents derive a number of direct benefits such as firewood, charcoal, fish, shellfish, and indirect functional benefits such as the watershed benefits, ecosystem services and the evolutionary processes of the mangrove ecosystem. The threats to the mangrove ecosystems could be broadly grouped into both natural as well as anthropogenic. The mangroves in the State are threatened with unprecedented destruction, which includes commercial exploitation of raw materials, land reclamation for agriculture, aquaculture and housing.

There have been significant changes in the use of resources within the mangrove system, which have much implication on its depletion. For instance, the traditional mangrove dwellers/dependents who often combined the use of land, sea, and inter-tidal resources, were basically involved in primary subsistence activities (agriculture and fishing). Now this trend has changed and a significant number of them are associated with commercial activities. The traditional mangrove ecosystem was, by and large, self-contained following subsistence production, but now it is closely related to market. In the context of commercialization, both the ecological and socioeconomic systems of mangrove are both greatly affected by processes and events beyond its geographical borders.

The coastal stretches, the natural home of mangroves, are also the places where there is an exuberance of population (Singh, 2006) that has resulted in high pressure on land. Land reclamation for various developmental activities is the general scenario. The changing land use has worsened the situation. The high returns from the high-tech aquaculture, especially shrimp farming has led to rather quick transformation of the mangrove lands to artificial water bodies. Many people sold out the mangrove lands to high-level investors, though many farmers also took advantage of the situation.

The socioeconomic system and mangrove ecosystem are closely interlinked although both the systems are not coterminous. For instance, the harvest rates are far higher than regeneration rates, commercialization of fishing often leads to over fishing, clear felling without replanting, among others. However, there is hardly any study, which gives details of the socioeconomic system of the mangroves and its linkage with its ecological system in Kerala. Besides, the mangroves carry out a variety of functions that generate economic, ecological, scientific and cultural benefits not only for the present generation but also for the future generations. In this backdrop the corpus of this study is the documentation of the linkage between economic and ecological systems of the mangroves and its various functions and benefits is essential for formulating strategies/policies for its sustainable conservation in Kerala. The specific objectives of the study are to:

1. Study the socioeconomic and ecological systems of mangrove forests and their linkages for its conservation , and
2. To identify important values of mangrove ecosystem.

STUDY AREA AND METHODOLOGY

Kerala had very thick mangrove vegetation (Plate 1) especially along its coastline. According to one estimate, Kerala once supported about 700 km^2 of mangroves along its coast (Ramachandran *et al.*, 1986). Now, the area under mangrove has dwindled significantly. According to the estimate of the Kerala Forest Department, the area under mangrove constitutes approximately 17 km^2 spread over the coastlines of 10 Districts (Table 1) in tiny patches.

Plate 1. Mangroves in Kadalunidi

Table 1. The District-wise distribution of mangrove vegetation in Kerala				
	District	Extent of Mangrove (Ha)	Population	Per capita mangrove holding (cent)
1	Thiruvananthapuram	23	3234707	0.001756
2	Kollam	58	2584118	0.005544
3	Alappuzha	90	2105349	0.010559
4	Kottayam	80	1952901	0.010118
5	Ernakulum	260	3098378	0.020727
6	Thrissur	21	2975440	0.001743
7	Malappuram	12	3629640	0.000817
8	Kozhikkode	293	2878498	0.025142
9	Kannur	755	2412365	0.077304
10	Kasargod	79	1203342	0.016216
Total		1671	26074738	

Source: Kerala Forest Department, 2006

About 88 per cent of the total mangrove areas in Kerala are under private ownership and rest with the State Forest Department. Some of the key mangrove areas in the State are depicted in Appendix 1.

The study consists of socioeconomic and ecological components. The study is based on primary data and supplemented by secondary data. Primary data on multiple stakeholders of the mangrove ecosystem, with special reference to the mangrove and their attitudes, resource use patterns and perceptions towards the sustainable use of the mangrove ecosystem were generated. Secondary data from official records and other reports were collected to comprehend the existing scenario. By linking the salient mangrove related

factors with selected socioeconomic factors or indicators, the ecological-economic linkage was assessed.

Of the 14 Districts in Kerala, mangroves are spread over in 10 Districts. Kannur has highest area under mangroves (755 ha), followed by Kozhikode (293 ha) and Ernakulum (260 ha). In Ernakulum District the major mangrove areas are concentrated in Puthuvipen. Based on the highest per capita mangrove holding and maximum human interaction or people mangrove interaction, Kannur and Puthivipen in Ernakulum District were selected for detailed primary studies. However, during data collection, it was found that more and more mangrove areas were cleared for developmental works and thus more focus was given to Kannur area.

The reconnaissance indicated that in Kannur mangroves are mainly found in ten Panchayaths belonging to five Blocks of Kannur, Edakkad, Payyanur, Thaliparamba and Thalassery. The identified Panchayaths are; Valapattanum, Edakkad, Muzhupilangad, Ezhome, Kunhimangalam, Mattol, Pappinissery, Cherukunnu, Dharmadam and New Mahe.

Primary data were collected from 182 households which were selected at random from the above places. As is evident in Kannur, the people-mangrove interaction is more in Mattol and Cherukunnu Panchayats from where 60 per cent of the total sample was selected. In addition to primary data collected from above areas, data from secondary sources and PRA conducted in mangrove areas in Kadalundy of Malappuram District, Puthivipen in Ernakulum District and Chettuwai in Thrissur District were also used in the study. In order to estimate the willingness to pay for the conservation of mangroves the contingent valuation method (CVM) was used. This is a direct approach, it asks people what they are willing to pay (WTP) for a benefit, or what they are willing to accept (WTA) by way of compensation to tolerate a cost or both.

2. MANGROVE ECOLOGY AND HUMAN DIMENSIONS

The mangrove forest is a complex ecosystem because it represents an inter phase between two contrasting types of communities: terrestrial as represented by lowland forests; and marine, as represented by distinctive ecosystem, notably seagrass meadows and coral reefs. It is characteristically swampy being regularly flushed by brackish water. The tidal inflow also brings in lot of debris and soil particles and the soil being saturated with water is very loose and therefore movement through the mangrove forest is not very easy.

Mangroves are composed of salt tolerant plants - the *halophytes.* Halophytes can successfully regenerate and establish in the saline environment. While many of them have specialized rhizomorphs with stilt roots that ensure anchorage in the highly unstable soil, some of them have specialized breathing roots (Plate 2) – the *pneumatophores that* protrude above the ground and augment the breathing ability in the anoxic soil. A few others have specialized secretary glands that excrete the salt contained in the absorbed water. Many of these plants also produce seedlings directly on the mother trees, a phenomenon referred to as *vivipary.* Mangrove vegetations show characteristic zonation with highly salt-tolerant and tide- tolerant species with stilt roots towards the tidal front and less tolerant species with pneumatophores distributed further landward.

Plate 2. Mangroves in Valapattanam

Mangroves are plants adapted to muddy, shifting, saline conditions. The characteristic mangrove species found along the west coast, *Rhizophora mucronata, Avicennia officianlis, A. marina,* and *Excoecaria agallocha* are sufficiently large trees. *Aegiceras corniculatam, Kandelia candel and Cerbera manghas* are trees of medium stature, and *Acanthus ilicifolius,* is a gregarious spinescent shrub. *Clerodendrum inerme* is a climbing or straggling mangrove associated shrub. There are places, where the swamp fern, *Acrostichum aureum,* grows gregariously. A species of grass belonging to the genus *Aeluropus lagopoides* is a pioneer on sandy beds and some species of *Cyperus* and *Elaeocharis* are also pioneers in muddy, more or less stagnant open swamps.

The mangrove areas are biodiversity rich areas. For instance in Kannur, CED (2006) recorded 106 trees, 87 fishes, 58 insects and 44 birds. Out of total birds, 31.82 per cent are long distant migrants. Another study by Jayson (2006) recorded eighty three species of birds from Kannur area belonging to 13 Orders and 31 Families. Out of the 83 species located from the whole study area, 18 species were migrants and others were residents. Based on the dominance index, the study pointed out that, barring a few species, all others are very rare. Presence of endemic and threatened species highlights the conservation value of mangroves at Kannur. Among insects, the abundance of butterfly species can be attributed to the large diversity and abundance of flowering trees.

It is true that a large body of the documented literature expresses the view that mangroves serve as '*nature's nursery*' for a variety of marine fishes and other animals of food value to man. Many saline fishes and shrimp species are believed to migrate to the mangroves, where they swarm their fingerlings and young ones. It is generally argued that the mangroves are safer sites for the young ones; the rugged geomorphology of the mangrove ground surface due to the intricately ramifying prop roots and the thousands of erect standing breathing roots provide a difficult-to move around three dimensional space, if not a difficult-to-access zone, for larger predators of the fishes and other fauna.

Here, unlike in the case of fishes, the mudflats and wetlands are actually the feeding grounds both for the young and adult birds, and the mangrove trees are safe roosting

sites directly overhead their food sources. However, recent study on avian fauna in the wetlands of Kerala (CED, 2006) revealed that, the migrant birds arrival to our wetlands have worn-out both in species and number, presumably because of the high rates of destruction of the mangrove habitats.

Many kinds of microorganisms are found growing associated with the roots, prop roots and the breathing roots of mangroves. These organisms are supposed to have much reciprocal utility to the host as well. In addition, the mesophyll of many mangrove leaves contains endophytic fungi. Fungal endophytes associated with mangroves are diverse, yet the fundamental aspects of their interaction with the hosts are unknown; some endophytes have a high metabolic versatility and produce novel secondary metabolites of industrial importance.

Mangroves, because of their numerous prop roots, knee and other respiratory roots form a skeletal biological meshwork underneath the ground, much like a shallow geotextile. This root-textile is a porous meshwork facilitating accumulation of debris. It does not easily yield to the tidal waves associated with natural disasters mentioned above, as it does not let the soil loosen. In other words, the mangrove stands tranquilize the tidal waves and are therefore rightly the '*coast guards*' or '*watch dogs*' of the shoreline geography and geomorphology. The lessons that we learn from the last few decades of coastline protection activities is that, construction of sea walls and bay building are not as effective as the mangroves in calming down the invading sea. All the more, when the global warming reaches its peak, for economic and other reasons also, it is not even practical to build such rock fortifications all around the shore(s).

Unlike artificial barriers, a bio-shield like the mangrove is quite effective; the beauty of the mangrove is that it would be self-regenerating and resource limitation would not arise, as the sea-land interface is a nutrient rich environment. Most mangroves are also highly regenerative, without any innate reproductive constraints; all what we need to provide is an undisturbed land flush with saline water.

Mangrove trees offer significant and unique habitat to birds, mammals, and fish populations through a complex marine food chain, creation of breeding habitat, and establishment of restrictive areas that offer protection for maturing offspring. Mangrove plants produce about one kilogram of litter (mainly leaves, twigs, bark, fruit and flowers) per square meter per year. Crabs consume some of this but most must be broken down before the nutrients become available to other animals. That is where the bacteria, along with fungi, come in. Dividing sometimes every few minutes, they feast on the litter, increasing its food value by reducing unusable carbohydrates and increasing the amount of protein - up to four times on a leaf which has been in seawater for a few months. Fish and prawns then eat partly decomposed leaf particles, loaded with colonies of protein-rich microorganisms. They in turn produce waste that, along with the smallest mangrove debris, is munched up by mollusks and small crustaceans. Even dissolved substances are used by plankton or, if they land on the mud surface, are browsed by animals such as crabs and mud whelks.

This process is not confined to the mangroves. While some litter is recycled on the spot, this system is one of the few to export much of the organic matter it produces. Every time the tide retreats, it carries a cargo of food out to sea. This material is deposited over an area of 260 km^2 of seabed. Here bacterial densities are almost as high as those in the mangrove mud and they do much the same job, breaking down the litter to be consumed by bottom-living fauna, prawns and fish. An estimated 75 per cent of commercially caught fish and prawns depend directly on mangroves at some time in their lives or feed on food chains leading back there. Since those species making up the remainder of the catch probably also owe much to nutrients exported from the mangroves, these coastal forests can be seen as one of our major assets. Major ecological functions are summarized in Box 1.

Box 1.Ecological Functions of Mangroves

Shoreline Stabilisation: Mangroves prevent or reduce erosion of coastlines. This is achieved through the binding and stabilization of soil by plant roots and deposited vegetative matter, the dissipation of erosion forces such as wave and wind energy, and the trapping of sediments. If mangroves are cut, flooding and erosion of the coast can occur.

Groundwater Recharge: Groundwater recharge refers to the movement (usually downward) of surface water into the groundwater flow system. Water which moves from the mangrove to an aquifer can remain as part of the shallow groundwater system, which may supply water to surrounding areas and sustain the water table, or it may eventually move into the deep groundwater system, providing a long term water resource. This is of value to communities and industries that rely on medium/deep wells as a source of water.

Groundwater Discharge: Groundwater discharge refers to the movement (usually upwards) of groundwater into surface water (e.g., springs). Mangroves typically have moderate or uncertain groundwater discharge functions.

Flood and Flow Control: Flood and flow control refers to the process by which excess amounts of water (which may occur in times of heavy rainfall or high flows in rivers) enter a mangrove and are stored or delayed in their down slope journey.

Sediment and Nutrient Retention: The physical properties of mangroves (e.g., vegetation, size, water depth) tend to slow down the flow of water. This facilitates sediment deposition. This deposition is closely linked to the beneficial removal of toxicants and nutrients since these substances are often bound to sediment particles. Nutrients are often associated with sediments and therefore can be deposited at the same time.

Habitat Protection and Biodiversity: Habitat may provide both food and shelter to organisms. Mangroves provide important habitats for the life cycle of important plants and animal species. For some species, especially plants, a particular mangrove may provide every element required to complete their life cycle. Other species may depend on the mangrove area for part of a more complex life cycle, including many aquatic animals such as fish and prawn which depend on mangrove areas for spawning and juvenile development.

Many species of migratory birds depend on mangroves for part of their life cycle (e.g., for resting or feeding while on migration) and in these cases the value of the mangrove on which they depend needs to be assessed on an international scale.

Biomass and Productivity: Ecosystem biomass represents the base of the food chain and as such is a critical variable to measure when one is interested in the overall functioning of the system.

The standing stock of plant biomass represents the 'natural capital' of the system that is combined with nutrients, water, and light to maintain the existing biomass, grow new biomass, and support the rest of the food chain. Plant biomass is also important as a structural, abiotic feature in the landscape. It can perform physical as well as biological functions, like trapping sediments and serving as nesting sites for animals.

Gene Bank: Many mangrove areas contain wild species which have the potential to contribute genetic material for the improvement of commercial species. For example, genes from wild species can be important for improving taste and growth rates of agricultural products, and in reducing their susceptibility to disease.

Recreation and Tourism: Mangrove areas may be used for recreation and tourism. Sites more suitable for recreation and tourism are those where adequate infrastructure is present or where there is the potential for developing adequate infrastructure.

Hunting and Fishing: Hunting and fishing refers to the removal and utilisation of mangrove-dependent wild animals by humans for commercial and subsistence purposes.

Forestry Products: Mangrove ecosystem provides wood for construction and energy. Energy products may be in the form of fuel wood or charcoal.

Water Transport: Waterways within a mangrove system may be used to transport passengers and goods to local markets. Water transport may be the most efficient, as well as the most environmentally sound method of transport. In some cases, it may be the only practical means of transport.

Source: Ruitenbeek, 1994.

Man-mangrove interaction

Mangrove resources are harvested for subsistence as well as commercial purposes (Plate 3a, 3b, 3c, 3d). Mangrove dwellers can be classified into two, namely, those who live nearby and depend heavily on mangrove for their livelihood and those who partially depend on mangrove. The first category consists of people who undertake a variety of economic activities such as fishing, prawn catching, crab catching, shell mining and processing, sand mining, coir retting, and ferry service. They also collect firewood, fodder from the mangroves. But the second category of dwellers do agriculture as, their main source of income besides, jobs in private and government sector. Their agricultural activities are nearby mangrove areas and ecological factors in the mangrove areas influence the agricultural productivities. For instance, the selection of rice varieties of a mangrove area is determined by level of tides, sedimentation, etc. in the area.

Plate 3a. Sand mining

Plate 3b. Shell mining

Plate 3c. Fishing

Plate 3d. Fuel wood collection

Profile studies

With an average family size of 4 the primary stakeholders in the study area depict a heterogeneous community feature (Table 2). Of the sample, only 40 per cent depend heavily on the mangroves for their livelihood and others are partial dependents. With an annual income of Rs. 56,170 and 97 per cent literacy, the employment scenario depicts primary sector dominance.

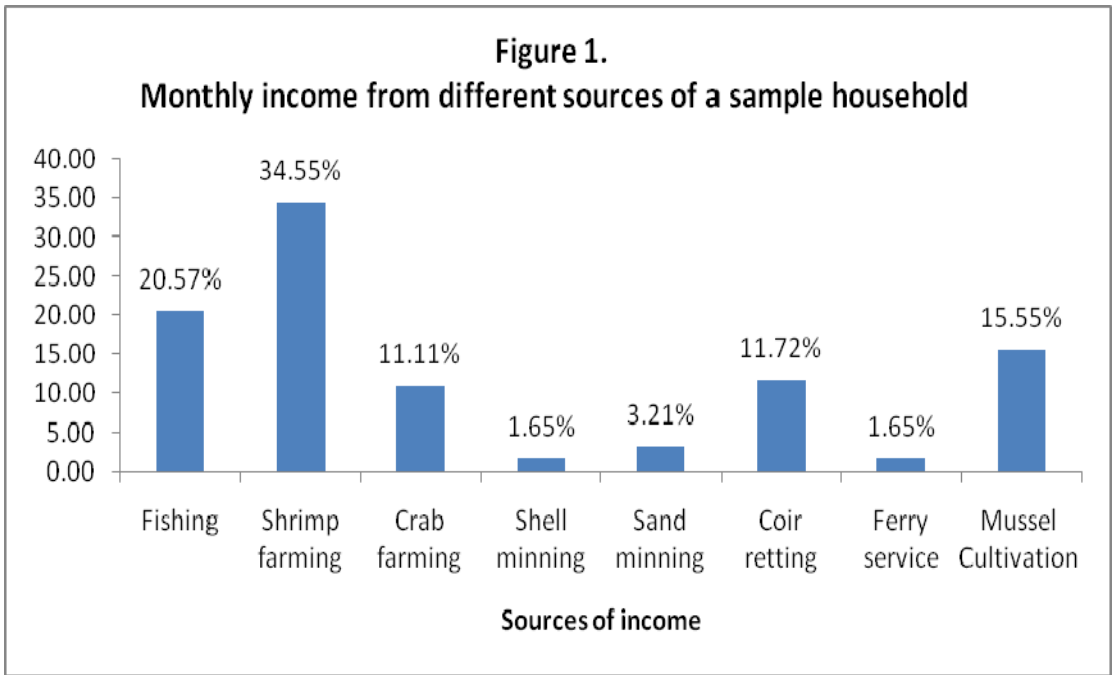
Table 2. Socioeconomic profile	
SOCIAL	
Community features	Heterogeneous
Average family size	4
Literacy	97 %
Primary	12 %
High school	73 %
College	13 %
Expenditure pattern (Food)	44 %
ECONOMIC	
Employment (primary sector)	74 %
Average annual income	Rs.56,170/-
0-50000	49 %
50,000-1,00,000	45 %
1,00,000-1,50,000	3 %
> 1,50,000	3 %

Primary data estimates

3. THE ECONOMICS OF MANGROVE ECOSYSTEM

The once self contained subsistence economy associated with the mangrove ecosystem is today highly /closely related to the market. Of the total income only 40 per cent income is derived from mangrove sector by means of catching fish and other seafood; rest is obtained from agriculture and service sector. Agricultural activities are carried out in nearby mangrove area, for instance 'Kaipad cultivation' (paddy cultivation in low lying areas) nearby mangroves in Kannur. Fuel wood and fodder are also collected from these areas. If the income from these sources is taken into consideration it accounts for 70 per cent.

The various economic activities undertaken in the study area include fishing, shrimp and crab farming, shell and sand mining, coir retting, ferry services, and mussel cultivation contributing to an amount of Rs.12.155 per month (Figure 1). Shrimp farming contributes approximately 34.55 per cent of the total monthly income followed by mussel cultivation (15.55 %) and fishing (20.57 %). Fishing helps the nearby workers to earn money and to meet their subsistence, which has significantly reduced poverty in the areas.



The two major alternative uses of mangrove areas are shrimp farming and paddy cultivation already mentioned. An attempt is made here to briefly examine how these contribute to the socioeconomic conditions of the mangrove dependents.

Shrimp farming

The production of shrimp depends not only on the fishing grounds but also on the quantity of shrimp which spawn offshore. Pelagic larve drift to estuaries, thus, mangrove swamps serve as nursery areas. It is generally said that there is a linear relationship between mangrove area and production of shrimp.

Shrimp cultivation is popular in Kannur District (Plate 4). Generally, this is done by economically well off farmers who are not living nearby. They generally come during the farming season and supervise it and rest of the work will be done by his workers. The farm was developed by felling mangroves as is evident for the farm is bordered with mangroves. A detailed study on cost of shrimp farming in the study area has been conducted by Cherukunnu Krishibhavan in Kannur (Appendix 2).

Plate 4. Shrimp farming in Ezhome panchayath

The wage amounts to Rs 30,800/- per hectare of which the permanent and temporary labour accounts for 98 and 2 per cent respectively, indicating that it is not labour intensive in nature. However, the profitability of shrimp farm is very high, for instance, profit of one hectare of shrimp farm amounts to Rs. 4.20 lakhs as against the cost of Rs. 1.05 lakhs. Details of shrimp farming are given in Box 2.

Box 2: Details of Shrimp farming

Preparation of the pond

Preparation of the pond is the first activity of shrimp farming. After dewatering the pond, lime is applied to kill the weed fishes and to reduce the acidity of the soil. Then water is let in through a netted sluice or through pump sets. Organic (cow dung) and inorganic (Urea and Super phosphate) fertilizers are applied to enhance natural food organisms. The pH and salinity of water is tested periodically to ensure that it is maintained properly. After that the post larvae are introduced into the pond.

Stocking rate

The normal stocking rate of post larvae is 50,000 numbers per ha. The seeds are collected from the *Malsyafed* @ 30 paisa / seedling. Water quality is continuously monitored and the optimum levels of important parameters such as dissolved oxygen, pH and salinity are regulated by resorting to periodical exchange of water. Some farmers resort to aeration of the ponds using mechanical/ electrical aerators.

Feeding

For better result large farmers give artificial feeds. These feeds are mixed with water and given in trays immersed in the water at four or five different places in the pond. The feed trays are immersed with the help of a stone and taken up with the help of rope tied to it. Some farmers also use Probiotics (Probiotics is a live microbial feed supplement, which beneficially affects the host animal nutrition and health by improving its intestinal microbial balance). Feed is the major cost of shrimp farming.

There are a variety of lethal viral diseases that affect shrimp. In the densely populated, monocultural farms such virus infections spread rapidly and may wipe out the whole

shrimp population. The disease is highly contagious and leads to mass mortality within 2 to 4 days. There are also a number of bacterial infections that are lethal to shrimp. The mortality rate can exceed 70 per cent. In Kannur, due to such viral diseases many of the farms are abandoned.

Rice Cultivation (*Kaipad)*

A historic analysis (Table 3) of the relationship between paddy and mangroves clearly indicates that over a period of time the commercialization of agriculture has had an adverse impact on the mangrove ecosystems.

Table 3 : Historic relationship between paddy cultivation and Mangroves

Period	Mangrove	Paddy	Reason
Before 1940	High	Low	✓ Traditional method of agriculture production
After 1960	Decreasing	Increasing	✓ Commercialization of agriculture
After 2000	Increasing	Decreasing	✓ Scarcity of skilled labour ✓ Afforestation efforts

Rice cultivation more commonly known as ‘Kaipad’ cultivation (Plate 5) is carried out in the erstwhile mangrove areas in Kannur. These areas are low lying where the cultivation is carried out during the summer period. Generally long varieties are grown, considering flooding during the monsoon season.

Plate 5. Kaipad cultivation

Per hectare labour input, the average wage expenditure and the cost of Kaipad cultivation as per Cherukunnu Krishibhavan indicates that it is highly labour intensive (Appendix 3, 4, 5).

A comparative analysis of the profitability of paddy and shrimp farming (Figure 2) in Cherukunnu highlighted that scientific shrimp farming is more profitable than paddy cultivation. Market price of shrimps is higher than paddy and is also catering to a larger market.

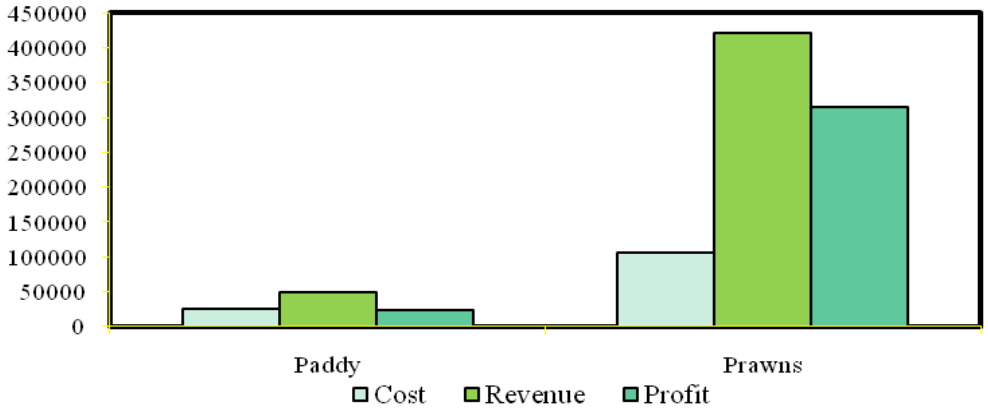


Figure 2. Profitability of paddy and prawns cultivation in Cherukunnu(per hectare)

4. THE ECONOMIC VALUES OF THE MANGROVE ECOSYSTEM

The full value of mangrove ecosystems is often not recognized. This may be attributed to two factors (Hamilton *et al*., 1989): (i) many of the goods and services provided by these ecosystems are not traded on markets and thus do not have an observable value; and (ii) some of these goods and services occur off-site and are therefore not readily acknowledged as being related to mangrove ecosystems. As a result, it is often concluded that mangroves should be developed for uses, which generate directly marketable products, such as aquaculture. However, such decisions ignore the opportunity cost of development. Methods for valuing environmental goods and services offer a more comprehensive valuation of the many goods and services provided by mangrove ecosystems, and thereby contribute to more informed decision-making. The values of the mangrove ecosystem in the study area are given in Box 3.

It is beyond the scope of the study to work out the economic value of mangroves in Kerala. However, Table 4 provides a range of values that have been arrived at in various countries for the mangroves. In Fiji it is around Rs.135,300 $ha^{-1}yr^{-1}$, and in Thailand it ranges from Rs.160,300 to Rs.205,600 hectare per year.

Box 3: Economic values of mangrove ecosystem

a. Direct use values

The direct use values are those outputs that can be consumed directly.

- *Firewood:* Wood from mangrove forests is also widely used as firewood by dwellers and people who live along the coastline.
- *Poles:* Poles are used for many purposes where water-resistance is needed.
- *Construction materials:* Mangrove timber is used for house construction mainly by people who live in or close to the mangrove forest.
- *Fishing gear:* Various types of fishing gear are used by mangrove dwellers, and some of the equipment is made of mangrove wood.
- *Tanning:* Mangrove bark can also be used for tanning.
- *Medicines:* Some mangrove species are used for medicines.
- *Fishery products:* Mangrove areas are extensively used for both capture and culture fisheries.

b. Indirect use values

The mangroves provide a number of indirect use values or functional benefits like ecological functions, flood control and storm protection, biodiversity conservation, habitat for birds, prevention of soil erosion, etc.

c. Other values

In addition to above values, the mangrove gives a number of other values such as

i. Option values- future direct and indirect use values,
ii. Bequest values- value of leaving use and non-use values for offspring
iii. Existence value- value from knowledge of continued existence.

Table 4. Economic value (US $ ha^{-1}yr^{-1}) of goods and services supported by mangroves in selected countries

No.	Value segments	Fiji	Indonesia	Philippines	Kosrae	Thailand
1	Forestry	6	6.7	251	178	140(-1059)*
2	Fisheries	100	117	60	461	8 (-63)*
3	Biodiversity	–	15	–	–	–
4	Erosion	–	3	–	–	2,990
5	Nutrient filter (Waste treatment)	2,600	–	–	–	–
6	Carbon sequestration	–	–	–	–	86
	Total (US $)	2,706	102	311	426(-640)	3,206 (-4,112)
	Rupee equivalent[+]	**1,08,240**	**4,080**	**12,440**	**17,040 (-25,600)**	**1,28,240 (-1,64,480)**

Source: Lal (2003). * Includes NTFPs plus coastal fishing; ** Offshore fisheries

[+] Rupee equivalent of US $ calculated at Rs.40/dollar

In India, Hirway and Goswami (2004) have arrived at the values, as given in Table 5, for the mangroves in Gujarat. The total value is Rs.243,700 ha^{-1}yr^{-1}, which is higher than that for Fiji and Thailand mentioned above. In the absence of other complementary studies from India, these values would give some broad idea about the values of mangroves.

Table 5 : Values of mangrove in Gujarat, as arrived at by Hirway and Goswami (2004)*

Ecosystem	Direct use value	Indirect use value	Non-use value	Total value
Mangroves of Gujarat	Rs. 17,600	Rs. 28,400	Rs.197,700	**Rs.243,700**

* All values per ha/yr.

Willingness to Pay

In the study area ie., in the selected Blocks (Kannur, Edakad, Payannur, Thaliparaba, and Thalassery) where mangroves are prevalent, the total number of households were 2,36,314. With regard to the Willingness to Pay (WTP) response for the protection and conservation of mangrove ecosystems, only 82 per cent responded in the affirmative and only they were included in the analysis. The mean WTP worked out to be Rs. 31/- with a standard deviation of Rs. 28.68 (Table 6). Thus, the total WTP amounts to Rs. 73,25,734. Only nine per cent of the respondents were willing to pay Rs.100/- to conserve mangrove and 18 per cent of the respondents were not willing to pay a single rupee for the same. Respondents stating a zero WTP were asked to express personal reasons for *not* wanting to contribute anything to the protection of mangroves. Of the total respondents 67 per cent opined that conservation of mangrove and biodiversity is the duty of Government.

Table 6. Analysis of WTP

WTP (in Rs.)	**Percentage**
0	18
5	8
10	7
15	5
20	1
25	26
50	26
100	9
Total	100
Mean WTP	Rs. 31
Min WTP	Rs. 5
Max WTP	Rs. 100
Std. Dev	28.68

5. THE ECONOMIC- ECOLOGICAL LINKAGES

The mangrove ecosystem and socioeconomic system are closely interlinked. The mangroves as a natural resource and as protector of the environment play a very important role in the economic and ecological well being of the localities. In fact the ecosystem is so delicate that these two aspects can not be separated without damaging the area. Any disturbance in the natural nutrient flow to mangrove seriously affects their structure and productivity. The mangroves are closely linked with the terrestrial system because the rivers carry down the much needed nutrient which in turn is re-exported in the form of leaf litter. Therefore the biomass productivity in the mangrove or similar areas is very high**.** Unar (1982) estimated 2000g m^{-2} $year^{-1}$ in the estuary as compared to 730 in land and 155 in at sea. In one hectare area, mangrove forest could produce 4 tonnes of detrital plants which deteriorate slowly and provide a constant supply of food for marine organisms.

The mangrove swamps provide a rich source of food for coastal and offshore marine communities. There is a large amount of inorganic nutrients from the land and decomposed leaves supply valuable organic nutrients. Thus mangrove swamps serve as feeding, breeding, spawning and nursery ground for many marine organisms. The tidal characteristics of the mangrove swamps provide an ecosystem which offers great productivity potential for marine biota and specifically are well suited for fish and shrimp production.

Human effects in the mangrove areas are twofold: reclamation of land for inhabitation and agriculture and the utilization of mangrove resources for economic profit. As mentioned earlier, there has been a drastic reduction in the area under mangrove ecosystem in Kerala, a consequence of growing human settlement and enlarging agricultural areas. The Kaipad cultivation and shrimp farm carried out in the mangrove areas are classic examples for agricultural development. Wood cutting for construction and fuel wood requirements were in practice in olden days. Due to dwindling of wood

resources in the mangrove areas, this was drastically reduced. Further mangrove soils are anaerobic and become acidic upon oxidation; hence they are not well suited for agriculture, unless lime is present. Pest and diseases are most common in the Kaipad cultivation areas and shrimp farming as a result of which many farmers have given up these activities in many places.

RESPONDENT PERCEPTIONS

The respective priorities of the respondents have been ascertained subjectively by ranking and scaling techniques.

On *social and environmental problems* associated with mangroves 79 per cent of the respondents indicated health problems (because inundation of water results in breeding of mosquitoes), 60 per cent low agricultural productivity (60 %), and 42 per cent highlighted water pollution (Table 7). Furthermore, they indicated that protecting natural habitats and wildlife is a social and environmental problem and is the responsibility of the Government.

Table 7. Ranking of social problems

Problem	Most important (in %)	Second most important (in %)	Total
Agricultural productivity	58	2	60 (2)
Health problem	31	48	79 (1)
Water pollution	7	35	42 (3)
Protecting natural habitat and wildlife	1	2	3 (5)
Improving quality of education	3	13	16 (4)

Figures in parenthesis represent respective percentages

In the case of environment, water pollution and logging were considered as the most important problems associated with mangroves (Table 8). Only 3 per cent of the population cited wildlife threat.

Table 8. Ranking of Environmental problems

Problem	Most Worry about (in %)	Second most worry about (in %)	Total
Air pollution	3	4	7 (3)
Water pollution	69	29	98 (1)
Logging	25	65	90 (2)
Landslides/ floods	0	2	2 (5)
Wild life threat	3	0	3 (4)

Figures in parenthesis represent respective percentages

On the *status of mangroves* over a period of time, 72 per cent of the respondents opined that area under mangroves has increased while 26 per cent held that there has been decrease. The major causatives for this increase in the study area as recorded by the respondents are replanting/afforestation efforts, natural processes, and enforcement of environment protection measures (Table 9).

Table 9. Respondent perception of increase in mangroves

Reasons	No. of respondents
Less use of mangrove forest	2 (2)
Natural processes	45 (34)
Replanting/ afforestation	69 (53)
Enforcement of environmental protection measures	15 (11)
	131

Figures in parenthesis represent respective percentages

Furthermore, respondents indicated that unauthorized harvesting/ clear felling and commercialization of agriculture were the main reasons for the reduction of the mangrove forest in the study area (Table 10).

Table 10. Respondent perception of decrease in mangroves

Reasons	No. of respondents	Percentage
Consumption by local people	0	0
Large scale shrimp farming	2 (4)	4
Unauthorized harvesting / clear felling	34 (72)	72
Commercialization of agriculture	11 (24)	24
	47	100

Figures in parenthesis represent respective percentages

The respondent perception on the *benefits derived from mangroves* highlighted forestry products (46 %) and seafood (26%) as the most important, followed by flood prevention and soil erosion and fodder (Table 11). This is indicative of the fact that respondents gave more weightage to the direct economic benefits of the ecosystem**.**

Table 11. Respondent perception on the benefits derived from mangrove

Type of benefit	No. of Respondents
Sea food	46 (36)
Forestry products	84 (46)
Fodder	11 (6)
Flood prevention/ soil erosion	17 (9)
Don't know	24 (13)
Total	182

Figures in parenthesis represent respective percentages

Respondent perception highlighted increasing commercial activity (58%) as the major *problem related to mangrove conservation* in the study area (Table 12). Increasing commercialization of agriculture, shrimp farming, among other commercial activities led to clear felling of mangrove areas.

Table 12. Respondent perception on major problems related to mangrove Conservation

Problems related to mangrove conservation	No. of respondents	Percentage
Waste disposal	3 (2)	2
Lack of public- private coordination	51 (28)	28
Lack of public effort	6	3
Increasing commercial activity	106	58
Unscientific development	2	1
Don't know	14	8
Total	182	100

Figures in parenthesis represent respective percentages

On the *major threat from mangroves*, the respondents highlighted wildlife threats followed by mangroves being a breeding ground for mosquitoes (Table 13).

Table 13. Respondent perception on major threats from mangroves

Threats from mangrove to local community	No. of Respondents
Wild life threat	96 (53)
Breeding ground for mosquitoes	63(35)
Unscientific mangrove forestry	2 (1)
Loss of agricultural land	21(12)
Total	182

Figures in parenthesis represent respective percentages

6. DEPLETION OF MANGROVES IN KERALA: SOCIOECONOMIC CAUSATIVES

The mangroves in the State are threatened with unprecedented destruction, which includes commercial exploitation of raw materials, land reclamation for agriculture, aquaculture and housing. Population increase, mining, and over-exploitation of mangrove forests without replanting are some of the other factors influencing depletion of mangroves in Kerala.

There have been significant changes in the traditional and present uses of resources within the mangrove system, which has much implication on its depletion. For instance, the traditional mangrove dwellers/dependents who often combined the use of land, sea, and inter-tidal resources, were basically involved in primary subsistence activities (agriculture and fishing). Now this trend has changed and a significant number of them are associated with commercial activities. The traditional mangrove ecosystem was, by and large, self-reliant following subsistence production, but now it is closely related to market, resulting in its depletion (Plate 6). Socially, afforestation programme would be benefiting people living in coastal areas in terms of protection, environmental services and support for livelihood.

Plate 6. Mangrove degradation

Why Mangrove Restoration Does Not Progress?

As in many other tropical countries (FAO, 1994), mangrove afforestation has been quite successful in India also (Singh, 2006). Tamil Nadu, Gujarat, Andhra Pradesh and some other states have materialized large-scale mangrove afforestation (Singh, 2006). Mass multiplication techniques and details of nursery management are now available in fair details for a number of mangrove trees (Singh, 2006). It is strange that the mangrove afforestation initiative does not make a successful leap in Kerala! The estuaries of the 41 rivers together with the backwaters provide a sizable area (Mohanan, 2004) congenial for mangrove afforestation.

Having discussed the need, it is worthwhile to make an analysis of the reason why mangrove afforestation is not progressing well in the State. Swarupanandan and Muraleedharan (2004) examined some ecological and economic aspects of the problem. Swarupanandan and Bose (2005, 2006) examined the problem using the General Theory of Succession, a tool that they developed for examining dynamic systems. We shall consider some of the more important results of this analysis here. Table 14 provides different resources needed for the active progress of mangrove afforestation.

Each one of the resources mentioned in Table 14 can be limiting and retarding the mangrove initiative, depending upon the site. Our current interest, however, is not to dwell on each one of these. Rather, we would address a select couple of limiting resources and to explore the possibilities to unlimit them to a positive standing. These are the land and financial resources that closely interact and mutate each other.

Table 14: Different resources needed for the active progress of mangrove afforestation

1. Natural resources	**3. Scientific resources**
• Tropical/ subtropical climate	• Knowledge of the biology/ ecology of mangrove species
• Land	• Mass multiplication technology
• Nutrient-rich soil	• Knowledge of appropriate afforestation techniques
• Inundation of salt-water	**4. Human resources**
• Mangrove genetic resources	• Experts having knowledge of the mangrove ecosystem
2. Socioeconomic resources	• Work force for afforestation
• Finance for afforestation	**5. Institutional resources**
• Congenial social environment	• An authority for coordination of mangrove initiatives across various agencies
• Appropriate policy facilitating mangrove afforestation	• An agency for conserving, protecting and managing the present and future mangrove forest patches
• Appropriate legal modalities	• Technical infrastructure including the tools & equipments
• Ample public awareness of the importance of mangroves	• Nurseries

The Land versus Financial Resource Conflict

In Kerala, the coastal and estuarine lands that are potentially mangrove sites belong to different categories of public as well as private ownership. Sample studies have shown that 80-90 per cent of the potential lands belong to private ownership (Nayak *et al*., 2000)**,** including that of communities and corporates. The public lands include the holdings with the Fisheries Department and the Revenue Department (Panchayaths). As the Revenue Department's mandate is not environment, in some areas the State Forest Department has rightly initiated procedures for notifying these areas for mangrove

conservation. However, it is quite unlikely that the Government Departments would invest in private holdings, as the land use policies in these holdings may change in shorter time spans. This would mean that the major chunk of the potential mangrove lands would either fall outside redevelopment initiatives, or that the initiative has to come from the owners of the land themselves. Unfortunately, private owners are not interested in growing mangroves, as they do not provide any significant direct economic benefits. Thus, there is a pronounced resource conflict, rather a paired paradox, across the two sectors of ownership. These are:

1. Apparently the Government is convinced of the need for massive mangrove redevelopment (and green belt planting) along the coastal belt and has the economic resources to afforest the same, but is precisely devoid of land.
2. On the other hand, the private owners with whom the major portion of the suitable land holdings are vested, do not have the willingness for mangrove conservation and afforestation and even if they desire so, they do not have the required financial resources to materialize the same, or it conflicts with their livelihood.

This conflict is a big bottleneck, holding the mangrove initiative back. If we are to move the mangrove conservation further, either of the two resource situations as detailed below should arise.

1. The Government is provided with the ownership of required coastal and estuarine lands, which can be afforested.
2. Ample financial resources are made available to the private sector, so that the land owners are motivated for mangrove redevelopment and benefited from that.

Which of the two resource situations is ideal for the mangrove initiative? The society can be divided in opinion. The State Forest Department apparently has a prospective plan to buy out potential lands along some selected estuarine biotopes and initiate mangrove afforestation. Mangrove afforestation if it has to be meaningful, has to be done at an ecosystem level, and therefore, the land requirement should be quite large and for the very same reason the scope can be constrained. The implication of the finding therefore is

that, for a successful coastal mangrove afforestation programme, the private land holdings cannot be ignored. So, we need a definitive programme to make available the financial resources targeting mangrove afforestation in private lands.

A large number of agencies, both Governmental (plate 7) and Non-Governmental, are involved in various mangrove-related initiatives. There is no coordination across these ventures so that the effort and resources go simply wasted. A funding source devoted to wetland/mangrove initiative is lacking for the State and this makes the mangrove ecosystem redevelopment programme un-coordinated and dissipated. The Government may constitute such a fund and enhance it with additional sources by opening up 'green channel' provisions. A statutory body – a *Mangrove Authority* – responsible for streamlining the programme and managing the fund may be constituted.

Plate 7. Afforestation programme of KFD in Kannur

7. FINDINGS AND CONCLUSIONS

1. Mangrove stands are composite communities made of eu-mangroves and mangrove associates. Mangrove associates though not capable of withstanding high salinity may have important roles to play, in ecosystem functioning, as pioneers or as living reserves of selected nutrients that release the same into the ecosystem slowly. Understanding the exact functions of the mangrove associates would be of use in plantation activities.
2. A characteristic zonation of mangroves in the order, highly salt tolerant eu-mangroves less tolerant mangroves, and herbaceous species, as we move away from the shoreline is generally observed in the mangroves. Generally vast extent of one and the same species is not seen in the mangroves. So, a stratified planting of different species might be a better option. However, we are not sure of the ecosystem advantages, in terms of nutrient competition, advantages to fish swarms, etc. It would be worthwhile to understand if any such exists, so as to make use of the finding for practical planting activities. Also, mono/oligo-culture plantation would in due course undergo natural succession and incorporate compositional changes. Under these presumptions again, a mixed planting stock would tend to be ideal, but the details of the events of plant succession in mono/oligo-culture plantations would be needed to evaluate the presumption. This could be an agenda for further research.
3. Large scale planting activities would demand a good seed source of various mangrove species. Identification and conservation of good stands as seed sources for the purpose would be badly needed. This would demand considerable field exercise in terms of field botany, assessment of stands of each species and mapping the locations.
4. The use of mangroves as a natural nursery of migrant fishes and other organisms lack hardcore empirical data. This is a very essential study.
5. It is evident that mangrove ecosystems have been, and are still, used for the extraction of a variety of plant and animal products by traditional methods for the benefit of local people. Continuation of these activities requires that the remaining mangrove areas should be conserved and managed in ways that will ensure their productivity. In

order to enhance the productivity, the relevance and importance of multiple use management may be a subject for future research.

6. There is hardly any study, which gives the basic knowledge about community structure, resource utilization, and economic conditions of people living in or depending on mangroves. This acts as a constraint for implementation of an effective plan for conservation of this ecosystem. It is therefore necessary to make intensive studies of mangrove settlements, which partly or fully depend on the mangrove for their livelihood.
7. As mangroves provide a variety of benefits, valuation of goods and services provided by this ecosystem is needed for better conservation. They should be preserved as much as possible for their multiple values as sources of economic, ecological, scientific, and cultural benefits now and for future generations. Thus more information about these values of mangroves and the synergy between these values is necessary in order to feed the public dialogues and to internalize these values as part of policy and decision-making. Further a comparison costs and benefits of mangrove conservation with those by alternatives uses are also needed to know its importance. The studies on economic valuation of benefits of mangrove or/and costs of replacement of the environmental functions of the mangrove-forest ecosystem may be undertaken.

Conclusion

Large extents of mangroves do not exist today, the reasons of which lie in the changing lifestyles and patterns of resource use. A common property is a buffer, where several things unwanted in places and occasions are to be found, the value of which cannot be understood in real time. Mangroves are environmental buffers offering common ecological and economic services for vast landscapes and people over longer time spans. While entering to a phase of large-scale rebuilding of the mangrove woodlands, many ecological and socio-economic observations may find a meaningful place in the venture.

Conservation is an act of delaying or denial of the use of a resource until such time that it becomes surplus and at the same time providing scope for restoration. Two elements are

identifiable here: (i) restriction on use, and (ii) restoration. Conservation of mangroves, therefore, means restriction of the use of existing mangroves and restoration through afforestation. In the absence of a policy ensuring the sustenance of mangroves, the rules and regulations that existed for the purpose could not be implemented. By the time the environmental importance of the mangrove ecosystem was more or less understood by the mass public, most of the stands have already disappeared permanently. Restoration, perhaps, is the only way to bring the potential lands under the cover of mangroves.

REFERENCES

Barbier, E. B. 1994. Valuing environmental functions: Tropical wetlands. Land Economics 70 (2): 155-73.

Basha, S.C. 1991. Distribution of mangroves in Kerala. Indian Forester, 117(6):439-448.

Basha, S. C. 1992. Mangroves of Kerala: a fast disappearing asset. Indian Forester, 118(3):175-190.

Centre for Environment and Development (CED) 2006. Survey and inventory of wetlands of Kerala for conservation and sustainable management of resources, report submitted to Kerala Forest Department, Trivandrum.

Deshmukh, S.V. 1991. Mangroves of India: Status Report. Global Network of Mangrove Genetic Resource Center.

Eganathan, P. and Rao, C.S. 2001. *Manual of Vegetative and Micropropagation of Mangroves.* MS Swaminathan Research Foundation, Chennai.

FAO 1994. *Mangrove forest management guidelines.* FAO Forestry paper 117. FAO, Rome.

Hirway, I. and Goswami, S. 2004. Valuation of Mangroves in Gujarat. Gujarat Ecology Commission, Vadodara.

Jayson, E.A. 2007. Birds. In. *Ecological Studies to Conserve and Rehabilitate the Mangrove Vegetation in Coastal Landscape in Kerala*, KFRI Research Report (Draft), Kerala forest Research Institute, Peechi.

Hamilton, L.S., Dixon, J.A. and Miller, G.O. 1989. Mangrove forest: an undervalued resource of the land and of the sea. In: E.M. Borgese, N. Ginsburg and J.R. Morgan (eds.) Ocean Yearbook 8. The University of Chicago Press. pp. 254-288.

Lal, P. 2003. Economic valuation of mangroves and decision-making in the Pacific Ocean and coastal management, 4: 823-844

Mohanan, C.N. 2004. Conservation of the fragile ecosystem diversity of Kerala. In : CESS, *Earth System Science and Natural Resources Management.* Centre for Earth Science Studies, Thiruvananthapuram : 381-398.

Nayak, N., Nandakumar, D., Amruth, M., Unnikrishnan, P. and Padmanabhan, T.P. 2000. Wetland resources of northern Kerala: a case study of Pazhayangadi and Kunhimangalam in Kannur District. Discussion paper No. 15. Centre for

Development Studies, Thiruvananthapuram.

Ruitenbeek, H.J. 1994. Modelling economy-ecology linkages in mangroves: Economic evidence from promoting conservation in Bintuni Bay, Indonesia, Ecological Economics 10: 233-247.

Singh, H S 2006. Mangroves and their environment, with emphasis on mangroves of Gujarat. Gujarat Forest Research Institute, Gandhinagar.

Swarupanandan, K. and Bose, K. A. 2005. Modeling mangrove ecosystem recovery based on succession theory. 15th Swadeshi Science Congress, Thalassery. p 100.

Swarupanandan, K. and Bose, K. A. 2006. Strategies for mangrove ecosystem redevelopment in Kerala: an analysis of some cardinal issues. In: Proc. 18th Kerala Science Congress, Centre for Earth Science Studies, Thiruvananthapuram. pp 427-428.

Swarupanandan, K. and Muraleedharan, P. K. 2004. The mangrove ecosystem in Kerala: An ecological and socio-economic perspective and research agenda. In Proc. Training Workshop on Conservation of Mangrove Ecosystem, Kannur, Kerala. pp 21-28.

Sathirathai, S. 1997. Economic valuation of mangroves and the role of local communities in the conservation of the resources: Case study of Surat Thani, South of Thailand, Final Report Submitted to the Economy and Environment Program for Southeast Asia (EEPSEA), EEPSEA, Singapore.

Unar, M. 1982. Socio-economic aspects of mangroves. In: Prosiding pertemuan Teknis Evaluasi Hasil Survai Hutan Bakau, Jakarta, 1-3 June 1982, Director General of Fisheries, Jakarta, pp.431-444

APPENDICES

Appendix 1. Mangrove Ecosystems of Kerala

Sl.No.	Mangrove Area	Location - District
1.	Chittari	Kasargod
2.	Dharmadom	Kannur
3.	Nadakkavu	Kannur
4.	Edakkad	Kannur
5.	Valapattanam	Kannur
6.	Pappinisseri	Kannur
7.	Muzhapilangad	Kannur
8.	Kunhimangalam	Kannur
9.	Pazhayangadi	Kannur
10.	Kavvai	Kannur
11.	Thalassery	Kannur
12.	Ezhimala	Kannur
13.	Mahe	Kannur
14.	Kotti	Kozhikode
15.	Koduvalli	Kozhikode
16.	Badagara	Kozhikode
17.	Kallai	Kozhikode
18.	Kadalundi	Kozhikode/ Malappuram
19.	Tirur	Malappuram
20.	Chetwai	Thrissur
21.	Edappalli	Ernakulam
22.	Panangad	Ernakulam
23.	Aroor	Ernakulam
24.	Kannamali	Ernakulam
25.	Puthuvypin	Ernakulam
26.	Kumarakom	Kottayam
27.	Asramom	Kollam
28.	Veli	Thiruvananthapuram

Source: Centre for Environment and Development, Thiruvananthapuram

Appendix 2: Cost of cultivation of shrimp farming (Rs. per hectare)

Sl. no	Particulars	Cost
1	Liming	375
2	Irrigation	1000
3	Seedlings	15000
4	Organic Fertilizer (Cow dung)	1500
5	Inorganic fertilizer	3500
6	Feed	40000
7	Water treatment	1500
8	Permanent labor	24000
9	Temporary labor (for harvesting)	800
10	Technician	6000
11	Transportation	10000
12	Maintenance	1000
13	Miscellaneous	1000
	Total cost	**105675**
	Total revenue	**420000**

Source: Cherukunnu Krishibhavan

Appendix 3: Per hectare labour input in *Kaippad* cultivation

Type of operation	No. of working days	
	Male	Female
Mount making	25	13
Boundary strengthening	10	0
Land preparation	10	5
Sowing	0	18
Transplanting	15	28
Weeding	0	30
Harvesting& Threshing	0	50
Transporting	5	3
Winnowing	0	20
Total	65	167

Source: Cherukunnu Krishibhavan

Appendix 4: Average wage expenditure incurred for one hectare of *kaippad* cultivation

Sl. no	Type of operation	Wage expenditure (Rs.)	
		Male	Female
1	Mount making	3750	1170
2	Boundary strengthening	1500	0
3	Land preparation	1500	450
4	Sowing	0	1620
5	Transplanting	2250	2520
6	Weeding	0	2700
7	Harvesting& Threshing	0	4500
8	Transporting	750	270
9	Winnowing	0	1800
	Total	9750	15030

Source: Cherukunnu Krishibhavan

Appendix 5, The cost of *Kaippad* cultivation

Sl. no	Particulars	Cost
1	Seed	1000
2	Mount making	4920
3	Boundary strengthening	1500
4	Land preparation	1950
5	Sowing	1620
6	Transplanting	4770
7	Weeding	2700
8	Harvesting& Threshing	4500
9	Transporting	1020
10	Winnowing	1800
Total cost		**25780**
Total revenue	**6.25 tonne (Rs 8/kg)**	**50000**

Source: Cherukunnu Krishibhavan