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Human-induced stresses on mangrove swamps along the Kenyan Coast

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Mangroves form important ecosystems in Kenya's coastal areas. They produce goods and services that are of environmental, ecological and economic importance to human society. However, mangroves are under continuing pressure from anthropogenic disturbances. A particular concern has been the clearing of mangrove areas to reclaim land for other uses such as aquaculture, salt manufacture, agriculture and housing. About 10 000 ha of mangrove areas have been cleared for salt manufacture between Ngomeni and Karawa, while in Lamu, close to 100 ha of mangrove forest was killed by dredged-up sediment that was deposited during the construction of the Mokowe sea jet. 100 ha of mangrove area have been converted for aquaculture at Ngomeni. At Gazi Bay, about l00 ha of mangrove forests was cleared for fuelwood and in Makupa Creek, Mombasa, 10 ha of mangroves died due to oil pollution. The total area lost is therefore 10 310 ha which represents about 20% of the total mangrove forest. In this paper, deforestation, conversion of mangrove areas for other land uses and pollution of mangrove swamps on the Kenyan coast are discussed and call for sustainable use, and the government policies that will enable this, is made.

Keywords

deforestation, oil pollution, mangrove conversion, sustainable management, Kenyan coastline

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Abstract

Mangroves form important ecosystems in Kenya's coastal areas. They produce goods and services that are of environmental, ecological and economic importance to human society. However, mangroves are under continuing pressure from anthropogenic disturbances. A particular concern has been the clearing of mangrove areas to reclaim land for other uses such as aquaculture, salt manufacture, agriculture and housing. About 10 000 ha of mangrove areas have been cleared for salt manufacture between Ngomeni and Karawa, while in Lamu, close to 100 ha of mangrove forest was killed by dredged-up sediment that was deposited during the construction of the Mokowe sea jet. 100 ha of mangrove area have been converted for aquaculture at Ngomeni. At Gazi Bay, about l00 ha of mangrove forests was cleared for fuelwood and in Makupa Creek, Mombasa, 10 ha of mangroves died due to oil pollution. The total area lost is therefore 10 310 ha which represents about 20% of the total mangrove forest.

In this paper, deforestation, conversion of mangrove areas for other land uses and pollution of mangrove swamps on the Kenyan coast are discussed and call for sustainable use, and the government policies that will enable this, is made.

Introduction

Mangroves are tropical and sub-tropical woody trees or shrubs that occur naturally in brackish waters or estuarine wetlands in intertidal zone (Tomlinson, 1986). Most of the mangroves occur in inter tidal areas with groundwater discharges or seepage rather than in estuaries (Ruwa & Polk, 1986). This seepage is responsible for the colonization and growth of man- groves in areas where there are no river discharges. Seepage of underground water to the seashore results in a change of micro-environmental conditions from oceanic to brackish water, creating suitable micro- habitats for colonization by mangrove seedlings and therefore offering suitable habitats for mangrove de- velopment.

The studies on mangrove forestry in Kenya have over the years tended to concentrate on distribution, utilization, community composition and zonation of the species (Graham, 1929; Isaac & Isaac, 1968; Kok- waro, 1985; Gang & Agatsiva, 1992). Some studies on macrofauna in mangroves have been undertaken by Ruwa (1990) and on macroalgae in mangroves by Coppejans & Gallin (1989). Existing accounts of mangrove zonation and structure over some parts of the Kenyan coast include publications by Walter & Steiner (1936), Gallin (1988), Beeckman et al. (1990) and Van Speybroeck (1992a). Ruwa (1993) and Van Speybroeck et al. (1993) give additional information. The utilization of the mangrove ecosystem in terms of its direct product as well as benefits derived from the manipulation of the ecosystem has well been known and widely discussed (FAO, 1982; Christensen, 1983; Hamilton & Snedaker, 1984; Kokwaro, 1985).

Two communities of mangroves occur along the Kenyan coast entailing eight species belonging to six families (Kairo, 1995). Detailed botanical descriptions of the species have been covered by Graham (1929), Kokwaro (1985) and Gallin et al. (1989), together with their zonal distribution pattern (Van Speybroeck, 1992a). The mangroves occur as creek or fringe man- groves (Macnae, 1968; Ruwa, 1993). The creek man- grove community is composed of mangrove trees that grow on low gradient shores in creeks and bays, and usually form well-developed forests that may show species zonation. From transects studies at Gazi and

Ngomeni (Ruwa, 1993) the distribution of the various species may be zoned in creek mangrove formations. More species of mangroves were rooted in lower shore levels than at higher shore levels. The zonation in an upward shore direction based on the prominent species was as follows; either *Rhizophora mucronata* Lam. or *Sonneratia alba* Sm. was the outermost species, followed by *Ceriops tagal* (Perr.) C. B. Robinson in the intermediate shore levels and then *Avicennia marina* (Forrsk.) Vierh. On the outermost landward part of the *A. marina* zone at higher shore levels conspicuous fringes of *Lumnitzera racemosa* Willd. may be encountered.

Fringe mangroves are either solitary or grow as single or mixed species clusters in front of or at the bases of rocky cliffs. In the fringe mangrove formation in Mombasa, only two species were observed *Sonneratia alba* and *Avicennia marina*, the former being the most predominant species. *Avicennia marina* grows in the landward zone of the *Sonneratia alba*. Other species found along the Kenyan coast are *Bruguiera gymnorrhiza* (L.) Lam., *Xylocarpus granatum* Koen. *Heritiera littoralis* Dryand. ex W. Ait. Zonation patterns are related to freshwater influences and to the frequency and duration of tidal inundation. The position of an individual species in the zonal sequence is presumably an expression of its physiological amplitude for the particular edaphic conditions which exist there and to competitive interactions between species. Creek mangroves are the more common along the Kenyan coast. These form the pioneer community, spreading from the shores and colonizing mud banks in creeks exposed at low tide. Continuing encroachment is impeded by strong wave action or tidal scour. Mangrove swamps, therefore, become most extensive in sheltered areas and only reach the sea at sectors of the coast within low wave energy (Abuodha, 1992; Othman, 1994).

The Kenya coastline extends from 1° 40′ S to 4° 41′ S from Kiunga in the northcoast to Vanga in the south, which is a distance of ca 575 km (Fig. 1). Along this coastline, mangroves are a common feature in deltas, creeks, protected bays, islands and river estuaries. They are mainly found in Lamu district (33 500 ha), Kwale district (8375 ha), Kilifi district (5570 ha), Tana River district (3045 ha) and Mombasa district (2490 ha) (Fig. 1). Doute et al. (1982) and Yap & Landoy (1986) while using Multi Spectral Scanner (MSS) estimated mangrove forests in Kenya to cover some 52 980 ha and 50 000 ha, respectively. Making use of aerial photographs, Forest Department of Kenya (1983) estimate total area of mangroves in Kenya as 64 990 ha representing about 0.1% of the total land area of Kenya and approximately 3.8% of the total forest cover in Kenya. The main difference in the cover estimates could be attributed to mapping of the vegetation area by the Doute et al. (1981) and Yap & Landoy (1986), against the Forest Department beacons that are set at the high water mark at spring tides. The largest concentration of mangroves occurs in Lamu (ca. 75%) including the islands of Manda and Pate and also along the Vanga-Funzi system near the Kenya–Tanzania border. Mangroves were first gazetted as forests in 1932, and the Forest Department is responsible for their management and exploitation.

Importance of mangroves

Ecologically, mangroves form nursery grounds for numerous fish and shellfish (De la Cruz, 1979). The main fisheries supported by mangrove swamps are edible crabs and small pelagic fish. Mangroves also provide habitat for birds, other vertebrates and invertebrates (Paw & Chua, 1991; Kimani et al., 1996). Mangroves also prevent siltation of coral reefs and contribute organic matter and nutrients to primary and secondary productivity of the coastal ecosystems (Heald, 1971; Odum & Heald, 1972; Van Speybroeck, 1992b). They have naturally high-energy production capacity (Christensen, 1983). A mangrove system provides a sink trap for pollutants by filtering land run-off as well as remixing terrestrial organic matter (Semesi & Howell, 1992). Heald (1971) and Odum (1971) have demonstrated the existence of food web that is dependent on the organic production of mangrove swamps.

Economically, the mangrove ecosystem serves as a source of important products to coastal populations in the form of poles and timber as building material for boats and houses, firewood, salt, tannins, dyes, charcoal and food (Macnae, 1968; Walsh, 1974; Hamilton & Snedaker, 1984). Most importantly, mangrove communities provide fishing areas for local communities. Because of these many uses, mangroves have been planted for silviculture, erosion control, recreation enhancement, restoration of damaged areas or experimental analysis of mangrove biology (Watson, 1928; Davis, 1940; Noakes, 1955; Banijbatana, 1958; Rabinowitz, 1975; Qureshi, 1990).

Mangroves systems also play an important role in coastal stabilization and protection (Macnae, 1968).

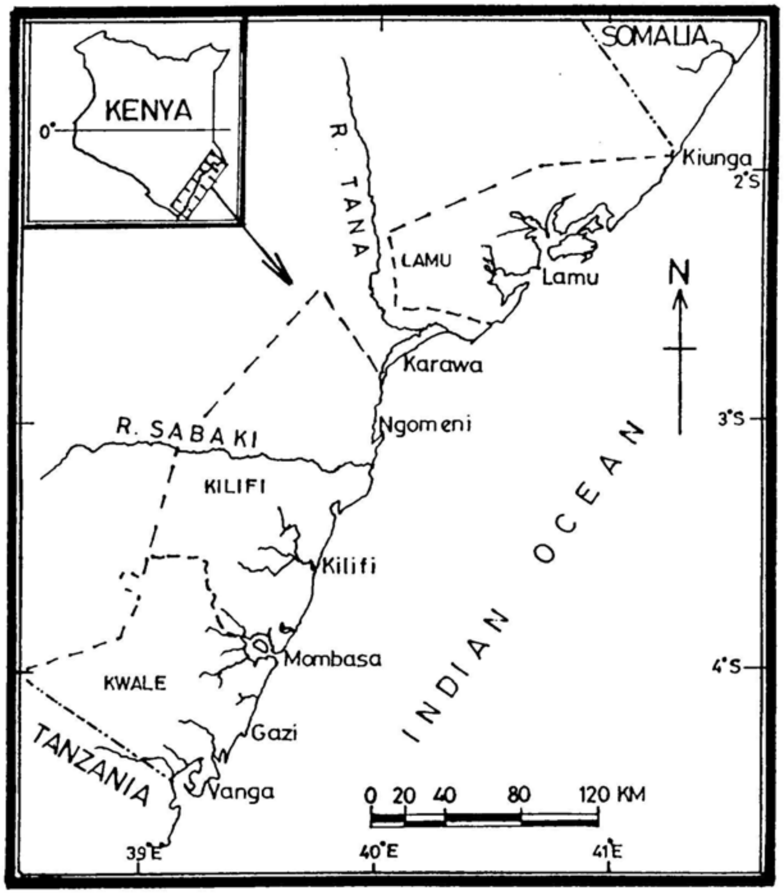

Figure 1. Map of the Kenyan coast showing mangrove areas.Approximate mangrove cover within the districts: Lamu (33 500 ha), Tana River (3 045 ha), Kilifi (5570 ha), Mombasa (2490 ha) and Kwale (8375 ha).

Davis (1940) observed that the network of prop roots and pneumatophores trap and accumulates sediments. Observations by Othman (1994) in Sungai Besar and Selangor Malaysia, suggest that even a 50 m wide belt of *Avicennia* is sufficient to reduce waves of 1 m to a height less than 0.3 m. They (especially *Avicennia),* attenuate wave energy by obstructing waves with their extensive root systems and trunks (Othman, 1994). Few estimates are available for the below ground biomas in mangrove forests, owing in difficulty of obtaining them. Of those available, most suggest that below ground biomas may represent 40–60% of the total biomas (Saenger, 1982; Lugo, 1990). These would interpret to a root biomas of 500–600 t/ha for un-disturbed forest of above ground biomas of 700 t/ha (Clough, 1992). As a wave passes through the mangroves, the roots and the trunks of the mangroves obstruct orbital water motion transmitting the wave energy. The closer the trees are together, the greater will be the attenuation of the waves. The water usually carries sediments in the form of suspended sediments and bed load. As the ability of water to carry sediments depends on flow velocity, slowing the currents results in the sediments settling. Mangroves thus exert a breakwater effect and may absorb most of the energy from storm-driven wave action particularly when stands are high density thus helping to protect housing and farms inland (Wolanski et al., 1992). In Malaysia,

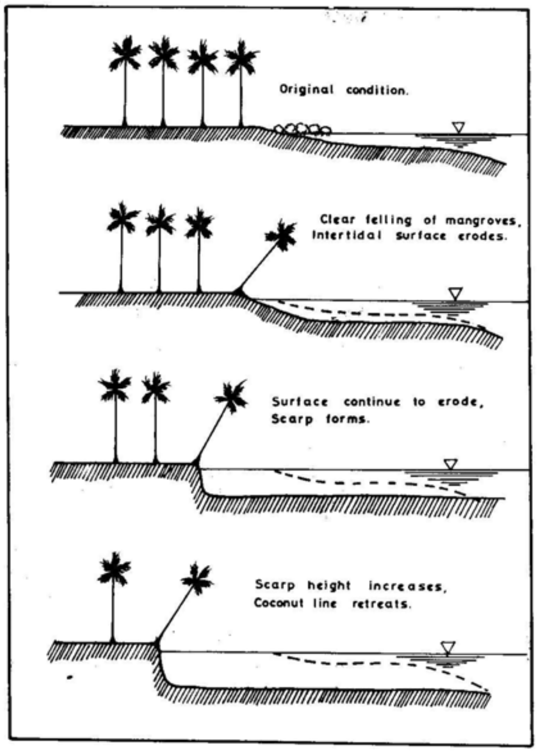

Figure 2. Retreat of the coconut plantation at Gazi. Stages in erosion (top to bottom) of the coastline. Erosion started after mangroves was clear felled for industrial fuel wood. Strong waves reaching the coconut plantation causes its erosion.

escarpment protection was first employed successfully to protect a stretch of 1.4 km of coastline (Othman, 1994). This method involves protecting the mangroves and they in turn protecting the agricultural land behind. With the success of this method, this concept is being used along the adjacent coast to protect another 1.2 km of coastline. The escarpment protection is still cheaper than the conventional method of protection using revetments as it uses less material. It also has the added bonus of retaining the mangrove swamp that can serve as a habitat for the fauna that depends on the swamp.

Mangroves need not be mature to be effective as wave attenuators. As long as trees are sufficiently dense and are as tall as the incoming wave, the trees will attenuate the waves. Othman (1994) has observed that a 5-year new growth of *Avicennia* can act as an efficient wave attenuator. Mangroves protect the coastline and farms against erosion. At Gazi, substantial erosion of the coastline commenced immediately after the clear felling for fuelwood of *Sonneratia* in front of a coconut plantation in 1977 (Fig. 2). About 100 ha of mangrove area was cleared. This exposed the roots of the coconut trees fringing the sea. Eventually, these trees toppled and the erosion continued further into the plantation. Clear-cutting of mangroves causes hydrodynamic changes in inshore circulation that tend to increase erosion of shorelines. Also at Ngomeni, much erosion has occurred after mangrove areas were converted to shrimp ponds. Ten meters of the coastline have been lost since 1970 giving a rate of loss of the coastline as 0.5 per year. The felling of mangroves was attributed partly to cutting for fuel, partly to the demand for construction material and in part to the reclamation of the rearward areas for coconut plantation. This plantation was far from successful. Apart from a coconut disease, the plants have most probably also a shortage of freshwater. It shows that one has to be quite reluctant with 'development' of this area for agriculture. Most probably the result will be very marginal agricultural land.

Human-induced stresses on mangrove swamps in Kenya

Deforestation-Timber production

The Forest Department of Kenya controls exploitation of mangroves through licensing procedures. Over cutting has seriously depleted the availability of export quality poles from most mangrove areas in Kenya. The average export of mangrove from Kenya between 1905 and 1910 was 24 150 scores (1 score = 20 poles). Between 1941 and 1956, this export average increased to 35 451 scores. This was a 47% increase. Illegal cutting and allocation of mangrove land to private developers are major problems. In Lamu alone, for example, the average annual export harvest was 30 009 scores (1 score = 20 poles) between 1941 and 1956 (Rawlins, 1957). This is 85% of all the mangroves cut along the coastline for export purposes within this period. As early as 1947, the colonial government in Kenya took strict control of mangrove exploitation by granting concession to private farms whose activities would be easily monitored. This was a highly unpopular move because of the general belief that mangroves were inexhaustible, and the long established custom of freedom from any sort of control. The exploitation of mangrove ecosystems for poles and charcoal caused political concern. In 1975, the Government of

Kenya imposed a ban on the use of mangrove poles for charcoal production. This was followed by a ban on export of mangrove poles in 1982, a step that seriously affected the economy of Lamu district. Despite the ban, the actual average harvest per year from Lamu for domestic use remained more or less equal to the 31 734 scores of mangrove poles extracted up until 1983 (Forest Department of Kenya, 1983). A removal rate from the Lamu area for domestic use is now estimated at 19 poles ha^{-1} yr^{-1}. In 1992, the Forest Department licensed the extraction of 72 100 scores of poles from Lamu forests for domestic use annually giving a removal rate of 43 poles ha^{-1} yr^{-1}. Kairo (1995) has noted that Lamu archipelago accounts for more than 60% mangrove production in Kenya. The recommendations were mostly based on the national demand of mangrove wood products rather than on the actual resource base. At this rate, the available stock of good quality wood from Lamu systems would be depleted in 5 years (Kairo, pers, comm.). These figures are also bound to exceed the natural resiliency capacity (Holling, 1973) of mangrove forests along the Kenyan coast.

Mangrove areas are destroyed because certain tree species (especially *Rhizophora, Heritiera, Bruguiera* and *Ceriops*) have strong, attractive and durable woods for firewood, charcoal, poles for boats and housing, tannin for leather among others. It is these species which should be considered seriously in the context of resource management. The species used in tradition and industrial fuel depend on the accessibility rather than on the quality. The mangroves have so much been exploited that in some areas they are threatened with extinction. This is in particular with *Xylocarpus granatum* and *Heritieri littoralis* in Kwale and Tana River districts, respectively. The estimated number of poles extracted in 1992 of these species was 440 000. This figure is quite high considering the poor growth rate of mangroves and the fact that replanting is not carried out except on an experimental basis (Kairo, 1995).

This continued loss of mangrove is associated with a decline in fisheries and other goods and services. Losses of mangroves are assumed to affect fisheries and other faunal components of the food web but little documentation exists. Lewis (1977) reports a 20% decline in commercial fisheries catches along Florida's Gulf coast, after 1960 and 1965 peaks. During this same period, 40% of the mangroves of Tampa bay was lost due to residential and commercial fills. Daugherty (1975) reports a 50% decline in the shrimp catch for El Salvador since 1964 and other decline in reptile, bird and mammal populations associated with a nearly 50% loss of mangroves for El Salvador. The decline of fisheries resources in Lamu district, Kenya, has been associated with loss of mangroves (Tiensongrusmee, 1991). Degradation of mangrove forests not only depletes the resources available within its boundary, but also affects the productivity of the adjacent waters. Anyone who has explored the mangrove and adjacent mudflats can attest to the abundance of juvenile shrimps and fishes. As to the role of mangroves in contributing to coastal productivity, the most convincing information involves the correlation between mangrove area and fisheries harvests. Jothy (1984) reports on the harvest of molluscs, crustacea and fish indicating that, with the area of mangroves along the west coast of the Malaysian peninsula being about five times that of the east coast, the overall fisheries of the former are about twice those of the latter. This differential is less for species not associated with mangroves (Marshall, 1994). However, wood extraction for fuel has declined since 1983 following the depletion of the largest mangrove trees and the inaccessibility of the resource in the remaining areas of mangrove swamps.

Conversion of mangrove areas for other land uses

Areas cleared of mangroves may be used for agriculture, aquaculture, housing and transportation networks. At Gazi bay, cultivation of oysters using artificial supports, demonstrate a possibly sustainable multiple use of the existing mangrove system. Other areas have been cleared deliberately for construction of mariculture ponds or for salt production. Release of brine from salt pans increase salinity in estuaries, especially during the dry seasons, causing salinity stress in mangroves.

Along the northern Kenyan coast, conversion of mangrove areas for pond culture is localized in Ngomeni. During the period 1921–1976, some 9922 ha of tidal swamps between Ngomeni and Karawa were converted for saltworks (Yap & Landoy, 1986). Six of the saltworks are operational, producing an estimated 71 400 metric tonnes of raw salt. Such a vast amount of salt production has a harmful effect on the mangroves. The underground seepage of the high saline water from the pans kills the neighboring mangroves (Kigomo, 1991). The destruction of such a higher biological system, without intensive utilization of the converted area illustrates the lack of resource management within an ecological framework.

In Lamu, close to 100 ha of mangrove forest was killed by dredged up sediment that was deposited during the construction of Mokowe sea jet. The non-sustainable use, over-exploitation of resources and conversion to other land and water uses (primarily fish-ponds, infrastructure development and salt pans) are reducing the mangrove areas.

It must be noted that aquaculture in mangroves, though often successful in terms of immediate returns, can fail completely as the high organic and iron content in some mangrove soils, and the ever present sulphate from tidal seawater, results in acid sulphate conditions when oxidized through exposure in pond construction and operation (Ong, 1982). In some areas, it has been possible to counteract this with the addition of lime and careful manipulation of flushing and water levels. Where this proves to be uneconomical, reclamation for pond culture has either been abandoned or, more wisely, never attempted. As to the agriculture alternative, such use often seems especially wasteful. The mangrove soils, with their high iron, sulfide and salinity, are unfavorable to many crops (Law, 1984) and, unlike aquaculture, the coastal physiographic features are usually of little advantage. The agricultural conversion become short term because the previously anaerobic soils when oxygenated became highly acidic (Hamilton & Snedaker, 1984). More successful conversion for mariculture and aquaculture has been achieved in the Philippines and Indonesia, yielding fish, shrimps and shell fish (Tomlinson, 1986).

Oil pollution

The worldwide total discharge of petroleum into marine environments is estimated between 1.7 and 8.8 million metric tonnes per annum (National Academy of Sciences, 1985). These discharges affect mangrove ecosystems. A number of marine accidents have occurred in Kenyan waters and have caused considerable environmental damage. This includes the grounding of the British *Cavalier* off Mombasa in 1972, spilling ca. 100 metric tonnes of oil.

During the decade between 1983 and 1993, the port of Mombasa and its adjacent waters have experienced five tanker accidents spilling a total of 391 680 metric tonnes of oil. Large expanses of intertidal mangroves, seagrasses, algae and associated invertebrates were covered by oil. These organisms soon died as oil soaked into the organically rich sediments of mangroves and seagrass beds. The mangrove area affected was 10 ha. We have observed at Makupa Creek that ten years after these spills, the effects of oiling are still visible both as a reduction of the area of substrate in the mangrove fringe and reductions of the cover of attached animals. The mangroves have not yet recovered. The saturated sediments act as long-term reservoirs of oil and are a major factor in continued re-oiling of the Makupa Creek at Mombasa. Organisms within the creek are still exposed to dissolved and suspended oil compounds, although visible tarry residues are declining. Chua et al. (1989) have noted that oil pollution impairs the life-support systems in the marine environment. It is possible that organisms living under chronic petroleum stress adapt to these conditions and are more tolerant of toxic effects of oil than organisms from unpolluted areas (Mertens, 1977).

A time period of up to 20 years or longer is required for deep mud coastal habitats to recover from the toxic impact of catastrophic oil spills (Burns et al., 1993). This is due to the long-term persistence of oil trapped in anoxic sediments and their subsequent release into the water column. The long time scale of these impacts accentuates the need for careful protection of these important habitats. Unless adequate measures are taken to protect mangroves and other coastal habitats, with their rich biodiversity, severe degradation of sensitive marine ecosystems seems inevitable.

Recommendations and conclusions

Experimental mangrove rehabilitation at Gazi Bay

The experimental cultivation of mangroves to rehabilitate degraded areas, restock denuded mudflats and transform disturbed forests into uniform stands of higher productivity was launched in October 1991 (carried out by KMFRI) at Gazi bay and funded by the Belgium government under the Kenya-Belgium Projects. More than 7000 propagules, saplings and small trees of *Rhizophora mucronata, Ceriops tagal, Bruguiera gymnorrhiza, Avicennia marina, Sonneratia alba, Xylocarpus granatum* and *Heritiera littoralis* were planted/transplanted at different heights along the intertidal complex and monitored for their growth at 14 days, 1, 2, 3 or 4 monthly intervals for more than a year, depending on the experiment (Kairo, 1995). Successful reforestation proved to be largely modified by a planting site with little or no wave action against the shore to dislodge plantings and proper elevation within the intertidal zone. Survival rate of the planted propagules and saplings after 12 months varied between 10% in areas heavily exposed to wave action and more than 85% in well protected areas.

The first phase of trial mangrove plantation covering approximately 50 ha was initiated in 1994 for a period of 4 years. This first phase covered part of the deforested mangrove areas of Gazi bay. The Biodiversity Support Program (USAID) and the Belgium government through the Kenya-Belgium Project, Mombasa, supported the program. The program was basically on community base. An important objective of the project was to transfer knowledge on the procedures and methodology, which has been developed in experimental plots at Gazi bay, to the people living around the mangroves. The experience obtained from this work shows that it is not possible to devise any single technique that will satisfy the planting requirements of all types of mangroves. It is, however, recommended that mangrove species should be planted at an elevation similar to that it originally grew. The use of propagules and saplings is a more appropriate method of revegetation, they are readily available and easy to install than the 'small trees'.

The Kenyan coast now has only less than 50 000 ha of remaining mangrove forests and the extant forests need to be managed carefully and sustainably. The concept of sustainable use involves sustainable harvest and/or other economic returns at rates enabling the system to maintain itself in as natural a state as possible. Current and significant problems for mangrove conservation include deforestation, conversion of mangrove areas to other uses and oil pollution. Mangrove forestry in Kenya suffers from inadequate knowledge of silviculture, denial of multiple use potential of resources and lack of economics and techniques of natural and artificial regeneration. KMFRI should do more research in these areas. It's also considered that future studies on mangrove reforestation in Kenya by KMFRI should concentrate on studies concerned with:

1. seeds/propagules: seasons, collection method, maturity, preservation;
2. nursery and transportation: type of nursery, season and method of transportation;
3. afforestation methods: technical aspects, and cooperation of villagers; and
4. management and utilization: role of mangrove forests, thinning, human stress etc.

On the international level, there should be effective linkages among countries, institutions, and professional groups and individuals working or concerned with mangroves to:

1. have better and faster exchange of information and technology on the management and protection of mangrove areas;
2. undertake cooperative research and development program; and
3. generate additional financial support for research and development programs notable reforestation of denuded and disturbed mangrove areas.

There are still no clear government policy guidelines for the management of mangroves in Kenya and, although mangrove cutters have to be licensed, their numbers are not controlled. It is only through the development, acceptance and implementation of proper non-exploitative practices that mangrove resources, goods and services can be perpetuated for the overall benefit to society. This urgent need to utilize the mangrove resources on a sustainable basis must necessarily include reductions in the conversion of land and water to other human uses. It would also be important to declare certain mangrove areas, especially those in a pristine state, as conservation areas or to confer other forms of protection. The long-term ecological and genetic value of the mangroves far outweighs the short-term value as a source of construction material and fuel. Some important suggestions as a basis for conservation of mangrove forests are highlighted below:

1. single use management of the mangrove system should be avoided; a multiple use approach in advocated;
2. effective pollution monitoring should be undertaken by KMFRI;
3. anthropogenic pressures, and particularly cutting for firewood and construction materials, need to be controlled because these activities are the primary cause of mangrove destruction along the Kenyan coast;
4. mangrove cutting should go hand in hand with replanting. The use of mangrove reforestation to restore degraded areas has shown success in Gazi bay and Funzi, Kenya. Some 300 000 mangroves have been restored in a program funded by Africa Academy of Sciences (Nairobi), Kenya Belgium Project (Mombasa), Kenya Wildlife Service

(Mombasa) and the Biodiversity Support Program (U.S.A.).

5. Creation of mangrove nurseries is now a necessity.

Since mangroves are a dynamic system, a national mangrove committee should be formed to advise the Forest Department of Kenya and other stakeholders on the roles and values of mangroves. The Integrated Coastal Area Management (ICAM) with its secretariat at the Coast Development Authority has initiated plans to set up a national committee to advice on mangrove related problems. Ngoile & Shunula (1992) have also called for the formulation of a national mangrove committee in Zanzibar. Tanzania already has such a body that looks into the management of its mangroves (Semesi, 1992).

In a semi-arid region, where there is a high dependence on mangroves by coastal populations, any management plan must also accommodate most of the people's requirements. The active participation of these people is required for effective implementation. Management practices to be adopted should be beneficial both to conservation and the local economy. Noting that the Kenya coastline is semi-arid, and that the major mangrove forest cover depends on discharges of groundwater, mangroves are dependent upon the sensitive management of groundwater aquifers and must be considered in water management decisions. It is, therefore, essential to develop an integrated management plan, which uses resources and services from mangrove ecosystems in a sustainable way (i.e. without jeopardizing the resource base). At government level, a major problem affecting the sustainable management of coastal resources is the conflict of responsibilities between government agencies. Therefore, a national mangrove committee has been formulated to look into the government policies for the better management of the mangrove forests.

The national mangrove committee, which was proposed in 1993 by the Kenya Government, will be to facilitate effective exchange of information on mangrove as well as co-operation in mangrove research and development. The roles of this committee will be to:

1. examine, inter alia, sustainable uses of mangroves;
2. define areas for genetic preservation of species threatened with extinction and over exploitation;
3. recommend strategy for regeneration and afforestation of mangrove bordered coastline with advantageous species;
4. educate the local population on the importance of mangroves and make them understand environmental and social impacts of large scale exploitation operation of mangroves on their land; and
5. look into the government policies for the better management of the mangrove forests.

Over-exploitation of mangrove forests in Kenya occurs due to a lack of awareness of the problems, than to a lack of economic alternatives. Policy makers, developers and the general public generally do not understand the need or the urgency to protect these resources. Decision makers must become aware along with citizens, that protecting mangroves is in their own best interests. The attitude that the benefits derived from protection are minimal when compared to the benefits of the activities, which degrade these ecosystems, must be changed.

Present approaches to the exploitation of mangroves in Kenya must be considered unsustainable. This conclusion is based on the observation that severe erosion of the shoreline is taking place due to the progressive loss of fringing mangroves caused by constant cutting. Meanwhile, clear felled areas with little or no regeneration are readily observed all along the Kenyan coastline. The concept of sustainable use involves sustainable harvest and/or other economic returns at rates enabling the system to maintain itself in as natural a state as possible. Heavy pressure is being exerted on all forms of mangrove for wood products, particularly for fuelwood and building, by the high and fast-growing populations in the coastal area. It is, therefore, clear that, unless sustainable methods for increasing the availability of fuelwood and poles are found, substantial losses of mangrove swamps and acute shortages in wood cover in the coming years will inevitably lead to increased hardships for the urban and rural poor. The reforestation will not only contribute towards increasing the supplies of wood, but will also fulfill the development goal for an improved environment which forms the basis of sustainable use and improved standards of living for the urban and rural poor. The reforestation project at Gazi had an important role to play in gathering basic information based on field trials as the necessary technical input towards present and future mangrove afforestation.

To win public acceptance and support for forestry programs, *in situ* pilot projects are required to demonstrate the economic viability, sustainability and manageability of planting mangroves, and sound forest management practice. From the foregoing discussions, one may make a conclusion that it is possible to implement mangrove plantation artificially in Kenyan coast, and thereby enhance the afforestation work in this region for achieving socioeconomic objectives both tangible and intangible as well as; control of soil erosion, supply of fuel, creation of employment opportunities and improvement of environmental conditions. This management strategy has the advantage that it retains as many resource use options as possible open for future use. Some extensive, fast growing mangrove species e.g. *S. alba, A. marina, X. granatum* and *R. mucronata* can be planted for fuel wood or timber as well as supplying fish and wildlife to nearby human population. For slower growing species e.g. *C. tagal* and *H. littoralis* exploitation must be slower.

The Forest Department lacks sufficient resources to undertake large scale forest operations. In this respect, it is necessary to encourage a degree of 'self-management' amongst the local people in order that reforestation programs can be implemented in degraded areas. Close liaison is required between the management agencies, research organization and community with direct or indirect interest on the management, utilization or research in mangroves. This is important in terms of implementing joint forest management policies amongst the stakeholders. The potential of mangroves for rural development has not been perceived in Kenya. The greatest challenge, therefore, is to ensure that planners and decision makers have access to information on the role and potentials of mangroves. A seminar, talks, exhibitions, workshops and film shows on mangrove products and services should be conducted to create public awareness. Multidisciplinary research to determine the biological, physical and socio-economic effects of the major users of mangrove areas is required. This is important in determining the inter-relationship between various land-uses, e.g. mariculture, forestry practices and other human activities, in mangrove areas.

A Memorandum of Understanding (MoU) formulated in 1993 between the Forest Department and Kenya Wildlife Services (KWS), now provides more collaboration in the enhancement of the management of mangrove biodiversity. It is, therefore, considered desirable to allow the joint subordinate staff (Forest Department and KWS a good deal of discretion in the control of the felling and to train them to enforce simple rules which though by no means perfect, should ensure sufficient natural regeneration. A fine (e.g. withdrawing of licenses or being made to plant the cut areas) can be introduced for non-observance or breachers of rules. For the adequate enforcement of harvesting rules, it is essential for the supervising guards to live in the immediate vicinity of the forest, and it may be necessary to increase the subordinate staff and physical management tools (e.g.) vehicles and boats to enable closer supervision.

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