Participatory appraisal for potential community-based mangrove management in East Africa

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Participatory appraisal for potential community-based mangrove management in East Africa

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Abstract

Mangroves are among the most threatened ecosystems in the world and the coastal forests of East Africa are no exception to this trend. Although conservation, rehabilitation and sustainable management plans have been developed in various tropical regions, only a few locally based approaches have been launched along the Indian Ocean coast of Africa. In order to identify possible conditions for sustainable management of mangroves based on socio-economic and ecological considerations, we present a participatory approach designed to evaluate the relationships between mangroves and human activities and the use of multi-criterion analysis to identify management solutions. To achieve this goal, all the subjects involved in mangrove management (local communities, institutions and researchers) took an active part in the process. The research was carried out in three communities relying on mangrove swamps: Kisakasaka village on the island of Zanzibar, Mida Creek in Kenya, both relying on mangrove forests known to be endangered by over-exploitation, and Inhaca Island in Mozambique, where mangroves are more pristine. Families were the hub of the research and the importance of each of their economic activities was assessed. We then examined the methods by which mangroves are exploited by the local community and by other stakeholders working in the study areas. Our results show that the mangroves in Inhaca are exploited only for household needs and the pressure on the forests is still ecologically sustainable. In contrast, there is a well-established demand for mangrove products in Kisakasaka and Mida Creek and the mangroves represent an essential source of income for the families, resulting in an ecologically unsustainable rate of exploitation. Therefore, possible alternatives to the current management practices were identified in the two areas by means of a participatory approach. Multi-criterion analysis was then used to compare and discuss the alternatives in terms of social, economic and ecological criteria.

Introduction

Mangrove ecosystems are the characteristic littoral plant formations of tropical and subtropical sheltered coastlines and their distribution, biology and ecology have been extensively studied and reviewed (Saenger et al. 1983; Field 1995, 2000; Spalding et al. 1997; Kathiresan and Bingham 2001). Although the most extensive forests are in South-East Asia and Indonesia, mangroves are also present along much of the East African coastline (Spalding et al. 1997), with well-developed forests in Tanzania (2,456 km^2), Mozambique (about 3,500 km^2) and Kenya (530 km^2).

These coastal ecosystems, traditionally looked upon as worthless mosquito-infested areas, have recently been re-evaluated. Today, it is commonly agreed that they are multi-functional ecological sys-

tems crucial for the health of the integrated coastal and shallow-water ecosystems of the tropics (Kathiresan and Bingham 2001). They are the primary barrier against coastal erosion (Kjerfve et al. 1997) and play a major role in shoreline stabilization (even of adjacent ecosystems) and storm control. Moreover, mangroves act both as nutrient and sediment traps (Hemminga et al. 1994) and as nutrient exporters, part of their production supplying other ecologically important shallow-water wetlands, such as seagrass beds and coral reefs (Lugo and Snedaker 1974). Last but not least, they increase species richness and biodiversity of estuarine and brackish areas, acting as hatching and nursery sites for sedentary and migratory marine species (Rönnbäck et al. 1999; Naylor et al. 2000).

Apart from their ecological value, these forests have provided, and still provide, coastal communities with numerous essential and commercial products, generating much needed economic opportunities in most East African countries (Semesi and Howell 1993; Dahdouh-Guebas et al. 2000; Dahdouh-Guebas 2001). These products are a primary resource for coastal people and they have a direct impact on the forest ecology, leading in some cases to over-exploitation of mangroves (Ngoile and Shunula 1992; Linden and Lundin 1996; Kairo and Gwada 1998; Dahdouh-Guebas 2001).

The present study is part of the interdisciplinary European INCO-DC Project ''Macrobenthos of East African Mangroves'' (MEAM), aimed at identifying possible conditions for the sustainable management of mangrove resources. The research focused on the socio-economic and ecological relationships between the mangrove ecosystem and human activities. In particular, the present paper presents a participatory approach designed to evaluate the relationships between mangroves and human activities and the use of multi-criterion analysis to identify management solutions. All subjects involved in the study (local communities, institutions and researchers) took an active part in the process and acted as partners to reach a solution able to satisfy present and future needs. In particular, the researchers contributed to the identification of possible solutions of the problems, combining scientific knowledge with local knowledge.

This approach was justified by the complex link between the mangrove forest and the local community, involving different elements. At the family and village level, the link involves a family's knowledge of natural resources, its cultural background and the opportunities to satisfy basic needs. At an institutional level, it involves various institutions and the rules that control the exploitation of mangroves. The real challenge of our research was in increasing the knowledge of these elements and the causal relationships among them.

Living in the study areas for several months was an essential part of the participatory approach. During this period, particular attention was paid to the attitudes and behaviour of the local people (Contini et al. 2000). This enabled us to effectively integrate the researchers' scientific knowledge with local knowledge and to talk with the community in a ''common language''. Moreover, it also provided us with the means to reach an agreement among different kinds of interests (Bernard 1997; Chia et al. 1992; Chia and Raulet 1994). This approach was fundamental for the success of the research; indeed it is not possible to deal with the management of an area without involving local communities.

Methods

Three communities were selected, living in the vicinity of mangrove swamps and depending on mangroves for their livelihood: the village of Kisakasaka (06° 14′ S, 39° 17′ E), on the island of Unguja, Zanzibar archipelago; the villages of the Mida Creek area (03° 21′ S; 39° 59′ E), on the northern coast of Kenya; the villages of Inhaca Island (26° S, 33° E), in Maputo Bay, southern Mozambique. The study was conducted in 1997–1999, when all the sites were repeatedly visited for several months.

Households represented the hub of the research. In dealing with families relying on many income-generating activities for their livelihood, it was necessary to collect information about farm and non-farm income, as well as the technological level employed (defining technical and economic parameters) and the economic importance of the different activities carried out by each family member. Subsequently, we examined the methods of mangrove exploitation, for household use or trade purposes, by the local community and by other stakeholders working in the area. Hence, we focused on the most exploited natural resources of the mangrove ecosystem at each site in order to quantify the rate of exploitation in physical and economic terms.

At each site, the first part of the field work was carried out through:

Table 1. Kisakasaka: criteria are selected by the locals during fieldwork and are ranked according to their importance; some criteria are represented by cardinal numbers (quantitative type of data), while the others are represented by linguistic terms (qualitative type of data). In the column ''objective'' the distinction is between those criteria which the locals wish to be maximised (i.e., annual income level) and those criteria which the locals wish to be minimised (i.e., labour time required).

Criteria	Type of data	Objective	Importance
To ensure a minimum income level	Qualitative	Max	Maximal
Degree of traditional perception involved in the activity	Qualitative	Max	Very High
Annual income level	Quantitative	Max	High
Experience required	Qualitative	Min	High
Income security (against the difficulty of putting the product on the market)	Qualitative	Max	High to Very High
Income security (against the risk of production loss)	Qualitative	Max	High to Very High
Family production for self-consumption	Qualitative	Max	Medium
High degree of seasonality	Qualitative	Min	Medium
Quick cash generation	Qualitative	Max	Medium High
Amount of labour involved in the activity	Qualitative	Min	Medium Low
Labour time required	Qualitative	Min	Medium Low
Environmental impact	Qualitative	Min	Low

- informal interviews with key informants, identified among representatives of institutions and among community members;
- participatory methods, such as transect walks, sea and mangrove maps, drawing matrixes to rank fish and mangrove resources, and seasonal calendars (Mascarenhas et al. 1991);
- semi-structured interviews with 60 families living in the study area;
- direct measurements of the quantity of charcoal produced and timber cut in the study area.

Thus, we were able to obtain some preliminary results that we presented and discussed with groups formed by men or women belonging to the local communities, and by both residents and immigrants in Kisakasaka. During these meetings it became clear to everyone that, in some of the study sites, the extensive mangrove cutting (carried out specifically by men) could easily get out of control, with obvious consequences for the natural environment and possible adverse effects on the local economy. Another important preliminary result was that the families belonging to the richest classes do not rely on mangrove cutting for their cash income. Only householders belonging to poor and middle-class families integrate their family incomes with heavy mangrove cutting. These ideas gave rise to the need to discover possible alternatives to the current management of the area, alternatives able to provide local inhabitants engaged in exploitation of this resource with the chance to supplement their farm income and satisfy their basic needs. These alternatives were selected by the locals, according to their perception of what is feasible with regards to the resource availability (land, labour and capital) and to the local knowledge.

Since men of the middle and poor families are mainly responsible for the extensive cutting, we began to draw matrixes describing some alternative activities according to criteria that they suggested. In Kisakasaka, we analysed alternatives that would limit the use of mangroves but not completely substitute the wood cutting, i.e., there would be a sustainable level of cutting. In contrast, the alternatives considered in Mida Creek would completely substitute the mangrove cutting.

On the basis of field work data, the local perception of welfare was identified and an evaluation matrix (EM) was drawn to characterise each activity according to decision-making criteria. Some criteria were represented by cardinal numbers, while the others were represented by linguistic terms (Tables 1 and 2).

To compare the different alternatives, we adopted a multi-criterion analysis according to the fuzzy logic method because this method allows one to combine quantitative and qualitative criteria, preserving the uncertainty and imprecision that characterise the evaluation process carried out with linguistic terms (Bernetti and Martini 1996).

As a result of the literature analysis, we chose the method suggested by Chen et al. (1992) since it fitted into our scope. According to this method, linguistic terms of the EM are expressed though fuzzy numbers and then converted to cardinal numbers. Finally, a multi-attribute method of analysis is applied in order to solve the problem.

According to the fuzzy number theory, each linguistic term can be defined by a mathematical func-

Table 2. Mida Creek: criteria are selected by the locals during fieldwork and are ranked according to their importance; some criteria are represented by cardinal numbers (quantitative type of data), while the others are represented by linguistic terms (qualitative type of data). In the column ''objective'' the distinction is between those criteria which the locals wish to be maximised (i.e., annual income level) and those criteria which the locals wish to be minimised (i.e., labour time required).

Criteria	Type of data	Objective	Importance
Long-term income generation	Quantitative	Min	Maximal
Water requirements (conditions of poor water availability)	Qualitative	Min	Maximal
Income security (against the risk of production loss)	Qualitative	Max	High
Income security (against the difficulty of putting the product on the market)	Qualitative	Max	High
Annual income level	Quantitative	Max	High
Fertiliser requirements	Qualitative	Min	Medium High
Quick cash generation	Qualitative	Max	Medium High
Seasonal income fluctuations	Qualitative	Min	Medium High
Family production for consumption	Qualitative	Max	Medium
Amount of labour involved in the activity	Qualitative	Min	Medium Low
Labour time required	Qualitative	Min	Medium Low
Work seasonality	Qualitative	Min	Medium Low
Water requirements (conditions of good water availability)	Qualitative	Min	Low
Environmental impact	Qualitative	Min	Low to Very Low

tion (fuzzy number) expressing the subjective probability that an indicator, whose real value is unknown, is correctly assessed by a linguistic term. A general definition of a fuzzy number is given by Dubois and Prade (1978, 1980) any fuzzy subset $M = \{(x, \mu M(x))\}$ where x takes its number on the real line R and $\mu M(x) \in [0,1]$. The membership function denotes the degree of truth that M takes a specific number x'. Two fuzzy numbers are equal if and only if they have the same membership function.

To attribute a numerical value to each linguistic term for comparison with the others, we used the evaluation scales of Chen et al. (1992). These are 8 different scales, with an increasing number of linguistic terms from scale 1 to scale 8, which convert each verbal term into a cardinal number.

Hence, for each criterion, we picked the figure that contained all the verbal terms given by our EM and used fuzzy numbers in that figure to represent the meaning of the verbal terms.

Tables 3 and 4 show the EM for Kisakasaka and Mida Creek, respectively; the alternatives to current mangrove exploitation practices are compared with each other and with the current practices, according to the criteria selected by the locals and their characterisation of each activity during the field work. The Chen et al. (1992) method is easily applicable and frequently used in the socio economic analysis that combine qualitative and quantitative data, in spite of its outward formal sophistry. This method requires the definition of minimum and maximum functions to order the fuzzy numbers:

$$\mu_{\min} = 1 - x, \quad 0 \le x \le 1$$

$$\mu_{\max} = x, \quad 0 \le x \le 1$$

Left and right utility scores are then defined by means of intersection of the left side of the fuzzy number with the minimum function and the right side with the maximum function, as follows:

$$\mu_L(i, j) = \sup_x [\mu_{\min}(x) \wedge \mu_{ij}(x)]$$

$$\mu_R(i, j) = \sup_x [\mu_{\max}(x) \wedge \mu_{ij}(x)]$$

where $L_{(i,j)}$ and $R_{(i,j)}$ are the left and right side values of the fuzzy number $\mu_{ij}(x)$ which represents the linguistic term used to evaluate the *j-th* criterion for the *i-th* alternative. The right side of the fuzzy number represents the highest (and thus optimistic) values of the indicator, while the pessimistic values are represented by left side. Finally, the crisp score of a fuzzy number $\mu_{(i,j)}$ is obtained from the mean of the two evaluation indexes $\mu_L(i,j)$ and $\mu_R(i,j)$ considering that the left side must be minimized and thus it is necessary to calculate its complement to 1. $\mu_{(i,j)}$, obtained as follows, is used to fill in the matrix:

$$\mu_{(i,j)} = \frac{[\mu_R(i, j) + (1 - \mu_L(i, j))]}{2}$$

Cardinal numbers are normalised using the vector method, which allows one to maintain the range of variation for each criterion:

$$r_{i,\,j}=\frac{x_{i,\,j}}{\sqrt{\sum_{j=1}^{m}(x_{i,\,j})^2}}$$

where $r_{i,j}$ is the normalised value of the *j-th* criterion for the *i-th* alternative.

We considered environmentally sustainable all the alternatives that required the interruption of trees cutting, without endangering the natural resouces; in Kisakasaka the sustainability was defined with regards to the governmental project for locally based sustainable management of the mangrove forest that limits to 700 kg the charcoal produced per month per person. It is possible to notice that both in Kisakasaka and in Mida Creek the exploitation of mangroves at the current rate has similar characteristics; indeed, though ecologically unsustainable, charcoal production and timber cutting are considered quick cash generating activities and are characterized by a low degree of seasonality, a satisfactory income level and great income security, both against the difficulty of putting the product on the market and against the risk of production loss.

The criteria were weighted according to the importance that the locals attributed to them during the participatory discussions. Scale 8 of Chen et al. (1992) was used to convert linguistic terms used by the locals into cardinal numbers (Tables 1 and 2).

The Decisional Matrix obtained can thus be resolved by any method of multi-attribute analysis. We used the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), which is based on minimisation of the distance from the ideal solution and maximisation of the distance from the anti-ideal solution (Hwang and Yoon 1981).

According to the TOPSIS method, we identified the ideal A^* and anti-ideal A^- solutions as follows:

$$A^*=\{v_j^*\}=\left\{\left(\max_i v_{ij}/j\in J\right),\left(\min_i v_{ij}/j\in J'\right)\right\}$$

$$A^-=\{v_j^-\}=\left\{\left(\min_i v_{ij}/j\in J\right),\left(\max_i v_{ij}/j\in J'\right)\right\}$$

with J the set of criteria to maximise and J' the set of criteria to minimise. Therefore, the distance of each alternative from the ideal and anti-ideal points is calculated by means of the Euclidean distance:

$$S_i^*=\left(\sum(v_{ij}-v_j^*)^2\right)^{1/2}$$

$$S_i^-=\left(\sum(v_{ij}-v_j^-)^2\right)^{1/2}$$

Finally, the preference index u_i is obtained as follows:

$$u_i=\frac{S_i^-}{S_i^*+S_i^-}$$

Results

Analysis of the current situation and problems of sustainability

Kisakasaka

The village of Kisakasaka (06° 14′ S, 39° 17′ E) is located in the West District of Unguja Island, Zanzibar, in Kombeni Bay, about 15 km from the town of Zanzibar (Figure 1).

There is no official population data for the village. According to local authorities, there are 118 families (34 immigrant and 84 local families), with a total of 739 individuals. In a sample of 60 families, the average income was estimated at 1,524 US$ (438 US$ per capita) per year, distributed rather homogeneously among the families. This income is divided into goods for direct consumption (approximately 40% of the total) and monetary income. The main activity is farming, followed by mangrove charcoal production, fishing, governmental jobs, livestock husbandry and trade (Figure 2).

Up to a few decades ago, the Kisakasaka area was one of the best-preserved areas in Zanzibar; it was famous for hosting the Zanzibar leopard, which is now thought to be extinct. Nowadays, the Kisakasaka forest is subjected to the same human pressure exerted on all mangroves of Unguja Island (Ngoile and Shunula 1992; Linden and Lundin 1996) and only a few forested areas remain, mainly along the coasts near the mangrove forest. The majority of the land is cultivated or seasonally left fallow. The research revealed that the reported degradation of the Kisakasaka mangrove forest is a recent phenomenon and is strongly related to charcoal production. The most used species are *Ceriops tagal, Bruguiera gymnorhiza, Rhizophora mucronata* and *Sonneratia alba* because of their suitability to produce charcoal and their local availability. Starting from the nearest area to the village, almost all the trees were cut down and only few left for regeneration. The process started around 15 years ago, mainly due to demographic growth, and has led to the total clearing of certain areas (Ngoile and Shunula 1992; Skov 2001).

To tackle this problem in 1994, a governmental

Table 3. Kisakasaka evaluation matrix: the alternatives to unsustainable charcoal production are compared with each other and with unsustainable charcoal production itself, according to the criteria selected by the locals and their characterisation of each activity during the field work. The column ''scale or measurements'' shows the scale of Chen et al. (1992) used to apply the multi-criterion analysis according to the fuzzy logic method; for cardinal numbers, it shows the measurement used. The annual income level is indicated using Tsh; the exchange rate during the interviews fieldwork (February–March 1998) was 1$ per 660 Tsh.

	Scale or measurements	Improved farming, with no charcoal production	One extra acre of farmland, with no charcoal production	Two extra acres of farmland, with no charcoal production	Two extra head of dairy cattle, with no charcoal production	Current charcoal production	Undertaking a trading activity, with no charcoal production	Sustainable charcoal production and one extra head of dairy cattle	Sustainable charcoal production and two extra head of dairy cattle	Improvement of fishing tools, with no charcoal production	Sustainable charcoal production and improved farming	Sustainable charcoal production
High degree of seasonality	4	high	high	high	medium	medium low	medium	medium low	medium low	medium low	medium low	medium low
Degree of traditional perception involved in the activity	2	medium	medium	medium	medium	medium	low	medium	medium	high	high	high
Amount of labour involved in the activity	3	low	medium	medium	very low	very high	low	high	high	high	high	high
Environmental impact	8	none	none	none	none	maximal	none	low	low	none	low	low
Experience required	3	medium	medium	medium	medium	medium	medium	medium	medium	very high	medium	medium
Family production for self-consumption	8	maximal	maximal	maximal	maximal	none	none	maximal	maximal	maximal	maximal	none
Quick cash generation	4	medium low	medium low	medium low	medium	high	medium low	high	high	medium high	high	high
Annual income level	Tsh	449496	459264	918528	440000	442010	480000	580000	800000	450000	659664	360000
To ensure a minimum income level	8	maximal	maximal	maximal	maximal	maximal	maximal	maximal	maximal	maximal	maximal	none
Income security (against the difficulty of putting the product on the market)	5	fairly high	low	low	fairly high	very high	fairly high	high	high	fairly high	high	very high
Income security (against the risk of production loss)[I]	6	more or less low	low	low	medium	high	more or less low	more or less high	more or less high	more or less high	more or less high	high
Labour time required	4	medium low	medium high	high	low	high	high	high	high	high	high	medium high

Table 4. Mida Creek evaluation matrix: the alternatives to timber cutting are compared with each other and with timber cutting itself, according to the criteria selected by the locals and their characterisation of each activity during the field work. The column ''scale or measurements'' shows the scale of Chen et al. (1992) used to apply the multi-criterion analysis according to the fuzzy logic method; for cardinal numbers, it shows the measurement used. The annual income level is indicated using Ksh; the exchange rate during the interviews fieldwork (May–July 1998) was about 1$ per 60 Ksh.

Criteria	Scale or measurement	To continue cutting timber for building purposes	One extra acre of Casuarina plantation	One extra acre of productive Casuarina plantation	One extra acre for coconut cultivation	One extra acre of productive coconut plantation	One extra head of dairy cattle	Undertaking an eco-tourist activity	Improvement of fishing tools	One extra acre of food crops
Amount of labour involved in the activity	2	high	medium	medium	low	low	low	low	high	medium
Annual income level	Ksh	10,667	36,000	36,000	10,322	10,322	22,000	5,000	22,050	17,704
Family production for consumption	3	high	high	high	very high	very high	very high	very low	very high	very high
Fertiliser requirements	2	low	medium	medium	low	low	low	low	low	low
Environmental impact	3	very high	low	low	low	low	low	very low	low	low
Labour time required	3	high	high	high	low	low	low	low	very high	medium
Income security (against the difficulty of putting the product on the market)	3	very high	very low	very low	very high	very high	very high	low	medium	very high
Quick cash generation	3	very high	high	high	very high	very high	very high	low	medium	very low
Seasonal income fluctuations	2	low	low	low	low	low	low	high	medium	medium
Long-term income generation	years	0	3	0	7	0	2	0	0	0.33
Water requirements	2	low	high	high	low	low	high	low	low	low
Work seasonality	3	very low	high	high	medium	medium	very high	high	medium	high
Income security (against the risk of production loss)	3	very high	medium	medium	very high	very high	medium	very high	medium	high

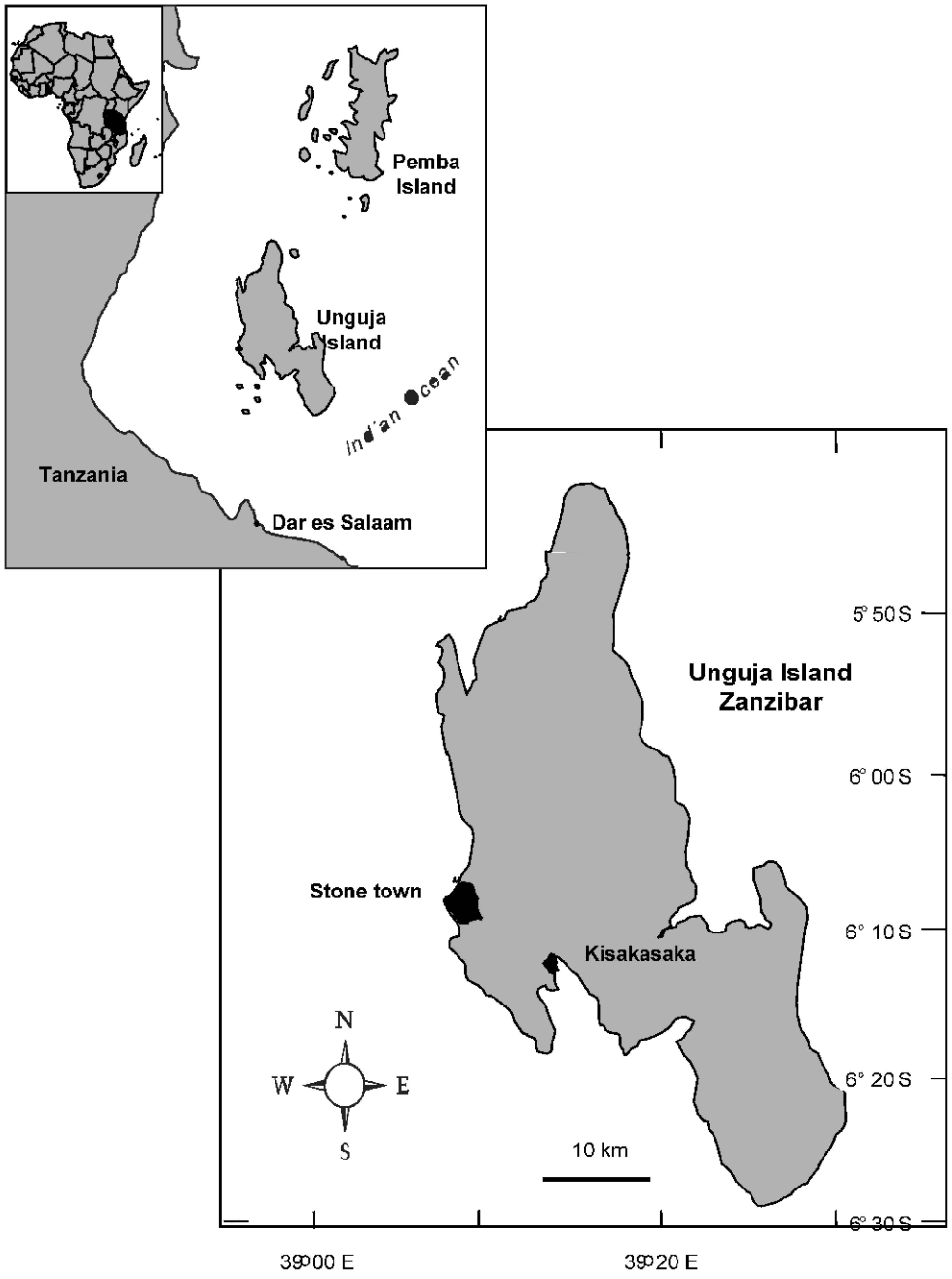

Figure 1. Map showing the location of Kisakasaka village with respect to Unguja Island and the position of the Zanzibar archipelago with respect to the East Africa coast.

project for locally based sustainable management of the mangrove forest was set up in the area. A production limit of 700 kg of charcoal per month per person was established and the cutting of mangroves by the immigrant community was banned. This was because immigrants, not being permanently linked to the land, could not be made aware of long-term sustainability issues.

Men, women and children go to the mangroves to harvest different products. Children go for small crabs (various species of swimming crabs, family Portunidae) and fish for self-consumption, while women

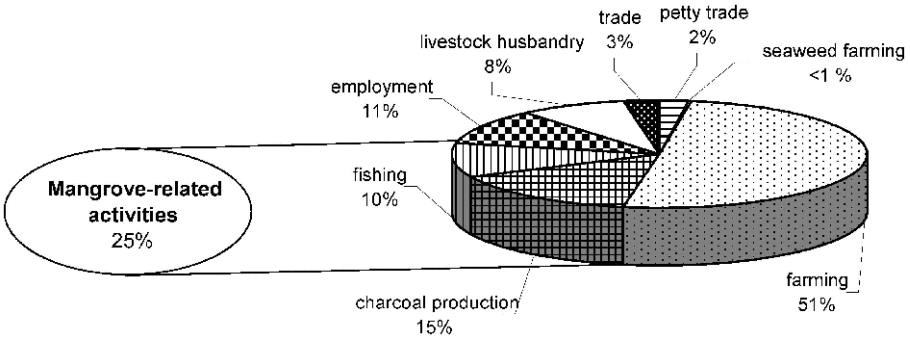

Figure 2. Kisakasaka, results of the participatory appraisal. Total Annual Income Composition of the local community; the activities related to mangroves are highlighted.

go for firewood and to collect oysters (*Saccostrea cucullata*) to sell on the market. Men are engaged in fishing, which is highly dependent on mangroves because it is carried out in the shallow water in front of the forest, and in mangrove cutting for charcoal production. Thus, the mangrove users who endanger the forest are the men.

Mangrove charcoal production is currently practised by about 80% of the local families. According to our estimates, the total annual production of charcoal in the whole village (from May 1998 to April 1999) is 461,426 kg, equivalent to 24,720 US$.

During the meetings held in the village, it was stated that the present limit of charcoal production is not sufficient to guarantee the basic needs and thus the household economy has to be integrated with other activities. However, there are currently no other income-generating activities able to replace charcoal production. These considerations explain why charcoal producers keep on cutting large quantities of mangrove trees. In fact, even while aware of the environmental consequences of their behaviour, they continue to produce charcoal in excess of the amount allowed.

Mida creek

The fieldwork was carried out in Mida Creek (03° 21′ S; 39° 59′ E), Malindi District, North Kenya coast, about 80 km North of Mombasa (Figure 3).

The site is populated by almost 750 families settled along the shore of the creek since 1936. In a sample of 62 families, the average total annual income was estimated at 4,345 US$ (453 US$ per capita), including goods for direct consumption produced by the family itself (approximately 40% of the total).

Agriculture provides almost 50% of the total income (Figure 4). Other important activities are hotel employment, small trade in farm products or in items bought from traders and sold in the nearby villages, and fishing. Fishing is very important, even though practised only in the creek with simple utensils (handlines and sometimes nets and canoes); this is especially true for poor families, as it is often the only possible means to supplement the income from farming. Livestock husbandry and crab harvesting, as well as collection of firewood from the mangroves, are indispensable sources of income for most of the families.

The mangrove forest, on the coast and the main islands inside the creek, covers about 1600 ha, of which 900 ha belong to the study site. The forest colonising the creek is the main resource of building wood in the Malindi area, which is heavily exploited for tourism. The forest is also strongly impacted by logging (Dahdouh-Guebas et al. 2000; Dahdouh-Guebas 2001) and only a few remote areas in its southern part can be considered pristine systems. Mature trees belonging to *Ceriops tagal, Bruguiera gymnorhiza* and *Rhizophora mucronata* species are cut for timber production without any planning. The results of a recent study by Kairo and Gwada (1998) confirm that there is satisfactory regeneration within the forest, but also a worrying decrease in the number of large trees due to the intensive exploitation of the area. Within the local community, there is again a clear division of mangrove uses on the basis of age and gender. At low tide in the shallow inlets within the forest, children catch small crabs and fish for self-consumption. Women go to the mangrove mainly for firewood. Men engage in fishing, which is totally

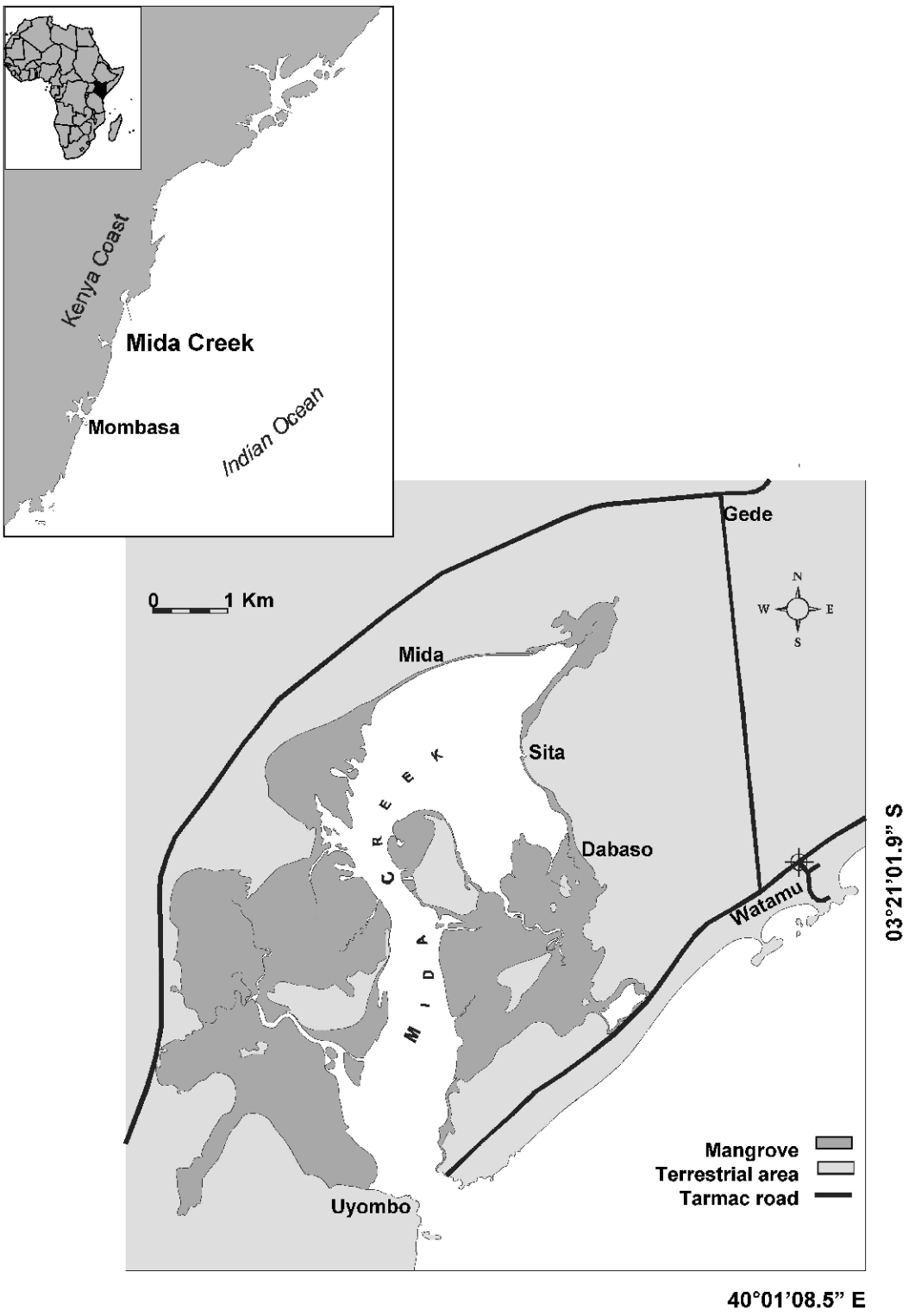

Figure 3. Map showing the location of Mida Creek with respect to the Kenya coast and the East Africa coast (redrawn from Dahdouh-Guebas et al. 2000).

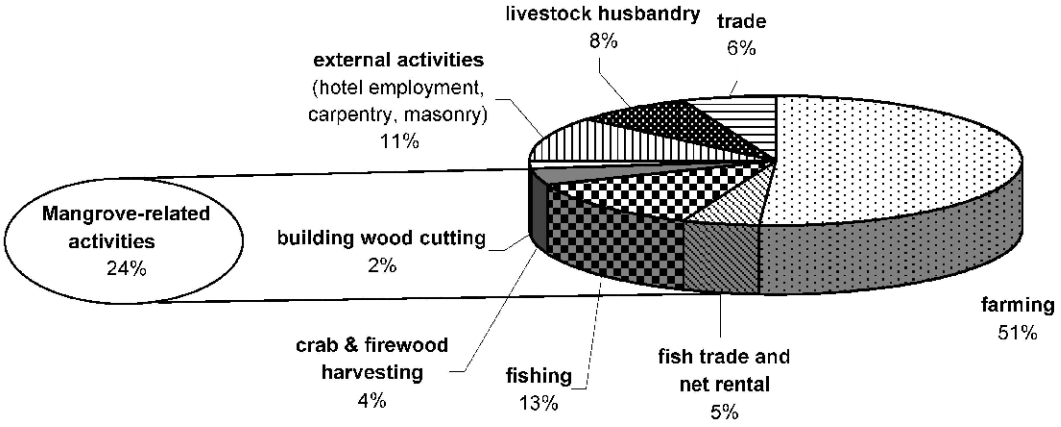

Figure 4. Mida Creek, results of the participatory appraisal. Total Annual Income Composition of the local community; the activities related to mangroves are highlighted.

dependent on the mangrove because it is carried out inside the Creek, and mangrove cutting for building wood.

Current laws ban locals from cutting trees, even for the purpose of house building. Licenses to cut mangroves are granted to traders, who do not live in the area. Under Forestry Department (FD) supervision, they carry out the operations of cutting, transporting and selling the timber. The FD allows the local inhabitants to cut firewood only for their own needs. However, thanks to the good relationships established through the participatory approach, it became clear that mangrove exploitation could easily get out of control, with dangerous effects on the environment. In fact, illegal mangrove cutting is an important source of cash for the poor and middle classes, representing an essential income supplement. The amount of building wood harvested in one year within the study site was estimated at around 2,650 m^3, corresponding to 37,400 US$.

Inhaca island

This Island (26° S, 33° E) is situated about 32 km East of Maputo in the Mozambique Channel and lies in the region of transition from tropical to temperate climate (Figure 5).

Inhaca covers an area of 42 km^2 and includes different vegetation types: forest, agricultural land, swamp and mangroves. The population was estimated at 4,759 people in the 1994 census. Families have an average size of 9 members.

The poor connections to the mainland strongly affect the overall economy of the island. Transport is available two or three times a week between the island and the continent. However, this service is neither regular nor safe. In addition, there are no means of transport within the island and people have to walk long distances.

In a sample of 60 families, the average annual income per family in Inhaca was estimated at around 1,300 US$; this includes both monetary income (749 US$) and direct consumption (551 US$). The annual income per capita corresponds to 154 US$. Natural resources are essential for families living in the island. In fact, many important activities are related to the natural environment. Fishing, farming, livestock husbandry, harvesting products from the mangroves and forestry account for 62% of the total income. The remaining 38% comes from employment and petty trade (Figure 6).

The exploitation of natural resources for household needs is not subjected to official control and people are allowed to cut trees for that purpose. However, to prevent the expansion of dunes and the consequent loss of forest and farmland, it is not allowed to cut forests for agricultural purposes.

Harvesting of large quantities of natural products is not frequent, because the lack of transport limits the demand. However, commercialisation of fish, crabs and bivalves is possible and these goods are exchanged for other products with people coming from the continent.

As the current management of mangroves is limited to local needs, there do not seem to be any dangerous effects on the ecosystem. Children browse the forest and adjacent mud flats in the shallow creeks for small crabs, fish and molluscs for self-consumption. Women go to the mangrove for firewood and they also exploit

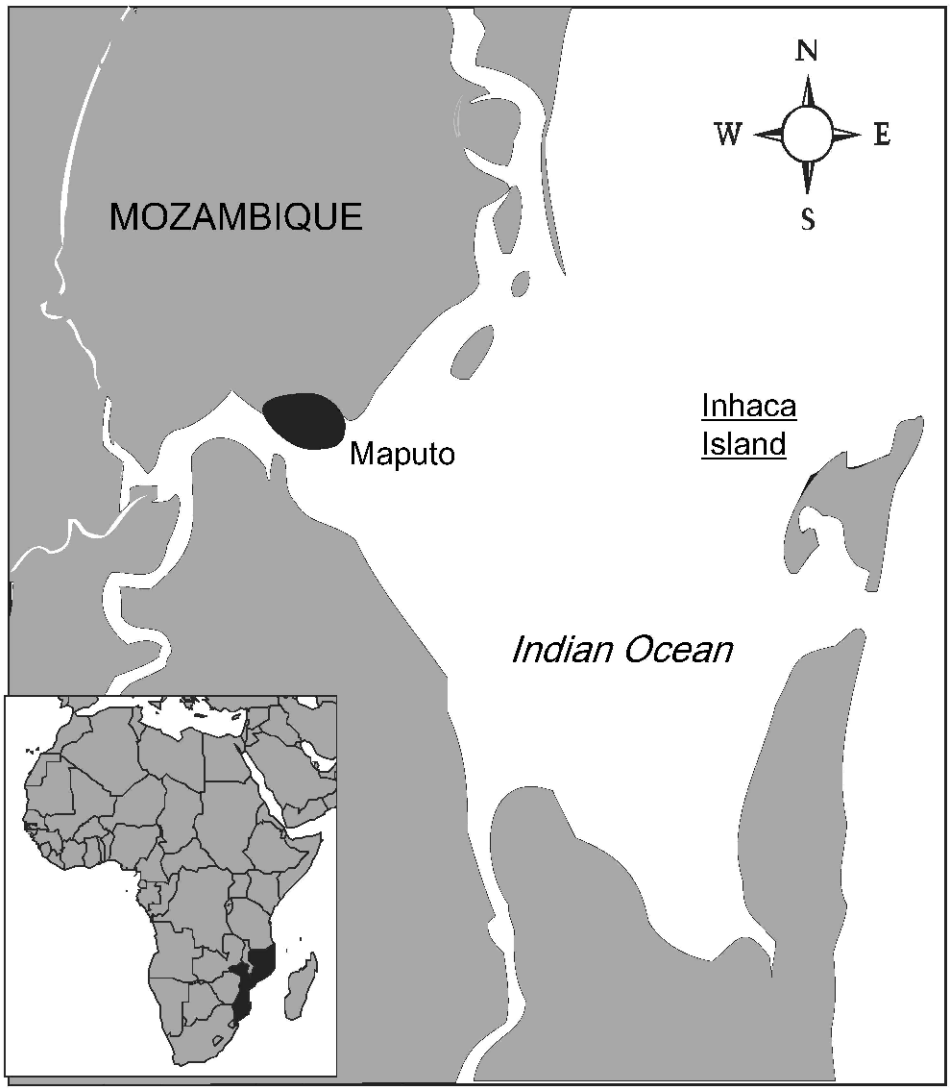

Figure 5. Map showing the location of Inhaca Island in Maputo Bay and with respect to the East Africa coast.

valuable resources, such as mud crabs (*Scylla serrata*), molluscs and other smaller crabs, to sell them in the local market. Men do not have any major impact on mangrove resources except for fishing, although they strongly prefer the shallow and sheltered waters of the western coast of the island. As already outlined, the resources coming directly from mangroves (crabs, molluscs and wood) are important for the local economy and represent 20% of household consumption. Thus, our results confirm the conclusions of previous ecological surveys that the rate of resource exploitation seems to be sustainable (Kalk 1995).

Focusing on sustainable alternatives

In Kisakasaka and Mida Creek, where the current management of mangroves is ecologically unsustainable (Ngoile and Shunula 1992; Linden and Lundin 1996; Kairo and Gwada 1998; Dahdouh-Guebas et al. 2000; Dahdouh-Guebas 2001), some alternatives were pointed out and described during informal discussions with local communities. The alternatives were selected and compared using criteria chosen by the local population according to their own perception of welfare; the purpose was to identify the best

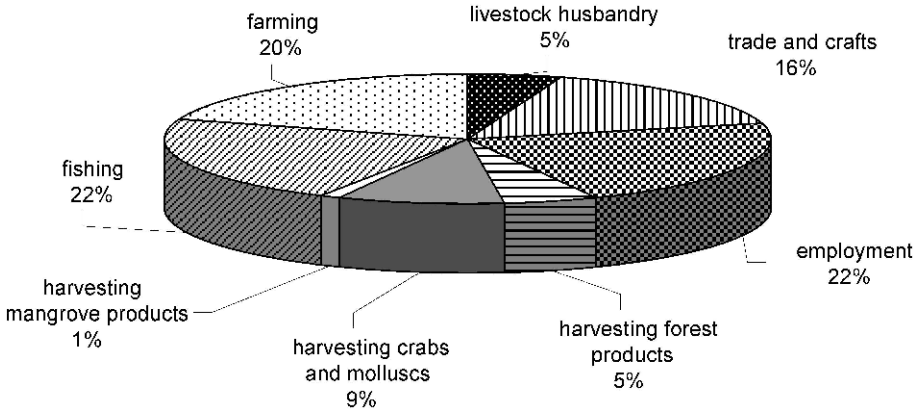

Figure 6. Inhaca Island, results of the participatory appraisal. Total Annual Income Composition.

solutions in terms of economic, social and ecological sustainability. Tables 1 and 2 list these criteria, ranked according to the importance attributed by the Kisakasaka and Mida Creek communities, respectively. It must be noted that both sites are characterised by uncertain conditions and the elements referred to as ''present needs'' take priority over the others because only their satisfaction can determine the conditions for a better standard of living in the future.

The results of the multi-criterion analysis reveal that innovations and improvements related to farming[1] and dairy cattle husbandry were the preferred alternatives in Kisakasaka, i.e., those able to reduce human pressure on the mangrove ecosystem and to ensure sustainable management of the area and a better standard of living for the families (Table 5). All the criteria selected by the population were combined to define the best alternatives; it is notable that the most important criteria are related to income and to the degree of traditional perception involved in the activity itself (Table 1). However, even the criteria related to labour (amount of work involved in the activity and the time required) can influence the definition of the best solutions. In fact, the results of the analysis show that people prefer the introduction of two dairy cattle (Table 5), which brings lower income but requires less work than livestock husbandry combined with sustainable charcoal production (Table 5).

Further on, it can be seen that the preferred alternatives to over-exploitation of mangroves through charcoal production are all related to substantial innovations of activities traditionally carried out in the village, such as farming, fishing and livestock husban-

Table 5. Kisakasaka multi-criterion analysis results: alternatives and related preference indexes, ordered according to the preference given by the local community.

1.	Sustainable charcoal production and improved farming	0.739
2.	Two extra head of dairy cattle, with no charcoal production	0.717
3.	Sustainable charcoal production and two extra head of dairy cattle	0.713
4.	Sustainable charcoal production and one extra head of dairy cattle	0.707
5.	Improvement of fishing tools, with no charcoal production	0.667
6.	Improved farming, with no charcoal production	0.638
7.	Current charcoal production	0.614
8.	Two extra acres of farmland, with no charcoal production	0.555
9.	One extra acre of farmland, with no charcoal production	0.555
10.	Undertaking a trading activity, with no charcoal production	0.537
11.	Sustainable charcoal production	0.481

[1] At present, farming is characterised by a lack of input, storage and marketing problems that strongly limit the income obtained from this activity.

dry. Instead, the alternatives which follow unsustainable charcoal production do not require any innovation but only represent the possibility of directing the work currently employed in charcoal production towards other occupations.

In Mida Creek, the local people identified the introduction of an extra head of dairy cattle as one of the possible alternatives (Table 6). However, due to the long time required to organise and set up dairy farming, mangrove timber cutting is still preferred. Yet if we compare the two activities as if they were both fully productive, the preference is for dairy farming. Furthermore, in areas where water availability limits the development of dairy farming, the assignment of one extra acre of farmland to each family could turn out to be a real alternative to the current management of the area.

Discussion

The Kisakasaka and Mida Creek areas are characterised by a well-established demand for mangrove products and these ecological resources are an essential source of income for the families. Unfortunately, the rate of exploitation of mangroves is ecologically unsustainable and these ecosystems are endangered by the over-exploitation. In contrast, the mangroves in Inhaca are exploited only for self-consumption and the pressure on the forests seems to be ecologically sustainable.

However, prohibiting locals from exploiting the mangrove forests, especially where the human pressure is high, does not seem possible if a valid alternative is not offered. Without an alternative source of income, the population cannot afford to satisfy basic needs, such as household expenses, medical care or school fees. Furthermore, governments do not seem able to ensure that the laws are respected.

Since the intensity of mangrove cutting is very high and cannot be considered sustainable, alternative resource management practices must be established. Therefore, the aim of our investigation was to find a solution to limit the use of the mangroves. For this purpose, we identified activities alternative to excessive exploitation of the forests that would allow the local population (particularly the men, responsible for the cutting) to decrease their demand for wood and provide them with an alternative income. The activities that we analysed were identified by the local populations on the basis of their experience and knowledge between those that were considered ecological sustainable, as stated in the methods.

The multi-criterion analysis with the fuzzy logic method allowed us to evaluate the results of the field studies in a flexible manner, taking into account the qualitative nature of much of the information. However, one of the limitations is the difficulty in correctly interpreting the value judgments expressed during group meetings and discussions; this is due to the limited level of researchers' knowledge of the area and difficulties in communication with the local population on account of the relatively short time spent at the locality. In fact, the multi-criterion analysis cannot replace field work, but it becomes increasingly valid as the researcher becomes more thoroughly involved in the life of the local population.

A second limitation of the analysis is that it does not allow one to consider possible conflicts of interest. This would require separate analyses for homogeneous groups, without the determination of a single solution valid for all groups at the same time. For this reason, we focused the analysis on the poor and middle classes, which are those that most exploit the

Table 6. Mida Creek multi-criterion analysis results: alternatives to the cutting of timber compared with the cutting of timber itself and ordered according the preference given by the local community.

Conditions of good water availability		Preference index	Conditions of poor water availability		Preference index
1.	One extra acre of productive coconut plantation	0.82	1.	One extra acre of productive coconut plantation	0.83
2.	To continue cutting timber for building purposes	0.75	2.	To continue cutting timber for building purposes	0.76
3.	One extra head of dairy cattle	0.70	3.	One extra acre of food crops	0.68
4.	One extra acre of food crops	0.66	4.	Improvement of fishing tools	0.67
5.	Improvement of fishing tools	0.64	5.	One extra head of dairy cattle	0.60
6.	One extra acre of productive Casuarina plantation	0.59	6.	Undertaking an eco-tourist activity	0.57
7.	Undertaking an eco-tourist activity	0.54	7.	One extra acre for coconut cultivation	0.57
8.	One extra acre for coconut cultivation	0.53	8.	One extra acre of productive Casuarina plantation	0.53
9.	One extra acre of Casuarina plantation	0.50	9.	One extra acre of Casuarina plantation	0.45

mangroves and whose interests coincided during the meetings.

As a whole, our field experience demonstrated that local communities would not carry out unsustainable exploitation of mangroves if they were not forced by the lack of resources to rely on various sources of income. In fact, during the survey activities carried out with the local community, the people proved to have a deep knowledge of the functioning of the mangrove ecosystem. They are very clearly aware that the presence of fish, crabs and molluscs in the swamps is directly linked to the health of the mangrove ecosystem. This awareness has also led the communities to become involved in mangrove replantation schemes, managed by the communities themselves (Kairo and Gwada 1998).

Once initiated, the alternative activities taken into consideration in our study should not modify the existing resource relationship patterns with regard to children and women. In fact, our aim was to find ways to regulate the over-exploitation by men. Thus it was important to focus on them and to provide them with alternative sources of income, so as to reduce the pressure on the mangroves. For this reason, we sought to identify alternative work activities for the men only. Therefore, the changes should not alter the current division of labour nor the resulting income. For this reason, the men expressed their willingness to engage in all the alternative activities we considered.

Moreover, especially in Mida Creek, the real pressure on mangroves is not due to local people because traders, who do not live in the area, manage most of the timber exploitation. Locals also cut mangroves as a supplementary activity, but often at the request of traders. Thus, a policy regulating the work carried out by these enterprises is needed, together with the promotion of alternative sources of income for locals.

When conditions allow it, the population itself could be the main protector of the mangroves and the most enthusiastic promoter of economically sound sustainable management plans. These plans should not be based only on a ban on forest exploitation but also on the promotion of various profitable ways to employ the local labour force.

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