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# The current status of mangroves along the Kenyan coast: a case study of Mida Creek mangroves based on remote sensing

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*Key words:* mangroves, Kenya, remote sensing, species composition and distribution

**Abstract**

Mangroves form a unique ecosystem of limited extent covering an area of about 53 000 ha along the Kenyan coast which need protection from overexploitation. Background information on the areal extent and status of these mangroves is limited and makes their protection and management difficult.

A model study has been carried out on the Mida Creek mangroves based on a double sampling approach starting with SPOT multispectral satellite imagery followed by ground checks to provide information on species composition, density and distribution of mangroves. The utilization of mangroves and uses around and within the mangroves were determined.

During this study, seven mangrove species were identified in Mida Creek, namely: *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Rhizophora mucronata*, *Sonneratia alba*, *Xylocarpus granatum* and *Lumnitzera racemosa*. This report briefly outlines the present utilisation of mangrove species. It is recommended that a multidisciplinary management plan be developed in order to conserve and manage the mangroves of Kenya on a sustainable yield basis.

## Introduction

Mangroves are a group of highly evolved halophytes occupying the intertidal zone in estuaries, lagoons and coastal mud flats in tropical and subtropical zones. While they have proven ability to function in poorly oxygenated water-logged, saline habitats, a seasonal flushing with freshwater is necessary for their continued survival. There are some which prefer a daily tidal wash while others find their optimum conditions in areas subject to only seasonal high tides (UNDP/UNESCO, 1984). This determines the distribution of mangrove species within a given community. Mangroves have been exploited by coastal people for their numerous natural products. These include poles for building, vegetable tannins, pulp, fuelwood and medicine (UNEP, 1988).

The Kenyan coastline has a total of about 52 980 ha of mangrove forest (Doute *et al.*, 1981). The bulk of these forests occur in the intertidal areas where submarine ground water discharge (SGD) or seepage occur rather than in estuaries (Ruwa & Polk, 1986).

### *Background and problem*

The lack of appraisal of the status of Kenyan mangrove forest has been a limitation on the formulation of an adequate management and conservation policy. Quite often, the exploitation of

mangroves has occurred in the past unnoticed or unquantified, as has been previously reported by Doute *et al.* (1981) who based their study on the use of Landsat Multispectral Scanner (MSS) imagery. The study is now under review (Agatsiva *et al.*, 1990) to up-date it at the same time giving more details which were never achieved in the 1981 study.

The lack of up-to-date and accurate data poses planning problems on conservation and management of such mangrove species. It has been noted that mangroves and their related ecosystems have in the past undergone drastic changes without much attention being paid to their ultimate fate. When exploiting a renewable resource, the concept of sustainable development should be borne in mind. Conflicting land-uses such as fishing, cutting of mangroves for different uses, salt mining and various marine activities are likely to exhaust the mangrove resources.

The Mida Creek mangroves (Gang, 1988) have been considered in an effort to design an appropriate methodology for having the Kenyan mangroves rapidly and cheaply assessed. The recommendations made may enable them to be properly conserved, managed and where exploited, to be appropriately harvested on a sustainable yield basis. Mida Creek was preferred because the area has a variety of mangrove types as well as different regeneration stages and some dense old stands. There are also several land use practices in and around the creek which may also influence the mangrove ecosystem along the coast. The broad recommendations made on this area are therefore likely to represent a wider spectrum of information concerning all mangroves along the Kenyan coast.

*The objectives of the study are therefore*

(i) To document the extent and status of the mangroves of Mida Creek.
(ii) To assess the suitability of SPOT multispectral satellite imagery in providing baseline data for the monitoring and management of mangrove areas.
(iii) To prepare a checklist of plants growing in close proximity to the mangroves both within and without the mangrove area in Mida Creek.
(iv) To give possible suggestions and recommendations that may be applied for sustainable utilisation of the mangroves.

## The study area

*Location of the study area*

Mida Creek is located in Kilifi district on the north coast of Kenya and is approximately 25 km south of Malindi town. The area lies within approximate bounds of longitude 39° 58′ E and latitude 3° 20′ S (Fig. 1).

*Climate*

The rainfall pattern is bimodal. The long rains fall in April to June, with a peak in May. The short rains fall from October to December. The area receives an annual rainfall of about 900–1100 mm (District Development Plant 1989/83).

*Soil types*

Soils of the mangrove swamps are poorly drained, deep and excessively saline, olive to greenish grey loam to clay and often with sulfidic material (District Environmental Assessment Report, 1985).

*Land use*

Agriculture is one of the land use types in the area. Tree crops occupy more than one third of the area under cultivation. The most important of which are cashewnuts, mangoes and coconuts. Coconuts are very much valued due to the role they play in providing daily requirements such as cooking fat, woodfuel, building materials, local beer and hair oil. Cashewnuts are sold to the processing plant based in Kilifi. Mangoes are sold to the village, hotel industry and traders in Mombasa.

Fishing is another important activity in the study area. Most of the catch is harvested by individual fishermen using their own boats and gear following traditional methods. They are often seen in their small boats in the creek which is surrounded by mangroves.

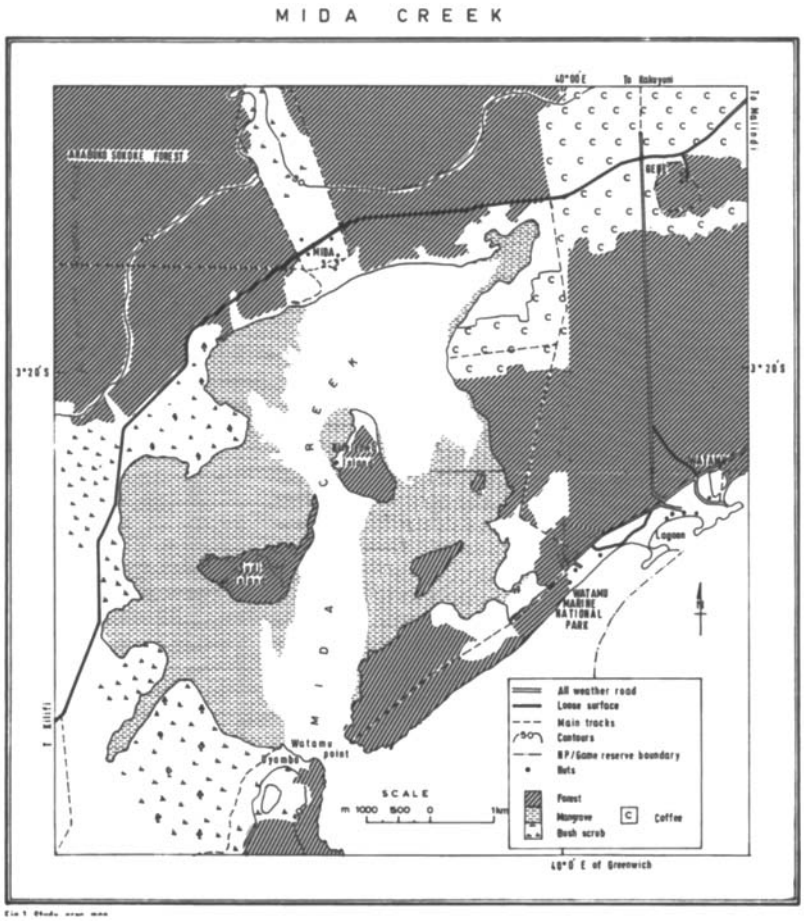


*Fig. 1.* Study area map.

## Methodology

The methodology used was based on a double sampling approach which include the following:

(i) Use of remote sensing to provide initial stratification of the area into major cover types and ground-truthing of the satellite image.

(ii) Use of ground checks for species identification and categorisation into various cover types.

*Remote sensing*

Remote Sensing is broadly defined as a process of gathering information about objects from a distance based on the electromagnetic energy reflected or emitted by that object. Satellite remote sensing data can provide natural resource managers and planners with periodic information on the extent, location and status of the resources. Such information types are used in the day to day decision making on the implementation of management policies such as conservation and resource allocation.

A whole range of remote sensing techniques could have been used to map the area but weather conditions did not allow all these techniques to be used and their results compared for the area of interest. The region is under cloud cover for much of the year. However, SPOT 1 multispectral imagery was obtained for the area from Toulouse – France. SPOT multispectral imagery KJ 146 357 (scale 1:50 000) which has a spatial resolution of 20 by 20 m was the ideal imagery for mapping cover types because different mangrove species and zonation could be easily identified from the

image. This was done by use of a transparent overlay put over the image and placed on a light table where all the distinguishable features were delineated. The differentiation was based on colour intensity, chroma and hue in addition to other image characteristics and interpretation elements including pattern and texture among others as described by Lillesand & Keifer (1979).

A topographic map at the scale of 1:50000 (sheets No 193/1 and 193/3 from survey of Kenya) was used to associate various manifestations in the image with contents of the map referring to land use and also for orientation and navigation during field surveys.

*Ground measurements*

In each stratum obtained, representative stands were sampled to obtain information regarding the mangroves on:

(i) Mangrove Species
(ii) Height class
(iii) Crown cover
(iv) Density of species
(v) Diameter at breast height (dbh).

Representative stands were selected within each stratum, using 50 m by 50 m quadrats. The total count method was used as described in Muchoki (1988). All mangrove trees 0.7 m high and above were measured and quantitative attributes such as height, dbh and crown cover were recorded. Visual observation was also done to determine the species being exploited. This included actual counting of stumps of the already cut mangroves and counting the dhows transporting mangrove poles to a collection yard at Uyombo. Finally an attempt was made to prepare a vegetation checklist of plants growing in close proximity to mangroves. The methods used were those used by Kenya Rangeland Ecological Monitoring Unit (KREMU) in its Rangeland Monitoring attempts (Kuchar, 1979) and those used by botanists elsewhere in compiling lists of plants by occurrence in different habitats.

## Results and discussion

The above double sampling approach yielded good results on the mangrove species distribution and uses. Seven major mangrove species were identified (Table 1).

The SPOT image delineated had the following cover classes (Fig. 2).

Avicennia marina
This is found in the landward fringe of the Creek. The underground is mainly covered by pneumatophores. This covers 160 ha (2.9%).

Avicennia/Ceriops/Rhizophora
This is characterised by species which have discontinous canopy formations and generally in poor state of health, covering 145 ha (2.6%).

Rhizophora/Ceriops
Dominated mainly by *Rhizophora mucronata* and *Sonneratia alba* at the edge of the creek and *Ceriops tagal* with few *Bruguiera gymnorrhiza* and *Xylocarpus* spp. The undercanopy consists of

*Table 1.* Mangrove species found in the study area.

| Mangrove species | Standard name in Swahili | Family |
|---|---|---|
| *Avicennia marina* (*Forsk.*) Vierh | Mchu or Mtu | Avicenniacea |
| *Bruguiera gymnorrhiza* (L.) Lam | Muia | Rhizophoraceae |
| *Ceriops tagal* (perr.) C. B. Robinson | Mkanda | Rhizophoraceae |
| *Lumnitzera racemosa* Wild. | Kikanda or Mkanda-Mwitu | Combretaceae |
| *Rhizophora mucronata* Lam. | Mkoko | Rhizophoraceae |
| *Sonneratia alba* Sm. | Mlilana or Mpia | Sonneratiacea |
| *Xylocarpus granatum* Koen. | Mkomafi | Meliaceae |
| *Xylocarpus* sp. | | Meliaceae |

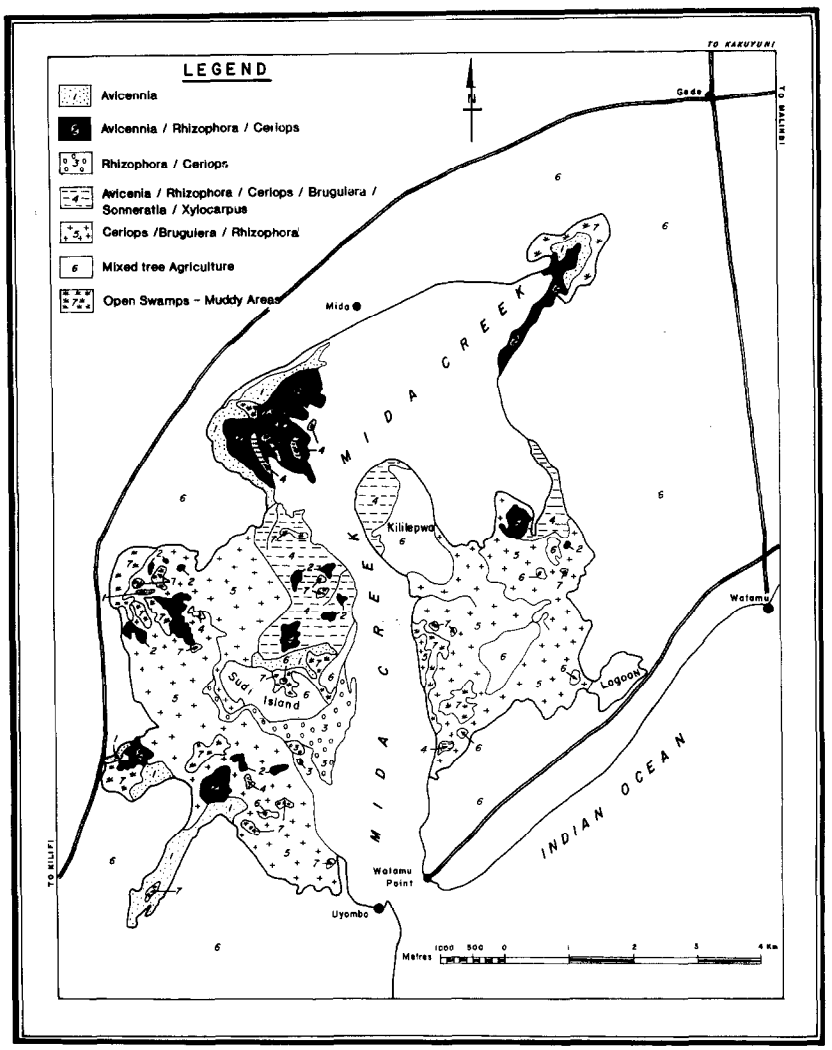


*Fig. 2.* Classification of Mida Creek mangroves and surrounding cover types based on SPOT imagery.

*Rhizophora* and *Ceriops* seedlings growing vigorously. Cutting in this zone is selective and rather intensive. This category covers 67.5 ha (1.2%).

Avicennia/Rhizophora/Ceriops/Bruguiera/ Sonneratia/Xylocarpus

This category is characterised by very mature stands of majority of the species. There are very-tall *Bruguiera*. Cutting of *Ceriops* and *Xylocarpus* is most intensive probably due to their straight poles. *Avicennia* is very scarce and least utilised. This unit covers 237.5 ha (4.2%).

Ceriops/Bruguiera/Rhizophora

This is dominated by *Ceriops tagal* with very high regeneration of both *Rhizophora* and *Ceriops* on the outer fringes. From the land seawards, this zone has few *Avicennia marina* while *Rhizophora mucronata* mixed with *Sonneratia alba* dominate the edge of the creek. This covers 890 ha (15.9%).

*Mixed tree agriculture*

This occurs in the hinterland surrounding the creek, Sudi and Kilelepwa islands found in Mida

creek. Tree crops found in this zone are mangoes, coconuts and cashewnuts. There is also natural vegetation growing together with tree crops. This includes *Thespesia danis* Olive and *Azadrachta indica* A. Juss. This class covers 3805 ha (68%).

*Open swamps/muddy areas*

These are swampy areas that no longer receive flooding except during high tides, immediately within the vicinity of these areas, small halophytic plants such as *Salicornia* sp. and *Sueda* sp. are dominant. The category covers 292.5 ha (5.2%).

Satellite imagery (SPOT image) proved to be very useful in identifying mangrove areas and other land use types in close proximity. Different mangrove zonations are easily identifiable using tonal differences in the image. It is not possible to identify mangroves to species level in the image but tonal differences interpreted were confirmed to represent different mangrove types during field surveys. It was not possible also to detect the cutting of the mangroves from the satellite imagery because the cutting is selectively done and it is not concentrated at one spot. Actual counting in the sampling plots indicated a cutting intensity of thirty poles per 50 × 50 m plot. Table 2 shows some of the mangroves species identified in the Mida Creek using the total count approach. The rest of the plants in the surrounding areas are indicated in Table 3. The cutting intensity decreases away from the landward fringes probably due to accessibility and convenience. The forest department controls the cutting by issuing licenses and ensures that poles are cut according to the quantity specified, and suspends further cutting in some areas until regeneration is restored. There are no afforestation activities in the creek but rather the mangroves regenerate naturally, growing into exploitable poles after 3–6 years. No quantitative measurements were carried out on regeneration but it was observed during field surveys that species like *Ceriops tagal* and *Rhizophora mucronata* have several seedlings actively growing. This may suggest that the forest department need to regulate the mode of harvesting in order to ensure sustainable exploitation of the mangroves in this creek.

*Table 2.* Total number of species obtained through the total count method from five sampling plots randomly chosen in Mida Creek.

| Mangrove | Plots | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Total |
| *Ceriops tagal* | 46 | 107 | 7 | 47 | 2 | 209 |
| *Xylocarpus granatum* | 7 | – | 12 | 1 | – | 20 |
| *Bruguiera gymnorrhiza* | 2 | 1 | – | 2 | 1 | 6 |
| *Avicennia marina* | 1 | – | – | – | 82 | 83 |
| *Rhizophora mucronata* | – | 32 | 27 | 23 | 1 | 83 |
| *Sonneratia alba* | – | – | – | – | 5 | 5 |

*Table 3.* Plants growing in close Proximity to mangroves in Mida Creek.

| Species | Family |
|---|---|
| *Aeva lanata* | Amaranthaceae |
| *Anisotes parviflora* | Acanthaceae |
| *Aristogeitonia monophylla* | Euphobiaecae |
| *Asparagus africanus* Lam. | Liliaceae |
| *Azima tetracantha* Lam. | Salvadoraceae |
| *Cremaspora trifloa* | Rubiceae |
| *Cyperus tuberosus* Rottb. | Cyperaceae |
| *Canaralia carthartica* Thouars | Papilionaceae |
| *Dactyloctineum germinatum* Hack | Gramineae |
| *Derris* spp. | Papilionaceae |
| *Digitaria milanjiana* (Randle) Stapt | Gramineae |
| *Eleaodendron schweinfurthianum* Loes | Celastraceae |
| *Enteropogon macrostachysus* (A. Rich) Benth | Gramineae |
| *Euclea schimperi* (A. D. C.) Dandy | Ebenaceae |
| *Flacourtia indica* (burn, f) Merr. | Flacourtiaceae |
| *Fimbristylis triflora* (L.) K. Schum | Cyperaceae |
| *Fuirena ciliaris* (L.) Roxb. | Cyperaceae |
| *Grewia vaughanii* exell. | Tilliaceae |
| *Hyphaene compressa* H. Wendl. | Palmae |
| *Ipomoea pes caprae* (L.) R. Br. | Convolvulaceae |
| *Mormodica trifoliata* Hook F. | Cucurbitaceae |
| *Panicum infestum* Anderss. | Gramineae |
| *Panicum piniplium* | Gramineae |
| *Phoenix reclinata* Jacq. | Palmae |
| *Phragnites communis* | Gramineae |
| *Premna* spp. | Verbanceae |
| *Psilotrichum sericeum* (Roxb.) Dal 2 | Amaranthaceae |
| *Saliconia* sp. | Chenopodiaceae |
| *Salvadora persica* L | Salvadoraceae |
| *Sesuvium portulacastrum* (L.) L | Aizoaceae |
| *Sideroxylon inerme* L | Sapotaceae |

The licensing policy of the forest department should be reviewed and strengthened to ensure that licenses issued to licensees are consistent in order to prevent illegal cutting of mangrove species and types which are not originally included in the license. This requirement should control the current practices in Mida creek where mangroves are cut to the edge of the creek. The cutting of *Rhizophora* sp. at the edge allows siltation since the stilt roots which hold sand leads to the death of the tree. This activity may interfere with the future of the creek since siltation may in the long run turn the creek into the beach.

Mida Creek mangroves are not much exploited for firewood. A random survey indicates that people living in the periphery of the creek prefer to collect their fuelwood from the neighbouring Arabuko Sokoke forest. Firewood is mainly obtained from the dead branches of common tree species including: *Brachystegia speciformis*, *Cynometra webberi*, *Afzelia quanzensis*, *Croton pseudopulchellus* and *maytenus undata*. Nevertheless, Mida Creek mangroves (Table 1) are heavily exploited for building and fencing poles. A visit to a collection yard at Uyombo, confirms the export of mangrove poles to the mainland. They are piled in the different classes depending on the diameter at butt end. These range from 3.8 cm to 14 cm in diameter.

Complementary studies on woodfuel/timber demand and supply may be essential to ensure sustainable utilisation of the woody biomass. These studies should be able to compute further, the attributes such as the ones shown in the Table 4 to precisely calculate the amount of biomass available to the entire creek.

## Conclusion

The superior resolution of SPOT data made it possible to identify different cover types in the study area. With the complement of ground survey, species identification was possible in the area. From these results, SPOT data promise a new dimension in the use of Remote Sensing particularly in this region where rapid acquisition of data is necessary for development planning. Hopefully, with further research into the use of satellite imagery for coastal resource planning and management, it will be possible to answer some of the questions arising from such studies and refine what amounts to a very useful and time saving method of monitoring mangrove areas. Questions such as how much area of kenya is currently under mangroves, their status and exploitation patterns will be answered.

### *Suggestions and recommendations*

#### *Use of further satellite imagery in monitoring mangrove areas*

Having proved the ability of satellite and recognizing it as a powerful aid to fast field data collection, it would be worthwhile to apply this tool in documenting the status of the mangroves in the entire Kenyan coast. A good sampling strategy incorporating aerial photography on a sample basis may rapidly enhance the results for mangrove management.

#### *Further studies into the parameters controlling the distribution of mangroves in a given habitat*

Further studies should be carried out in order to

*Table 4.* Summary of mangrove data in plot No. 2 near Dabaso in Mida Creek.

| Name of plant | Total above ground biomass kg/ha | Utilizable woody biomass kg/ha | % of trees per species | Density | Frequency |
|---|---|---|---|---|---|
| *Rhizophora mucronata* | 11832.0 | 9727.0 | 32.0 | 46.0 | 23 |
| *Bruguiera gymnorrhiza* | 1029.0 | 846.0 | 3.0 | 4.0 | 2 |
| *Ceriops tagal* | 24178.0 | 19877.0 | 64.0 | 94.0 | 47 |
| *Xylocarpus granatum* | 514.0 | 423.0 | 1.0 | 2.0 | 1 |

gain in-depth understanding of the parameters controlling the distribution of each mangrove species within a given habitat. Effects of such parameters as land use activities and erosion in the hinterland, salinity, temperature and depth of substrate type are important for designing advisory and protection schemes for the proper interpretation of the results from monitoring programmes.

*Use of computers and digital mapping techniques*
The capability to digitize SPOT data should be enhanced as well as the use of computers and digital mapping techniques in the region in order to derive data from the imagery. Certainly for any time series this would ease the problem of identifying changes to mangrove cover.

*Increased awareness of mangroves values*
The efforts to conserve the mangroves would benefit from a greater awareness in Governmental, Non Governmental organisations and amongst the general public of the importance of mangroves. To this end, an educational campaign should be initiated which emphasizes the values of the mangroves and their links to other elements in the ecosystem, principally seagrass beds, coral reefs and fish populations.

Silvicultural measures could potentially enhance the productivity of the mangrove forests, but at present there is very limited information available on which to base such measures. Further research should therefore be carried out to document the correct silvicultural practices that may be useful for the Kenyan coast.

A National inventory of the mangroves of Kenya should be made. The Status of the entire mangrove ecosystem should be highlighted in this inventory report. It is after this that a national mangrove management scheme can be framed and prepared by a multidisciplinary group.

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## References

Agatsiva, J. L., J. P. Delsol, N. Ochanda, M. Shimba & J. M. Terresa. (unpublished results). A remote sensing approach to mapping and monitoring forest cover in Kenya.

Doute, R., N. Ochanda & H. Epp, 1981. Forest cover mapping using remote sensing techniques Kenya Rangeland Ecological Monitoring Unit, P.O. Box 47146, Nairobi, technical report No. 30, 72 pp.

Gang, P. O., 1988. Application of Remote Sensing in Landuse/Landcover assessment of Coastal Environments (Dissertation submitted to the Kenya Polytechnic, P.O. Box 52428, Nairobi, Kenya).

Gang, P. O., 1988. The distribution of mangroves forest of Kenya. A case study in Mida Creek, Sabaki and Ngomeni areas, Kenya Rangeland Ecological Monitoring Unit, Box 47146, Nairobi (unpublished results).

Kuchar, P., 1979. A methodology for sampling in order to monitor conditions, trend and plant biomass. Kenya Rangeland Ecological Monitoring Unit, Box 47146, Nairobi.

Lillesand, T. M. & R. W. Kiefer, 1979. Remote sensing and image interpretation. John Wiley and Sons Inc., New York: 528–590.

Kenya Government, Ministry of Planning and National Development 1989, Kilifi district Development plan. 1989/93, pp. 1–3.

Muchoki, C. H. K., 1988. A preliminary survey of efficiency of three methods used in studying rangeland vegetation: The quadrat method, PCQ and line transect methods, Kenya Rangeland Ecological Monitoring Unit, Box 47146, Nairobi. Technical Report No. 132. pp. 3–10.

Kenya Government, National Environmental Secretariat, 1985. District environmental assessment report of Kwale district, 6 p. (6 pp.)

Ruwa, R. K. & P. Polk, 1986. Additional information on the mangrove distribution in Kenya: some observation and remarks – Kenya J. Sci. Ser. B7: 41–45.

UNEP, 1988. Ambio, A Journal of the human environment. Royal Swedish Academy of Sciences/Pergamon Press, vol. xvii No. 3 1988: 214–216.

UNDP/UNESCO, 1984, Regional Mangrove Project RA/79/002 in Asia and the Pacific.