Variability of mangrove forests along the Kenyan coast

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ABSTRACT

Mangroves have a wide environmental tolerance, adapting to growth in different conditions. Different mangrove formations have been identified and are thought to be influenced by the environmental settings prevalent to sites in which these formations occur. It is thus important for mangrove management agents to incorporate site conditions in management plans. Mangrove forests in Kenya occur in six landscape types; sheltered bays and reef patches, drowned river valleys, bays, behind marine influenced barrier dunes, behind barrier dunes and abrasion (reef platforms). Preliminary studies in Kenya have shown that mangrove forests north and south of Tana River differ in structural attributes. Therefore, this study aimed at describing mangrove forest structural attributes in relation to the biophysical features along the Kenyan coast. Information on biophysical features and mangrove forest structure (for the north coast and some sites in the south) was reviewed from published peer-reviewed articles and other literature materials. Vegetation data for the mangroves of the Shirazi-Funzi and Majoreni in the south coast was generated by the standard sampling techniques. Plots (10 m x 10 m each) ranging from 22 to 44 were established in each site and within each plot tree height (m), diameter at breast height (DBH; cm) and canopy cover (%) were determined for all trees with ≥5.0 cm DBH. The mangroves of Lamu and Ungwana Bay showed superior structural features than most sites in the southcoast. Likewise, mangrove forests under riverine influence (Ungwana Bay and Ramisi) were more complex than other sites, except Lamu. *Rhizophora mucronata* **Lam**. was the overall principal species in most sites, however, most sites depicted mangrove species distribution typical of the Kenyan coast. Tudor creek (Mombasa) was the poorest in most forest structural attributes probably due to degradation associated with proximity to urban setting. In the Shirazi-Funzi and Vanga complex the overall stand density ranged from 1573 to 1839 stems/ha; with height and basal area ranging from 6.0 to 7.4 m and 17.7 to 30.3 m^2/ha respectively. Ramisi mangrove forests were more structurally complex than the other site and consequently had significantly larger trees than those in other sites in the southcoast ($p < 0.001$). Funzi mangroves were significantly taller than most sites in the area ($p = 0.001$). As in other areas along the Kenyan coastline, *R. mucronata* had the highest Importance Value in this section (ranging from 110 to 194) while *Bruguiera gymnorrhiza* (L) **Lamk**. and *Xylocarpus granatum* **Koenig** were least important in most sites. Findings from this study have wide application in sustainable utilization and management of mangroves along the Kenyan coast. Management plans which take in to consideration the harvesting systems need to be applied to reduce the effects of selective harvesting in most sites. Critical areas such as seaward fringe and degraded areas need to be protected to avoid shoreline recession and to allow sufficient regeneration potential and maintain forest cover.

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1.0 INTRODUCTION

Mangroves have a wide environmental tolerance, adapting to growth in different conditions (Schaeffer-Novelli *et al.* , 1990). Their growth is influenced by various environmental factors that vary in intensity and periodicity (Twilley, 1995). The mix of fluvial, tidal and wave energies creates a landscape whose geomorphology is a function of the environmental setting of that region (Lugo and Snedaker, 1974) and varies from site to site. It is, thus, critical for mangrove managers to understand environmental settings affecting these ecosystems prior to implementing management strategies. Collectively, six basic types of mangrove formations have been identified: riverine, fringe, basin, overwash, scrub and hammock mangrove forests (Lugo and Snedaker, 1974; Thom, 1982; Twilley, 1995). Riverine mangroves occur along rivers and streams and are flooded by daily tides and hence are the most productive of mangrove communities because of the high nutrient concentrations associated with sediment trapping. On the other hand the scrub mangroves, which commonly occur in extreme environments, are the least productive. While studying variability of Brazilian mangrove ecosystems, Schaeffer-Novelli *et al.,* (1990) observed that maximum mangrove growth is achieved where suitable topography is subjected to large tidal ranges and ample inputs of river water, rainfall, nutrients, and sediments. Schaeffer-Novelli and Cintron-Molero (1993) attributed highly developed forest stands to non-climatic forcing functions such as tidal, wave and current energy. Other studies relating site environmental conditions and mangroves stand structure include publications by; Chapman (1976), Thom (1982), and Fujimoto *et al* (1995). However, no similar studies have been done for the East African region.

Kenya has over 54,000 ha of mangrove forests occurring in several patches along its 574 km coastline, the bulk of which occur in Lamu district (Doute *et al.* , 1981; Ferguson, 1993). Preliminary studies indicate that mangrove forests in the north and south of Tana River differ significantly in structure, size range and distribution (Ferguson, 1993). Mangroves in the north have been reported to be superior in terms of biomass, height and basal areas (Kairo, 2001). Higher scale of past and present anthropogenic pressures on the mangrove of the south coast of Kenya has also been reported (Kairo, 2001). Since there is lack of quantitative evidence on the scale of influence by the different environmental settings on the mangrove structure and productivity in Kenya, the present study is designed to fill the existing gap. The study aimed at identifying different mangrove forest types along the Kenyan coast together with their environmental forcing functions. It was also aimed at providing a better understanding on the distribution patterns, size range and extent of Kenyan mangroves.

Mangrove forests along the Kenyan coast provide goods and services to the coastal people. It is estimated that 70 % of the wood requirement by the coastal people is met by the mangroves (Wass, 1995). Extraction of mangrove poles is controlled by the Kenya Forest Service (KFS) through licensing procedures and recommendation on the number of scores to be extracted (a score = 20 poles). However, these recommendations are based on the national wood demand rather than the actual resource base (Abuodha and Kairo, 2001). In addition unlike the terrestrial forest ecosystems, no critical areas that require special attention in mangrove forest ecosystems have been identified and delineated. Therefore, it is important to not only provide baseline information on mangrove structural attributes, but also their relationship with site environmental factors.

Despite the important role played by mangroves, very little has been done on rehabilitation, conservation and sustainable utilization of mangroves in the region. Thus, through provision of knowledge on how mangrove forests in Kenya develop in relation to environmental site conditions, the proposed study, by identifying mangrove areas that require special attention, will be a boost to mangrove management planning and sustainable utilization. The same can then be emulated regionally.

1.1 Objectives

The objectives of the study were to:

1. Assess structural characteristics of mangroves in selected areas along the Kenyan coast.
2. Describe biophysical features (e.g. climatic, hydrologic, oceanographic factors) of mangrove formations along the Kenyan coast and relate to the mangrove structural attributes in each pilot study site.

2.0 MATERIALS AND METHODS

2.1 Study area

2.1.1 Location

The study was carried out in major mangrove formations along the Kenyan coast. These include: Kiunga (1^{o} 40’S, 41^{o} 34’E), Tana River (3^{o} 05´ S, 40^{o} 00´W), Mida creek (3^{o} 20’S, 40^{o}00’E), Kilifi, Mombasa, Gazi bay (4^{o}25’S, 39^{o}50’E), Shirazi-Funzi, Ramisi and Vanga (4^{o}25’S, 39^{o}17’E). Kenya has a 574-km coastline running in a south-westerly direction from the Somalian border in the north, at 1° 41'S to the border with Tanzania at 4° 40'S. It lies in the hot tropical region where the weather is influenced by the great monsoon winds of the Indian Ocean.

2.1.2 Climate

Climate and weather systems on the Kenyan coast are dominated by the large scale pressure systems of the Western Indian Ocean and the two distinct monsoon periods. From November/December to early March, the Kenyan weather, particularly at the Coast, is dominated by the Northeast Monsoon which is comparatively dry. During March and April the monsoon winds blows in an east to south-easterly direction with strong incursions of maritime air from the Indian Ocean bringing heavy rains. During the months of May, June, July and August, the South-easterly Monsoon influence gradually sets in and the weather becomes more stable with comparatively cooler temperatures. Between September and November, the Northeast Monsoon gradually re-establishes itself and by December the northern influence is dominant once again (UNEP, 1998; Obura, 2001).

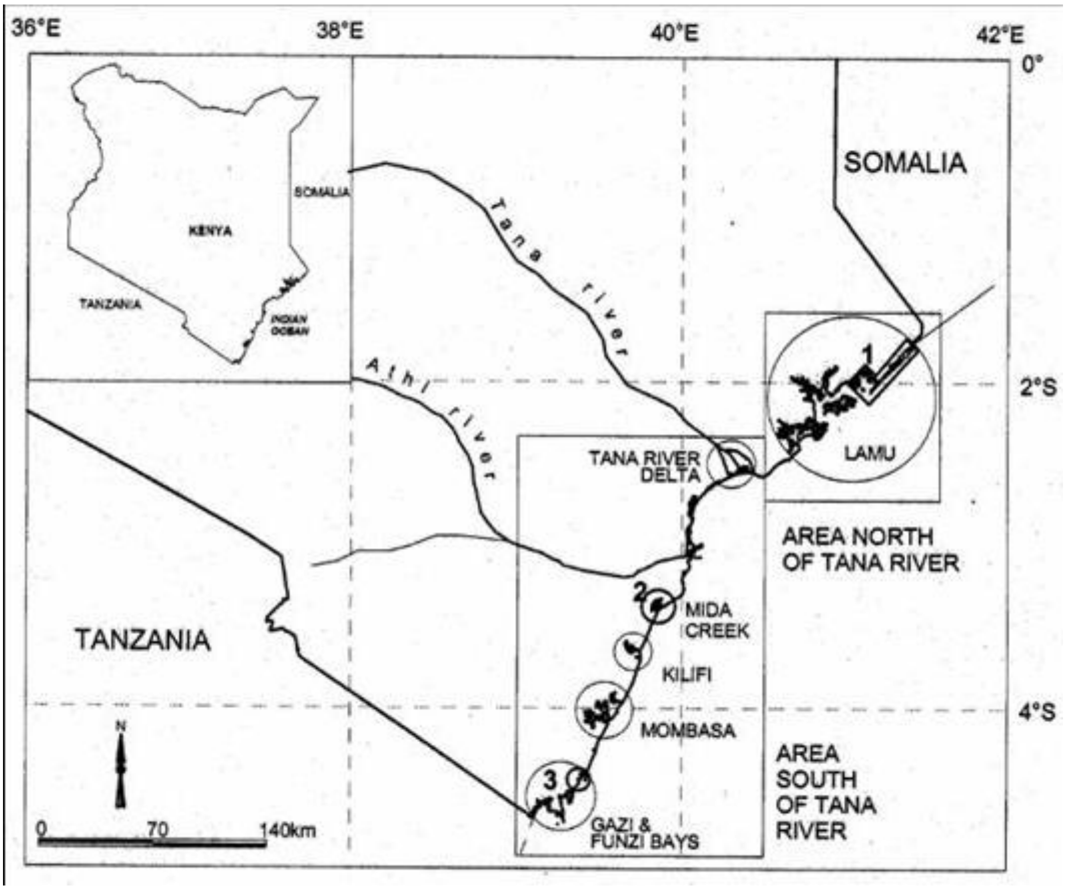

Figure 1. Map of the Kenyan coastline (Source; Kairo, 2001)

The annual rainfall on the Kenyan coast follows the strong seasonal monsoon patterns. The main rains come between late March and early June with the rainfall decreasing from August. Some rain occurs between October and November but from December, rainfall decreases rapidly once again to a minimum during January and February (Mutai and Ward, 2000). Mean annual total rainfall ranges from 500-900 mm in the drier, northern hinterland to 1000-1600 mm in the south (Ferguson, 1993; Mutai and Ward, 2000). On the other hand, the annual average evapotranspiration varies respectively from 1650-2300 in the north to 1300-2200 in the south (Figure 2) (Jeathold and Smidt, 1976; Ferguson, 1993).

The mean monthly evaporation rates range from 128 mm (winter) to 221 mm (summer). Relative humidity is comparatively high all the year round, reaching its peak during the wet months of April to July. The windiest time of the year at the Kenya Coast is during the Southeast Mon-soon from May to September, while the calmest months are March and November when the winds are also more variable in direction. The temperatures in coastal areas of Kenya range from 22-34^{o} C during NEM season, reducing to about 19-29^{o} C during the SEM (Abuodha, 2004).

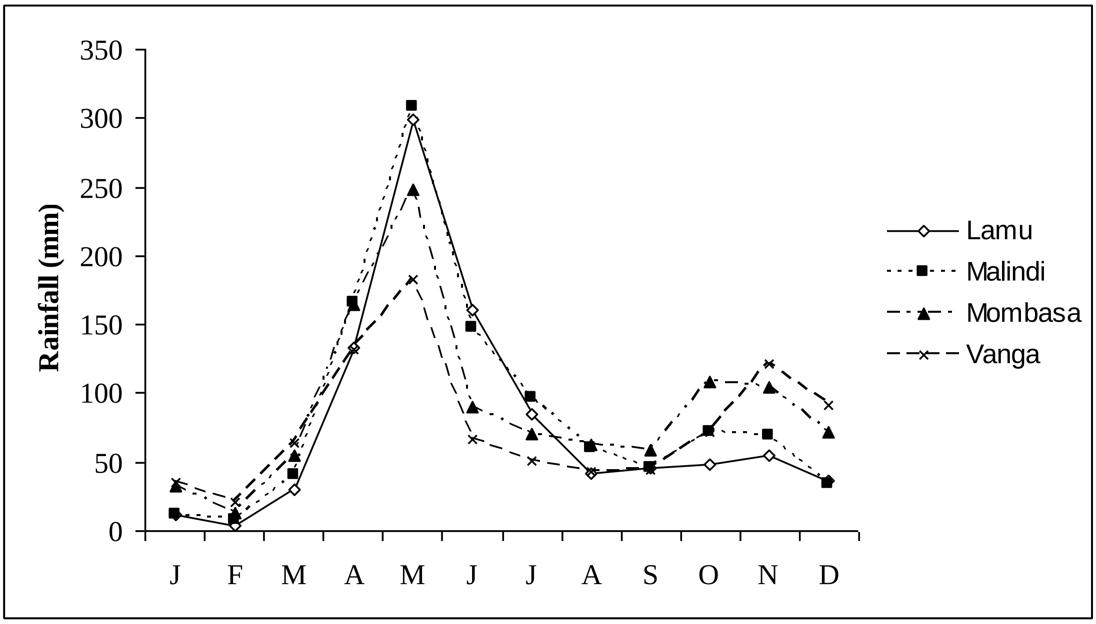

Figure 2. Rainfall patterns along the Kenyan coast

2.1.3 Hydrology

The hydrology of the coastal region of Kenya is influenced by the drainage patterns of both perennial and seasonal rivers draining into the western Indian Ocean basin. There are two main perennial rivers, namely; the Tana River and the Sabaki River, which originate from the Highlands around Mt. Kenya and Nairobi. Discharge from both rivers is highly seasonal, characteristic of dry land rivers, which can deliver over 80 % of their annual sediment loads within a period of a few days at the onset of heavy rains (Dunne, 1979; Obura, 2001).

The Tana River is the longest in Kenya being approximately 850 km in length and it has a catchment area of 95,000 km^2. An average of 4.7 x 10^9 m^3 of freshwater and some 3 million tonnes of sediment are discharged annually. It enters the ocean about halfway between Malindi and Lamu, near Kipini, into Ungwana Bay. However, before it does, and about 30 km upstream, it gives off a branch which leads to the complex of tidal creeks, flood plains, coastal lakes and mangrove swamps known as the Tana Delta. The Delta covers some 1,300 km^2 behind a 50 m high sand dune system, which protects it from the open ocean in the Ungwana Bay. The Sabaki River is the second longest with a length of 650 km and a catchment area of 70,000 km^2 extending into the southeastern slopes of the Nyandarua Range in central Kenya. The Sabaki River discharges 2,000 million m^3 of freshwater and 2 million tonnes of sediment annually into the sea through the Sabaki estuary north of Malindi (UNEP, 1998).

There are also a number of semi-perennial and seasonal rivers such as the Mwache, Kombeni, Tsalu, Nzovuni, Umba, Ramisi, Mwachema and Voi, all of which drain into the coastal region from arid and semi-arid catchments. The Ramisi River, which arises in the Shimba Hills forested area, discharges 6.3 million m^3 of freshwater and 1,500 tonnes of sediments annually into Funzi-Shirazi Bay in the southern part of the Kenya coast. The Umba discharges 16 million m^3 of freshwater into Funzi-Shirazi Bay while the Mwachema and Mwache rivers discharge 9.6 million m^3 and 215 million m^3 of freshwater annually, respectively (UNEP, 1998).

2.1.4 Coastal Geology and Geomorphology

The Kenyan coastline has experienced eustatic sea level oscillations and/ isostatic and differential tectonic movements, which have considerably influenced the coastal configuration. The continental shelf south of Malindi is 2-3 km wide; however, it widens significantly at the mouths of rivers Tana and Sabaki exceeding 15 km of the northern end of Ungwana Bay. A shallowing south of Lamu is due to the sediments brought in by Tana River and the terrigenous sediment load has dominated the development of the coast (UNEP, 1998).

Geomorphologically, the Kenyan coastal zone is an emergent coastline. Consequently, most of the coastline except Malindi area has been subjected to marine regression due to coastal erosion. Three different coastal types are recognized along the Kenyan coast, which include the fringing reef shoreline of the southern part; the deltaic shoreline of Sabaki and Tana Rivers and the ancient delta area of the Lamu Archipelago (Kairu, 1997). The geomorphology is divers consisting of sandy beeches, dunes, creeks, muddy tidal flats and rocky shores bordered by cliffs (Oosterom, 1988; Abuodha, 1992).

2.1.5 Oceanography

There are four essentially wind-driven oceanic currents affecting the Kenyan coastline: the East African Coastal Current (EACC), the Somali Current (SC), the Southern Equatorial Current (SEC) and the Equatorial Counter Current (ECC) (UNEP, 1998). The westward moving SEC branches in to the Mozambique Current, which flows southwards and the EACC that flows northeastward all year round at least as far as Malindi and beyond Malindi during the Southeast Monsoon winds (SEM). During the Northeast Monsoon (NEM) the northwards extent of EACC is restricted by the south flowing SC (which changes direction under the influence of the monsoon). The two currents converge between Malindi and north of Lamu depending on the strength of the monsoon in any particular year, and turn eastward and flow offshore as the ECC. During the SEM the SC reverses its flow and it appears as the northward extension of EACC flowing as far as the Horn of Africa. At this time ECC is not distinguish from the general Southwest Monsoon drift at the lower northern latitudes of the Indian Ocean. Generally the net onshore currents result in the sinking of surface waters along most of the Kenyan coast, with the exception of Kiunga where a mild upwelling is thought to occur during NEM (UNEP, 1998).

The Kenyan coastal waters are characterized by semi-diurnal tides, i.e. approximately two tidal cycles for every 24 hour period. However, except for a limited period in the year the levels of high and low water of each successive tide differ appreciably from the corresponding tide before and after tide following. Spring tidal variations in Eastern Africa can be up to 4.0 m and up to about 1.8 m during neap tides (UNEP, 1998).

2.1.6 Mangrove Vegetation

Mangrove forests occur within six distinct landscape categories in Kenya; (1) within sheltered bays and reef patches (Vanga, Shimoni and Gazi), (2) in drowned river valleys at Mombasa, Mtwapa, Kilifi, Mwachema, Takaungu and Dodori, (3) in bays (Mida Creek), (4) behind marine influenced barrier dunes (Ngomeni), (5) behind barrier dunes, predominantly estuarine (Sabaki and Tana deltas) and (6) on abrasion (reef platforms) behind protective outcrops of coral limestone and coquinas (mangroves of Lamu) (Ferguson, 1993).

There are nine species of mangrove trees and shrubs found along the Kenya coast (Table 2). The mangrove swamps along the Kenyan coast cover approximately 53,000 hectares with the largest stands occurring in the Lamu area (Doute *et al*., 1981; Table 1). The mangrove forests around Lamu are the second largest on the Eastern African coast. None of the mangrove species is endemic to Kenya. The commonest Kenya mangrove species are *Rhizophora mucronata* and *Avicennia marina* and both are found all along the entire Kenyan coast. On the other hand, *Heritiera littoralis* is found only in a small pure stand at the Tana River estuary near Kipini (UNEP, 1998).

Table 1. Areas of mangroves along Kenyan coast

Locality	**District**	**Area (ha)**
Kiunga	Lamu	3,025
Lamu	Lamu	30,475
Ungwana Bay	Tana River and Kilifi	6,325
Mida Creek	Kilifi	1,600
Takaunga	Kilifi	30
Kilifi Creek	Kilifi	360
Mtwapa Creek	Kilifi and Mombasa	525
Tudor Creek	Mombasa	1,465
Port Reitz	Mombasa and Kwale	1,575
Gazi (Maftaha) Bay	Kwale	615
Ras Mwachema	Kwale	5
Funzi Bay	Kwale	2,715
Vanga	Kwale	4,265
Total		**52,980**

Source; Doute *et al*., (1981).

Table 2. Mangrove species found in Kenya and their uses

Species Name	Local Name	Uses
Rhizophora mucronata (Lam)	*Mkoko*	Timber, firewood, charcoal
Bruguiera gymnorrhiza (L) Lam.	*Muia*	Timber and firewood
Ceriops tagal (Perr) C. B. Robinson	*Mkandaa*	Timber and firewood
Sonneratia alba (Sm)	*Mlilana*	Timber and firewood
Avicennia marina (Forsks) Vierh.	*Mchu*	Firewood and fencing
Lumnitzera racemosa (Willd)	*Kikandaa*	Firewood, Ribs for boats
Xylocarpus granatum (Koen)	*Mkomafi*	Timber, firewood and carving
Xylocarpus molucensis (Lam.) Roem.	*Mkomafi dume*	Firewood and fencing
Heritiera littoralis Dryand in Aint	*Msindukazi*	Poles, timber, boat mast

Source: Kairo, (2001)

Avicennia marina and *Sonneratia alba* are the first colonizers of the swamps. Once established, mud accumulates around their roots and produces favourable conditions for *Ceriops tagal* and *R. mucronata*. The latter is the commonest and most important constituent of the Kenyan mangrove swamps. It usually occupies the most favourable sites between *S. alba* and *A. marina* on the creek edges, with *C. tagal* on the landward side. *Bruguiera gymnorrhiza* is normally found scattered within stands of *R. mucronata* (UNEP, 1998).

Coastal geomorphology and other abiotic factors are thought to influence the zonation of mangroves. In the Western Indian Ocean, *S. alba* and *R. mucronata* are usually at the outermost edge on the seaward side, followed by a *C. tagal* zone in the intermediate levels, then by an *A. marina* zone at the higher shore levels, and lastly, *L. racemosa*, which usually occurs as a narrow fringe behind the *A. marina* zone at the highest landward zone. Mangroves of Kenyan exhibit this typical zonation pattern. Of the other species, *B. gymnorrhiza* occurs frequently just above the *Rhizophora* zone, while *X. granatum* is most often found well above the *Avicennia* levels. This pattern of zonation exhibited by mature, adult trees is reflected in the survival pattern of specific seedlings (UNEP, 1998).

2.2 Methodology

Since a lot of information on mangrove forest structure exists for sites like Kiunga, Mida creek and Gazi bay, forest structural studies was restricted to the south coast areas like Shirazi-Funzi Bay, Ramisi and Vanga.

2.2.1 Mangrove forest types along Kenyan coast

There exists a lot of published information on mangrove forest structure and productivity, especially for the north coast. Published literature for the mangroves of Kiunga, Tana River, Mida creek, Tudor creek and Gazi Bay was reviewed.

The structure and productivity of mangroves of Kenya are believed to differ significantly north and south of Tana River. Thus the coastline was divided into two sections; North and South of Tana River sections (Figure 1; Kairo, 2001). The north of Tana River section comprises of the mangroves of Lamu Archipelago, and Kiunga. The coastline south of Tana River was further subdivided in to 4 subsections; (1) Ungwana Bay; comprising of mangroves of Sabaki-Tana deltas, (2) Mida and Kilifi Creeks (3) Mombasa; consisting of Ports Reitz, and Tudor, and Mtwapa Creek, and (4) Gazi-Vanga section; consisting of Gazi, Shirazi-Funzi and Vanga Bays. Information on the environmental factors and mangrove forest structure for each section was obtained from existing peer-reviewed articles and other literature materials. Thereafter, environmental settings occurring in each site were described.

2.2.2 Structural Properties of Mangroves of Shirazi-Funzi and Vanga bays

Vegetation data for the Shirazi-Funzi and Vanga bays was generated by standard sampling techniques (Muller-Dombois and Ellenberg, 1974; Cintron and Schaeffer-Novelli, 1984). Sampling was done using standard 10 m x 10 m plots for adults and 5 m x 5 m for juveniles (Sukardjo, 1987) laid along transects. Measurements included tree heights and diameters at breast height (DBH) for all trees $\geq$ 5 cm DBH; from which were derived basal area (BA) stand density, Importance value (IV) and Complexity Index (CI). A total of 44, 34, 24, 22 and 43 plots were established in Shirazi, Bodo, Funzi Island, Ramisi and Majoreni respectively.

3.0 RESULTS

3.1 Biogeophysical features and mangrove forests along the Kenyan coast

3.1.1 Lamu

Lamu has the largest area of mangroves in Kenya, covering some 30,745 ha. Mangrove forests in Lamu occur in regions such as; Northern swamps, North central swamps, Lamu, Manda and Pate Island swamps, Southern swamps and Mongoni and Dodori creek swamps. The Lamu mangroves can be characterized by their relatively low elevation, with most areas less than 2.0 m above datum (Yap and Landoy, 1986). Lamu archipelago and Kiunga receive average annual rainfall of 950 and 560 mm respectively, much of this being during SEM. The rainfall patterns in Lamu, except from the period 1996-2005, do not show a distinct bimodal distribution typical of the Kenyan coast (Fig. 3). During the last 10 years, the average annual rainfall of Lamu increased to 1118 mm (1996-2005 period; Kenya Meteorology Department); much of which was contributed by the El Niño rains of 1997/98 (2263 mm). However, there was no variation from the long term monthly means except for the short rains period (October to November; Fig. 3).

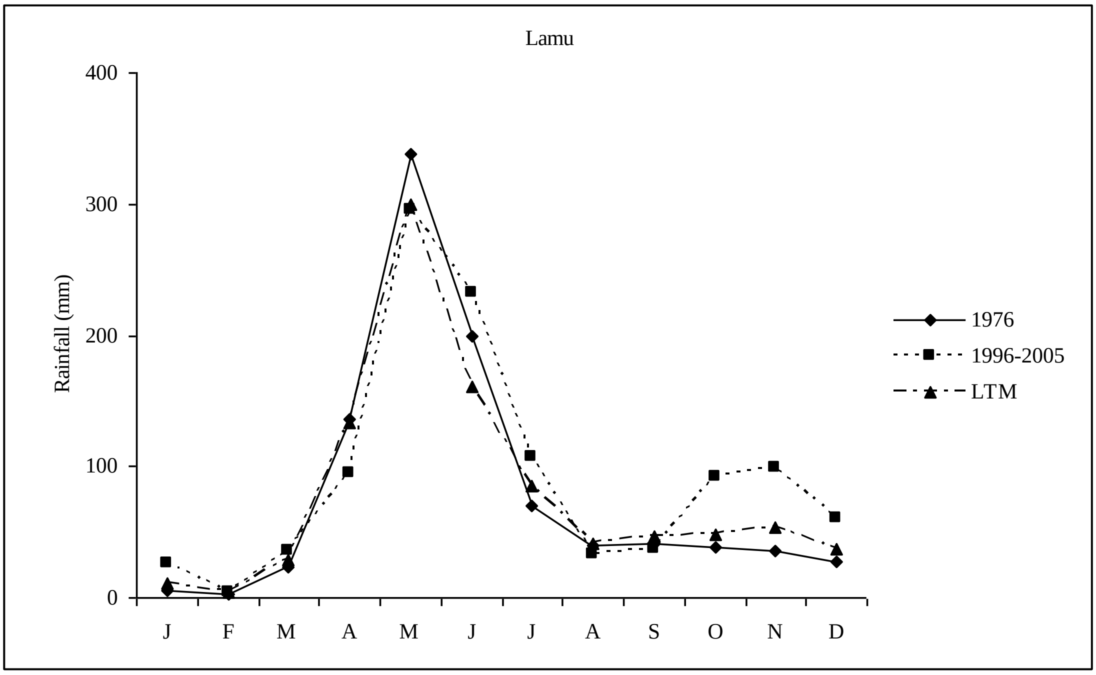

Figure 3. Monthly rainfall pattern for Lamu; LTM = long term mean

The Northern swamps region, which extend from Mlango wa Tano to Kiunga, is the smallest of the five regions; covering 2,969 ha, with a stand density of 2343 stems/ha, of which is dominated by *R. mucronata* stands (Roberts and Ruara, 1967; Kairo *et al.* , 2002a). The basal area and average height for mangroves of this region are 46.97 m^2/ha and 7.86±3.76 m respectively (Kairo *et al.* , 2002a). The North central region, which includes Uvundo and Ndau Islands, extends from Mlango wa Tano to the mouth of Dodori creek. It is the second largest region covering 12,229 ha dominated by *R. mucronata* and *C. tagal* (Roberts and Ruara, 1967). The North central mangroves have a basal area and an average height of 24.05 m^2/ha and 6.14±2.22 m respectively (Kairo *et al.* , 2002a).

Mongoni and Dodori creek swamps comprise of mangroves found at the bank of Mongoni and Dodori creeks and on the mainland of Mongoni creek down to Manda bay. It covers an area of 8,621 ha dominated by *C. tagal* (Roberts and Ruara, 1967). The mangrove forests of Pate Island swamps include those surrounding Pate, Shindamwe and Ndau Islands. The mangroves in this region cover an area of 9,414 ha, with similar attributes as those of the Northern swamps (Roberts and Ruara, 1967; Kairo, 2001). The Southern swamps region is the largest covering an area of 12,951 ha and is dominated by *R. mucronata*. *Ceriops tagal* is scarce and generally of poor form in this region (Roberts and Ruara, 1967), probably due to selective cutting. *Avicennia marina* is found growing at the head of Hidio creek, likewise *B. gymnorrhiza* is found in large numbers at the head of Kimbo creek (Roberts and Ruara, 1967).

The Southern and Mongoni and Dodori swamps have the lowest coverage of merchantable poles due to overexploitation; while the Northern swamps have the highest (Roberts and Ruara, 1967).

3.1.2 Ungwana Bay
The configuration of the Ungwana bay is dominated by wide shallow embayment in front of Sabaki and Tana rivers. It is characterized by presence of barrier island with lagoons near present and former outfalls of the Tana delta. The delta covers some 1,300 km^2 behind a 50 m high sand dune system which protects it from the open ocean (UNEP, 1998). The bay in front of Sabaki delta stretches between Malindi and Ngomeni peninsular. Between Mambrui and Malindi it forms an open bay with four minor coves, where minor reef segments and reef patches occur between them. These bays are separated by two arcs of coral reef patches of the Ngomeni peninsula and Mwamba Zeboma (Oosterom, 1988). Lagoons within these systems have mangrove swamps, tidal flats and creeks. Barrier beaches and sand ridges occurring at the transition of the mangrove swamps and the ocean waters indicate a considerable longshore transport of sediments derived from the Sabaki and Tana rivers. This situation is not found in other sections of the Kenyan coast, especially in the south as indicated by smaller amount of sediments brought in to the rivers there (Oosterom, 1988).

Ungwana Bay experiences bimodal pattern of rainfall distribution typical of the Kenyan coast; with an annual average rainfall ranging from 500-1200 mm/yr. However, annual evaporation exceeds the annual rainfall; 1200-1800 mm/yr. Air temperature ranges from 19 to 35 ^{o}C (UNEP, 1998). The bay receives an average river discharge of 229.8 m^3/s from river Tana (Kitheka *et al.* , 2005).

The mangrove forests of Ungwana Bay comprise of Kipini, Mto Tana and Ngomeni mangroves. Kipini mangrove forests occur at the current mouth of River Tana, while those of Mto Tana occur at the old mouth and Ngomeni mangroves occur at the southern part of the bay (Ferguson, 1993; Bundotich, 2008). Kipini has a unique mangrove composition; it is only at this region that *Heritiera littoralis* forms a pure stand (Ferguson, 1993). The dominant mangrove species at Kipini is *A. marina*, followed by *H. littoralis*; with an overall stand density, basal area and average height of 936 stems/ha, 47 m^2/ha and 13.6±4.6 m respectively (Bundotich, 2008). Mto Tana mangroves, which are dominated by *A. marina*, have a stand density, basal area and mean height of 734 stems/ha, 32.68 m^2/ha and 7.05±2.6 m respectively. Likewise, the mangroves of Ngomeni are dominated by *A. marina*; with overall stand density, basal area and mean height being 2074 stems/ha, 25.73 m^2/ha and 7.9±2.9 m respectively (Bundotich, 2008).

3.1.3 Mida and Kilifi Creeks

The Kilifi coastline, most of which comprises of sandy beaches, starts at Mto Kilifi and extends southward to Mtwapa Creek for a total length of 265 km. Prominent tidal swamps in the area are Mida and Kilifi creeks, which are dominated by mangrove vegetation. The mangrove areas within Mto Kilifi to Ngomeni (southern part of Umngwana Bay) are relatively higher than those of the Lamu area, with elevation ranging from 2.5 to 3.8 m (versus Lamu's 0.92 to 2.0 m) (Yap and Landoy, 1986).

Kilifi receives an annual rainfall between 600-1000 mm; with the highest monthly rainfall normally recorded in May. Air temperature ranges between 24^o C in July to 32^o C in February. Mean monthly evaporation rate is 200 mm/yr (Kitheka *et al.* , 1999a). Mida and Kilifi creeks are almost identical in area and both have narrow openings to the Indian Ocean. But the terrain around Mida slopes gently upward while that of Kilifi rises abruptly to as high as 10.0 m within 1 to 2 km from its shoreline. Consequently Kilifi has a much narrower tidal zone and only has a third of Mida's 1 800 ha mangrove and tidal flats. At Mida the much narrower opening prevents a faster turnover of water; consequently the water inside the lagoon is reportedly always higher in salinity than the open sea (Yap and Landoy, 1986).

Mida Creek is located approximately 100 km northeast of the city of Mombasa. It is situated in the centre of a slight bend of the coastline and may have been formed due to a concentration of wave energy (Oosterom, 1988). The total area including that covered by the mangroves is 32 km^2. Mida creek lacks a discharging river and the mangrove ecosystem is partly sustained by groundwater outflow. The lower parts of the creek are relatively shallow with a maximum depth of about 7·0 m, but this increases to a depth of 11·0 m in the central lower region and to about 4 m in the shallow wide basin to the north (Kitheka, 1998).

Mangrove swamps are represented by mud flats vegetated by mangrove forests, dominated by *R. mucronata*, *C. tagal*, *A. marina* and *S. alba*, at the edge of bays and estuaries. Mangroves of Mida creek have a total coverage of 1,746 ha; 573 ha at Kirepwe and 1,172 ha at Uyombo (Gang and Agatsiva, 1992). Seven of the 9 mangrove species described in Kenya are found in Mida creek (Kokwaro, 1985), with a mean height and DBH of 20 m and 18 cm respectively (Kairo *et al.* , 2002b). Kirepwe mangroves have a stand density of 1,197 stems/ha, dominated by *R. mucronata*. Uyombo, having a large intertidal area, depicts a marked difference in vegetation structure across the land-sea interface. The landward section is dominated by dwarf *A. marina*, while the seaward margin is dominated by tall *R. mucronata*. The stand density at Uyombo (1,585 stems/ha) is higher than at Kirepwe and is dominated by *C. tagal* (Kairo *et al.* , 2002b).

3.1.4 Mombasa

This section is characterized by branching bays and estuaries constituted by water bodies that are connected to the Indian Ocean by tidal channels through the present reef platform. The prominent bays are the Port Reitz, Port Tudor, and Mtwapa creek with narrow channels; Kilindini and Mombasa Harbours and Mtwapa creek respectively connecting them with the Indian Ocean. Large drainage of Voi and Mwatate rivers are connected with these branching bays. The outlets of Mwachema and Sinawe rivers constituted estuaries connected with the drainage area of the two rivers (Oosterom, 1988).

Mombasa Island is bounded by two creeks; Kilindini and Tudor, which connect Port Reitz and Tudor bays respectively to the open ocean. Mombasa region receives rainfall ranging from 13 mm in the driest month to 248 mm in the wettest month, giving a mean annual rainfall of 1079 mm. The mangroves of Mombasa cover 2,000 ha and are dominated by *R. mucronata*, *S. alba* and *A. marina*.

Port Reitz, situated to the south of Mombasa, was formed as a result of drowning of former river valleys due to sea level rise and is characterized by varying depth (Caswell, 1953). The channels fringing the mangroves have depth below 5 m. the creek experiences semi-diurnal tidal pattern; with average tidal range being 1.0 and 2.5 m at neap and spring tides respectively. Three seasonal rivers, Mwache (the largest), Cha Shimba and Mambone, with a total catchment area of 1480 km^2, drain into the area (Kitheka *et al.* , 1999b).

Tudor creek, situated to the North-west of Mombasa Island, has a long and deep inlet (average depth of 20 m) connecting shallower inner basin to the open ocean. The creek receives freshwater discharge from two seasonal rivers; Kombeni and Tsalu, draining an area of 450 and 150 km^2 respectively and with an estimated average freshwater discharge of 0.9 m^3/s (Nguli *et al.* , 2006). The tidal range at the entrance of the creek is 3.2 m at spring and 1.1 m at neap. The inner basin is fringed by mangrove forests and mudflats, with an average area of 6.37 and 22.5 km^2 at low and high water spring respectively. Mangrove forests occupy about 8 km^2 of the bay (Nguli *et al.* , 2006). Vegetation survey indicated that these forests are dominated by *R. mucronata*; with a stand density, basal area and mean height of 1283 stems/ha, 13.0 m^2/ha and 4.4±1.7 m respectively (Omar Said *et al.* , 2008).

Mtwapa Creek is situated 25 km north of Mombasa. It receives freshwater from River Luadini, a seasonal river, with an annual mean discharge of 0.3 m^3/s (Magori, 1997). The creek is relatively eutrophic with evidence of seasonal contamination attributed to river discharge, surface runoff and raw sewage disposal (Mwangi *et al.* , 2001). Mangrove forests, mainly dominated by *R. mucronata* occupy the extensive mudflats along the edge of the creek.

3.1.5 Gazi-Vanga Section

The landscape configuration of the southern section of Kenyan coastline is dominated by three sheltered bays behind discontinuous coral reef: Gazi, Shirazi-Funzi and Vanga bays. These embayments, unlike the branching bays of the Mombasa-Mida sections, are connected to the ocean by a wide bay mouth. The landward limits are mostly formed by a low bluff developed in unconsolidated clays, while the seaward margins constituted reef fronts and reef patches forming kind of discontinuous barriers which protect the bays from direct ocean swell. The coastline is subjected to intense dissection due to the absence of a protecting coastal range. The reef flats are characterized by thicker muddy sediments that had given rise to mangrove swamps in the centre of reef patches and on the inner reef flats. Within the sheltered bays are extensive mangrove swamps and tidal flats greater than those of Mombasa and Mida sections (Oosterom, 1988).

3.1.5.1 Gazi Bay

Gazi bay is a shallow, tropical coastal water system with mean depth often less than 5·0 m, situated about 55 km south of Mombasa city. The bay is open to the Indian Ocean through a relatively wide (3500 m) and shallow entrance in the south (Kitheka, 1997). It is sheltered from strong wave action by the presence of the Chale peninsula to the east and a fringing coral reef to the south. There are two major creeks draining the upper section of the bay, which is dominated by mangrove vegetation. Kidogoweni creek on the western site, receives freshwater from a seasonal river; Kidogoweni. Kinondo creek, a tidal creek on the eastern side, lacks freshwater input, but there may be groundwater influx as water salinity fluctuates significantly in the wet season. Mkurumuji River, which has higher flow rates, discharges into the south-western region of the bay. The drainage basin of Mkurumuji and Kidogoweni Rivers extends into the coastal ranges of Shimba hills with the drainage areas being 164 and 30 km^2, respectively (Kitheka, 1997).

Gazi bay receives an annual rainfall ranging from 1000 to 1600 mm, however, annual evaporation ranges from 1950 to 2200 mm. The bay has a semi-diurnal tidal regime with amplitude varying between 2.90 m at spring tide and 0.70 m at neap tide (Hemminga *et al.* , 1994). Salt flats occur at elevated areas with a very low inundation frequency (Middelburg *et al.* , 1996).

Gazi bay has a total area of 700 ha mangrove forest, with all the 9 mangrove species described in Kenya being present (Kairo, 2001). The general pattern of mangrove communities at Gazi appears to be similar to that of other parts in Kenya. *Sonneratia alba,* the most important pioneer species along open coast, occupies the lowest zone. The next zone is characterized by mixed vegetation: *Rhizophora-Avicennia-Bruguiera* community; followed by *Ceriops-Avicennia* community and *Lumnitzera, Xylocarpus* and *Heritiera* to the land ward side (Van Speybroeck, 1992; Kairo, 2001). The mangrove forest is dominated by *R. mucronata, C. tagal* and *A. marina*; with an overall stand density of 4077 stems/ha, basal area of 34.7 m^2/ha and mean height of 7.3 m (Bosire *et al.* , 2003). The landward zone is dominated by *A. marina*, followed by *C. tagal*, while the seaward zone is dominated by *R. mucronata*, followed by *A. marina* and *S. alba* (Dahdouh-Guebas *et al.* , 2004).

3.1.5.2 Shirazi-Funzi and Vanga Complex

The Msambweni-Vanga region covers approximately 150 km^2, which extends from Msambweni to Vanga at the Kenya-Tanzania boundary, comprises of the Shirazi-Funzi and Vanga bays in the upper and lower parts respectively. The area is basically a low-lying coastal submergent complex (below 30 m contour) dominated by extensive cover of mangrove forests, intertidal areas covered with seagrass beds and the coral reef in the shallow water lagoons. Mangrove forests dominate three main creek systems, namely, Mamuja, Vikurani and Uvinje. Ramisi and Mwena rivers enter the complex through Mamuja and Vikurani Creeks, respectively. The sediments consists of mud and silt in the backwater zones dominated by mangroves and coral reef derived carbonate sand in the lagoons located in the front water zone. The hinterlands are underlain by Mto Mkuu formation of Upper and Lower Cretaceous of the post Karoo systems (Caswell, 1953).

In the plot studies carried out for Shirazi, Bodo, Funzi, Ramisi and Majoreni in the Shirazi-Funzi and Vanga complex six mangrove species were encountered; *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Rhizophora mucronata*, *Sonneratia alba* and *Xylocarpus granatum*. However, other species such as *H. littoralis* and *L. racemosa* were noted in few sites on the landward margin outside the plots. Based on importance values *R. mucronata* was dominant in all the sites. Except in Bodo, *B. gymnorrhiza* and *X. granatum* had the least IV. *Sonneratia alba* had its highest IV in Ramisi, probably due to riverine influence on site conditions. However, most sites depicted distribution patterns typical for Kenyan mangroves. Wherever present, *S. alba* was found in front of *R. mucronata*; with *C. tagal* dominating next zone and scrubs of *A. marina* at the extreme landward fringe. *Rhizophora mucronata* in association with tall *A. marina* flanked the branching creeks. The overall stand density in this section ranged from 1573 to 1839 stems/ha; with height and basal area ranging from 6.0 to 7.4 m and 17.7 to 30.3 m^2/ha respectively (Table 3). Shirazi had the highest stand density, while Ramisi had the least. However, the reverse was true for basal area. The mangrove forests of Ramisi were structurally more complex, while those of Bodo were the least.

Ramisi mangroves had a significantly larger mean DBH than the other sites ($p < 0.001$); while mean DBH of Bodo did not significantly differ from those of the other sites ($p > 0.10$). Likewise there was no variation between the mean DBH of Shirazi and Majoreni ($p = 0.92$); but that of Funzi was significantly larger than that of Shirazi ($p = 0.000$) and Majoreni ($p = 0.003$). In terms of mean height, mangrove forests of Bodo, Shirazi and Majoreni did not significantly differ ($p > 0.11$). However, those of Funzi had a significantly higher mean height than those of Bodo, Ramisi and Majoreni ($p < 0.001$).

Most of the stems for *R. mucronata*, *C. tagal* and *B. gymnorrhiza* were small sized (5-13 cm DBH) in all the sites; while most stems for *A. marina* were large sized (Table 4). For *S. alba* majority of the stems were large sized in all sites except Ramisi, where there was an almost even size class distribution across all size classes. This species also had its highest stand density and IV in Ramisi (Table 3).

Table 3. Structural attributes of Shirazi-Funzi bay and Majoreni mangrove forests

Site	Species	Stems/ha	Mean Height (x±sd; m)	Basal Area (m^2/ha)	Relative values *Freq	Relative values Dom	Relative values Density	Relative values IV	CI
Shirazi	*A. marina*	102	10.2±2.5	2.5	8.6	14.1	5.6	28.4	14.1
	B. gymnorrhiza	61	6.7±1.8	0.4	9.9	2.5	3.3	15.7	
	C. tagal	157	5.5±1.8	0.7	19.8	3.7	8.5	32.0	
	R. mucronata	1416	7.1±2.4	12.1	49.4	68.2	77.0	194.6	
	S. alba	34	11.3±2.4	1.0	3.7	5.6	1.9	11.2	
	X. granatum	68	6.8±2.1	1.0	8.6	5.8	3.7	18.1	
	Mean		**7.2±2.6**						
	Total	**1839**		**17.7**	**100**	**100**	**100**	**300**	
Bodo	*A. marina*	215	7.8±2.4	6.1	13.5	28.9	12.4	54.8	13.1
	B. gymnorrhiza	200	5.2±1.2	1.6	19.1	7.4	11.6	38.0	
	C. tagal	265	5.2±1.5	1.6	22.5	7.5	15.3	45.3	
	R. mucronata	868	5.9±1.5	8.9	31.5	42.1	50.2	123.8	
	S. alba	3	12.0±0.0	0.3	1.1	1.2	0.2	2.5	
	X. granatum	179	5.9±1.4	2.7	12.4	12.9	10.4	35.6	
	Mean		**6.0±1.8**						
	Total	**1730**		**21.2**	**100**	**100**	**100**	**300**	
Funzi	*A. marina*	163	11.2±3.0	3.4	10.9	15.2	9.2	35.3	17.4
	B. gymnorrhiza	88	5.7±2.0	0.6	14.5	2.5	5.0	22.1	
	C. tagal	138	6.1±2.2	0.8	18.2	3.5	7.8	29.5	
	R. mucronata	1125	7.4±3.1	12.7	41.8	57.4	63.8	163.0	
	S. alba	96	7.3±1.4	2.6	3.6	12.0	5.4	21.0	
	X. granatum	154	6.4±1.4	2.1	10.9	9.4	8.7	29.1	
	Mean		**7.4±3.1**						
	Total	**1763**		**22.1**	**100**	**100**	**100**	**300**	
Ramisi	*A. marina*	318	9.3±2.6	14.3	20.5	47.3	20.2	88.0	18.6
	B. gymnorrhiza	5	5.0±0.0	0.02	2.3	0.1	0.3	2.6	
	C. tagal	264	4.2±1.1	1.4	18.2	4.7	16.8	39.7	
	R. mucronata	641	6.3±2.6	9.5	38.6	31.4	40.8	110.8	
	S. alba	341	6.2±1.3	5.0	18.2	16.3	21.7	56.2	
	X. granatum	5	5.5±0.0	0.1	2.3	0.2	0.3	2.7	
	Mean		**6.5±2.7**						
	Total	**1573**		**30.3**	**100**	**100**	**100**	**300**	
Majoreni	*A. marina*	107	10.0±3.4	2.5	8.5	13.8	6.3	28.6	11.5
	B. gymnorrhiza	79	5.8±2.2	0.7	8.5	3.8	4.6	16.9	
	C. tagal	447	5.4±2.8	3.2	25.6	17.3	26.2	69.0	
	R. mucronata	914	5.7±2.1	6.9	42.7	37.7	53.5	133.9	
	S. alba	137	8.2±4.1	4.6	9.8	25.0	8.0	42.8	
	X. granatum	23	8.7±1.68	0.4	4.9	2.4	1.4	8.7	
	Overall	1707	6.1±3.1	18.3	100	100	100	300	

***** Freq = frequency, Dom = dominance, IV = importance value and CI = complexity index.

Table 4. Yield table for Shirazi-Funzi and Majoreni mangrove forests

Site	Species	Size Class (DBH; cm)							
		5.0-7.0	7.1-9.0	9.1-11.0	11.1-13.0	13.1-17.0	17.1-20.0	20.1-35	>35
Shirazi	*A. marina*	14	5	16	11	25	9	16	7
	B. gymnorrhiza	36	11	5	5	2	0	2	0
	C. tagal	100	34	18	5	0	0	0	0
	R. mucronata	495	373	225	141	102	16	64	0
	S. alba	0	0	5	2	11	2	11	2
	X. granatum	11	25	14	7	2	2	5	2
	Total	**657**	**448**	**282**	**170**	**143**	**30**	**98**	**11**
Bodo	*A. marina*	29	26	29	15	29	18	59	9
	B. gymnorrhiza	103	32	32	15	12	0	3	3
	C. tagal	153	50	26	12	15	6	3	0
	R. mucronata	274	194	135	91	97	38	29	9
	S. alba	0	0	0	0	0	0	3	0
	X. granatum	56	41	18	32	12	6	9	6
	Total	**615**	**344**	**241**	**165**	**165**	**68**	**106**	**26**
Funzi	*A. marina*	25	8	17	38	25	17	33	0
	B. gymnorrhiza	46	13	17	8	0	4	0	0
	C. tagal	63	38	25	4	8	0	0	0
	R. mucronata	354	200	163	113	163	67	63	4
	S. alba	13	13	4	4	8	21	29	4
	X. granatum	54	46	17	0	13	17	4	4
	Total	**554**	**317**	**242**	**167**	**217**	**125**	**129**	**13**
Ramisi	*A. marina*	0	9	23	32	59	36	123	36
	B. gymnorrhiza	0	5	0	0	0	0	0	0
	C. tagal	105	95	50	9	0	5	0	0
	R. mucronata	205	127	77	41	77	36	68	9
	S. alba	41	55	68	82	23	36	36	0
	X. granatum	0	0	0	5	0	0	0	0
	Total	**350**	**291**	**218**	**168**	**159**	**114**	**227**	**45**
Majoreni	*A. marina*	7	7	9	21	21	14	28	0
	B. gymnorrhiza	47	12	5	0	7	5	5	0
	C. tagal	267	72	37	12	26	7	26	0
	R. mucronata	326	244	153	88	63	28	9	2
	S. alba	5	16	9	19	19	16	51	2
	X. granatum	0	2	5	5	5	2	5	0
	Total	**651**	**353**	**219**	**144**	**140**	**72**	**123**	**5**

Six juvenile species; *C. tagal*, *R. mucronata*, *B. gymnorrhiza*, *A. marina*, *S. alba* and *X. granatum* were encountered in Shirazi, Funzi, Ramisi and Majoreni, with all these except *S. alba* being encountered in Bodo (Table 5). Bodo mangroves had the highest juvenile density (72036 juveniles/ha) of which more than 50 % were RCI; Shirazi had the least (21811 juveniles/ha) out of which 53 % were RCII. In Shirazi, Bodo and Majoreni *C. tagal* constituted the dominant juvenile species, while *R. mucronata* was dominant in Ramisi and Funzi.

Table 5. Natural regeneration in Shirazi-Funzi and Majoreni mangrove forests

		Species (Juveniles/ha)						
Site	Class	*A. marina*	*B. gymnorrhiza*	*C. tagal*	*R. mucronata*	*S. alba*	*X. granatum*	Total
Shirazi	RCI	84	45	5577	373	0	9	6089
	RCII	20	0	4641	6825	0	155	11641
	RCIII	32	68	1145	2750	86	0	4082
	Total	**136**	**114**	**11364**	**9948**	**86**	**164**	**21811**
Bodo	RCI	35	897	25886	10544	0	447	37810
	RCII	71	332	8579	8162	0	382	17526
	RCIII	144	1871	7641	6685	0	359	16700
	Total	**250**	**3100**	**42107**	**25391**	**0**	**1188**	**72036**
Funzi	RCI	0	855	11517	3171	0	0	15543
	RCII	0	1427	10265	12321	0	83	24096
	RCIII	41	455	2609	9796	500	0	13401
	Total	**41**	**2737**	**24391**	**25288**	**500**	**83**	**53041**
Ramisi	RCI	782	2727	9168	10727	18	0	23422
	RCII	0	5455	5859	9614	105	55	21087
	RCIII	14	36	5782	15700	618	0	22150
	Total	**796**	**8218**	**20809**	**36041**	**741**	**55**	**66659**
Majoreni	RCI	1163	388	12076	1847	16	2	15493
	RCII	12	53	9676	4551	23	12	14328
	RCIII	28	172	6457	5077	88	7	11830
	Total	**1202**	**614**	**28210**	**11474**	**128**	**22**	**41650**

4.0 DISCUSSIONS

The largest basal areas were observed for mangroves of Northern swamps (Lamu) and Kipini (Ungwana bay), while the smallest was for Tudor (Mombasa) (Table 6). Despite receiving less mean annual rainfall (≈ 950 mm) mangrove forests in the Kenyan north coast have the largest basal area than most sites in the south coast. Lamu mangroves, despite having a high stand density than all other sites, except Gazi, recorded a larger basal area. This was contrary to observations that, basal area tends to increase with decline in stand density (Twilley, 1995). Similarly, the high complexity index that has been observed for Lamu is attributed to the high stand density and basal area. This could be due to probably nutrient enrichment from upwelling thought to occur at the convergence of the Somali Current and the East African Coastal Current (UNEP, 1998) and limited human accessibility than other sites. The mangroves of Ungwana bay also showed superior structural features than those of most sites in the south coast. This is probably attributed to the influence of Sabaki and Tana rivers. Mangroves of Ungwana bay and Ramisi were typical of forests with large trees since they had large basal areas and low stand densities. This is likely attributed to more access to freshwater and nutrients (Lugo, 1997) than maturity of forests because of presence of large river system for each case. The presence of large trees does not necessarily represent old growth forests, since the difference with dwarf ones may not be age but site conditions (Lugo, 1997). The high CI for Gazi mangroves is likely due to high stand densities observed for most mangrove stands in this site. On the contrary, the mangroves of Tudor Creek were observed to have the poorest structural attributes. This could be attributed to the influence of degradation associated with the urban settings (Omar Said *et al.* , 2008). Most sites in the south coast that are easily accessible showed evidence of intense anthropogenic pressures, resulting in low complexity indices. This situation was found to be consistence within the same area. For instance mangrove forests in Funzi were structurally more complex than those in Shirazi and Bodo, since most areas in Funzi experience high wave action thereby limiting their accessibility. Kairo *et al*. (2002b) have demonstrated that areas subjected to intense human activities tend to have low complexities indices. In terms of species dominance, *R. mucronata* was dominant in most sites along the coastline. However, the species distribution across the topographic gradient is similar for most sites along the Kenyan coastline (Fig. 4).

Table 6. Mangrove forest attributes along the Kenyan coast

Section	Dominant Species	Stand density (Stems/ha)	Mean Height (x±sd; m)	Basal area (m^2/ha)	CI	Source
Lamu						
Nothern swamps	*R. mucronata*	2343	7.9±3.8	47.0	62.8	Kairo *et al*., 2002b
North central swamps	*R. mucronata*	1980	6.1±2.2	24.1	25.1	"
Ungwana Bay						
Kipini	*A. marina*	936	13.6±4.8	47.0	41.9	Bundotich, 2008
Mto Tana	*A. marina*	743	7.1±2.6	32.9	8.6	"
Ngomeni	*R. mucronata*	2074	6.5±2.9	25.7	25.3	"
Mida						
Kirepwe	*R. mucronata*	1197	8.9	23.6	15.1	Kairo *et al*., 2002a
Uyombo	*C. tagal*	1585	7.3	15.8	10.9	"
Mombasa (Tudor Creek)	*R. mucronata*	1283	4.4±1.7	13.0	4.4	Omar Said *et al*., 2008
Gazi	*A. marina*	4160	6.1	27	27.4	Bosire *et al*., 2003
	R. mucronata	3370	7.5	42	35.6	"
	S. alba	4300	8.3	35	12.5	"
Shirazi-Funzi						
Shirazi	*R. mucronata*	1839	7.2±2.6	17.7	14.1	This study
Bodo	*R. mucronata*	1730	6.0±1.8	21.2	13.1	"
Funzi	*R. mucronata*	1763	7.4±3.1	22.1	17.4	"
Ramisi	*R. mucronata*	1573	6.5±2.7	30.3	18.6	"
Vanga Bay (Majoreni)	*R. mucronata*	1707	6.1±3.1	18.3	11.5	"

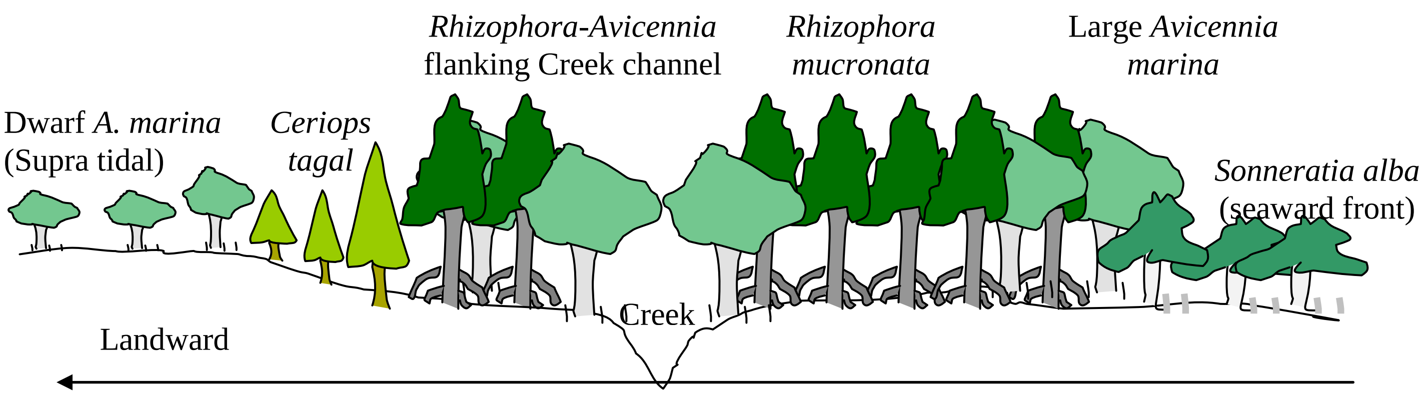

Figure 4. Mangrove vegetation profile typical of the Kenyan mangrove forests

5.0 CONCLUSIONS

Mangroves of Kenya are continuingly undergoing degradation with about 50 % of mangrove cover lost in the last 50 years (FAO, 2003). Lack of clear management plans and inadequate resources have largely contributed to the declining trend (Abuodha and Kairo, 2001). Findings from this study have wide application in sustainable utilization and management of mangroves along the Kenyan coast. This study has shown some evidence of variation in mangrove forest structural attributes along the Kenyan coastline. Despite a number of sites having high stand densities (e.g. Gazi), most stems are of poor quality due to selective harvesting of good quality poles. This calls for adoption of management plans that takes into account harvesting systems. For instance pilot sites should be set aside where harvesting techniques such as strip harvesting should be employed. Likewise, critical areas such as seaward fringe should be set as 'no cutting zone' in order to protect the coastline against coastal erosion. Protection should also be accorded to areas under severe degradation due to easy accessibility or with adverse environmental conditions (e.g. hypersaline areas like the supra tidal sites) to allow regeneration and/or maintain forest cover.

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