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Workshop 2: Farming and rural systems methodology

A MULTI-CRITERION ANALYSIS FOR THE SUSTAINABLE USE OF NATURAL RESOURCES IN MANGROVE ECOSYSTEMS WITH THE INVOLVEMENT OF THE LOCAL COMMUNITY

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ABSTRACT
The research focused on the relationships between the mangrove ecosystem and human activities. Using a participatory methodology, we analysed the local ways of mangrove exploitation and identified the contribution of each activity to the family income. Thus, we focused on the natural resources that are most exploited and we quantified their rate of exploitation in both physical and economic terms. The results of the research were discussed with the local community and their comments were recorded. Finally, in collaboration with the local people, some alternatives to the current management of mangroves were delineated and compared on the basis of social, economic and ecological criteria. The multi-criterion analysis, employing the fuzzy logic method, allowed us to use quantitative and qualitative measures. The final results reveal the preferences of the local people involved in mangroves exploitation.

INTRODUCTION

The concept of sustainable development has different meanings (Roling and Jiggins, 1998). From the environmental point of view, it is related to three aspects: the rate of exploitation of renewable resources in relation to their capacity for regeneration, the rate of exploitation of non-renewable resources in relation to their replacement and the rate of emission of pollutants in relation to their potential to be recycled (Daly, 1990).
From the social and economic points of view, attention is focused on the community. In particular, the social idea of sustainable development concerns the maintenance and improvement of the quality of life, while economic sustainability implies reaching income levels that will ensure that individuals, families and the whole community remain above the poverty threshold.
Usually these meanings are all defined from an intergenerational point of view; thus, important decisions and their consequences should refer to a future context, beyond the present needs.
Since these meanings of sustainable development are essentially different from one another, they also involve different subjects and interests, as well as different times of action and of achievement of goals, which can even be in contrast. Nevertheless, in a systematic approach, the aspects of sustainable development cannot be analysed separately. Therefore, sustainability should be defined on a comprehensive basis and studies should focus on the search for points of contact between the different subjects involved in the development (Dent and McGregor (eds), 1994).
An interdisciplinary approach is needed to combine the ecological, social and economic aspects of sustainable development. This requires that all the subjects involved (local community, institutions and researchers) take an active part in the process. In particular, the researchers' contribution to the resolution of the problem should be to combine scientific knowledge with local knowledge (Bernard, 1997; Chia, Brossier and Benoît, 1992; Chia and Raulet, 1994). All the subjects involved in the process should act as

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partners in order to reach a definitive solution and to satisfy their needs and those of future generations.
The present research is an attempt to apply this concept of sustainable development to a case study in which natural resources play a crucial role in the local economy.

OBJECTIVES

The research focused on the relationships between the mangrove ecosystem and human activities. It is part of an interdisciplinary European INCO-DC Project, MEAM[2], also involving ecologists and marine biologists, aimed at identifying possible conditions for the sustainable management of mangroves, both on socio-economic and ecological bases.
The link between the mangrove forest and the local community is complex and relies on different elements. At the family and village level, it depends on the family's knowledge of the natural resources, its cultural background and opportunities to satisfy its basic needs. At the institutional level, it depends on the various institutions and the rules that control the use of mangroves. Knowledge of these elements and the cause-effect relationships among them was fundamental for the achievement of our goals.
Families were the hub of the research and we set out to assess the importance to their economy of each activity in the area. We then wanted to examine the methods of mangrove exploitation by the local community (for consumption and trade) and by other agents working in the study area. In particular, we wanted to analyse the activities related to both the vegetation and fauna. Thus, we focused on the natural resources that were most exploited in order to quantify their rate of exploitation in physical and economic terms. Through discussion of the preliminary results of the research with the local community, we intended to point out some alternatives to the current management of mangroves and to compare them according to social, economic, and ecological criteria.

METHODS

Field work

The field work took place in Mida Creek (Malindi District, Kenya), located about 80 km north of Mombasa. It was carried out in three phases: the first in October-November 1997, the second in February-March 1998 and the third in February-May 1999. At the same time a research to identify parameters of ecological sustainability was conducted by a group of researchers from the Kenya Marine and Fisheries Research Institute and the University of Florence.
During the first phase of our study, key informants were identified among the representatives of the institutions and among the community members. The interviews were carried out in an informal manner, covering all the items concerning the specific knowledge of the informants (social structure, institutional organisation, economic activities of the village, services and infrastructures present in the village). In particular, we had several meetings with the Chief and the Assistant Chief of the area, with the Forestry and the Kenya Wildlife Service Officers. They are all in charge with the management of Mida Creek mangroves and provided us with information related to mangrove ecosystem status and its management.
The practice of participatory methods, such as transect walks, sea and mangrove maps, drawing matrixes to rank fish and mangrove resources, seasonal calendars and the daily routine (AA.VV., 1991), gave us the opportunity to initiate a friendly relationship with the local community. This proved to be of great value for the development of our study and for clarification of the relationships existing within the community itself and between the community and the surrounding environment.

[2] Macrobenthos of Eastern African Mangroves; contract number: IC 18-CT96-0127

During the second phase, we used semi-structured interviews to identify the contribution of each activity in the area to the family economy, with particular attention to mangrove resources. According to the participatory methodology, we took great care to put the informants at ease.
The family study was undertaken on a two-level basis. One questionnaire (general) was administered to a broad, randomly selected sample, while the other (specific) was administered to a smaller sample. The broader survey level, that involved 62 families, was mostly qualitative[3]; it had to identify family typologies, on the basis of their wealth. In order to group the families according to the above- mentioned criteria, we performed a "wealth ranking" (Grandin, 1988). The selection of the smaller sample (16 families) was not random and included families that we considered most representative of each of the wealth groups. The questionnaire, structured like the one described for the broader survey, was devised on a quantitative basis and regarded data acquired by direct measures and discussions with family members.
The third phase of the research did not have a strictly defined protocol and its program was determined during the field work. In fact, we adapted the method, the hypothesis and the goals to the development of the field work itself.
During earlier data analyses, we drew several graphs (histograms and pie charts) to present and discuss them with the local people. The graphs compared the different sources of income with the defined wealth classes and with the different areas of the study site. They were illustrated not only with titles and tags written in the local language, but also with some ideograms.
During the field work, we were surprised to notice how easily the people understood the graphs and how actively they participated in the discussions that followed our introduction. These discussions, which at times were guided by our questions, very often arose naturally from their considerations.
Thanks to the good relationships resulting from the practice of this technique, we were able to raise and discuss with the community the problems and contradictions of the area.
In this way, the real importance of mangrove cutting for the family economy, both for consumption and trade, could emerge, something that did not occur in the previous phase.
Then, in parallel with the participatory discussions, we conducted 150 short interviews to cross-check the values of the annual local consumption of building wood calculated during the participatory activities.
Because of this positive relationship, it became clear to everyone that the mangrove cutting could easily get out of control, with obvious consequences for the natural environment, which might adversely affect the local economy. These ideas gave rise to the need to discover a possible alternative to the current management of the area, an alternative able to provide the local inhabitants, presently engaged in the exploitation of this resource, the chance to supplement their farm income and satisfy their basic needs. Consequently, with different groups, we began to draw matrixes that described some alternative activities, according to the criteria suggested by the groups themselves.

Data processing

To compare the different alternatives, we adopted a multi-criterion analysis, according to the fuzzy logic method suggested by Chen and Hwang (1992). The principal advantage of this method, which allows one to combine quantitative and qualitative criteria, is that it

[3] The survey was divided into four parts, the first one concerning the family structure, the second describing every activity carried out by the families, the third focusing on the problems related to the activities and the expenses of the families. The last part of the questionnaire dealt with the impressions of the researcher about the state of the house, the sanitation and dietary level of the family

preserves the uncertainty and imprecision that characterise the evaluation process carried out with linguistic terms (Bernetti and Martini,1996), (Fig. 5a).
On the basis of field work data, a decisional matrix (DM) was drawn to characterise each activity, according to decision making criteria. Some criteria (income, time required to generate the income) were represented by a cardinal number, while the others were represented by linguistic terms[4] (Tab. 2). To convert verbal terms into fuzzy numbers, Chen and Hwang identified 8 different scales, composed of an increasing number of linguistic terms moving from scale 1 to scale 8. Hence, for each criterion, we picked the figure that contained all the verbal terms given by our DM and used fuzzy numbers in that figure to represent the meaning of the verbal terms. Then, the crisp score of the fuzzy numbers was obtained[5] and used to fill in the matrix. Cardinal numbers were normalised using the vector method, which allows one to maintain the range of variation for each criterion. Finally, the criteria were weighted according to the importance that the locals attributed to them during the participatory discussions. We then compared them using 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 (Bernetti and Martini,1996).

RESULTS AND PRELIMINARY DISCUSSION

The site is populated by almost 750 families settled along the shore of the creek since 1936. They are farmers from the nearby hinterland whose main source of income remains agriculture. The average total annual income was estimated at 260,687 Kenyan Shillings (Ksh)[6,] subdivided into consumed goods (approximately 40% of the total) and monetary income[7]. The total annual income differs significantly among the three wealth groups (χ^2 = 8.86; df = 2; p = 0.0119, Wilcoxon Kruskal-Wallis test). However, the incomes of the poor and middle classes do not differ in quantity, since both of them are not far from subsistence (Tab. 1). What differs is how they reach that level: while the poor people are always in uncertain conditions, struggling against poverty, the middle class families can rely on farm income which provides them with better living conditions and food security (Tab. 1).
Agriculture represents almost 50% of the total income (Fig. 1). Other important activities for the family economy are hotel employment in Watamu and Malindi (the most important

[4] According to the Chen and Hwang method, each linguistic term can be defined by a mathematical function which expresses 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.

[5] In order to obtain the crisp score, Chen and Hwang (1992) defined a fuzzy max and a fuzzy min as follows:
$\mu_{max}(x) = x,\ 0 \leq x \geq 1$
$\mu_{min}(x) = 1-x,\ 0 \leq x \geq 1$
They then defined a left and a right utility score:
$\mu_L(i) = \sup \min [\mu_{min}(x) \wedge \mu_{M\,i}(x)]$
$\mu_R(i) = \sup \min [\mu_{max}(x) \wedge \mu_{M\,i}(x)]$
Finally, the total score of a fuzzy number was obtained:
$\mu_T(i) = [\mu_R(i) + 1 - \mu_L(i)] : 2$

[6] The exchange rate during the interviews field work (February-March 1998) was about 1 $ per 60 Ksh

[7] The annual income per capita and per adult are respectively 21,305 and 46,449 Ksh. They do not differ among the three wealth classes, because the richer families are also the larger ones and have more labour units than the others.

item in the "external activities" category[8]), small trade in farm produce or items bought from nearby traders and sold in the villages of the area (trade), and fishing. Fishing is very important, even though practised only in the creek with simple utensils (hand-lines and sometimes nets and canoes); this is especially so for poor families, since it is often the only possible means to supplement the income from farming. Livestock husbandry and crab harvesting, as well as the collection of firewood from the mangroves, are indispensable sources of income for most of the families; the former activities provide them with goods and money, while the latter is practised mainly for consumption.

According to the interviews in the second phase (described in Methods), the cutting of the mangroves to obtain timber for building did not seem to be carried out by the locals. Indeed, current laws ban them from cutting trees, even to construct their own houses. Licenses to cut mangroves are granted to traders, who do not live in the area. Under Forestry Department (F.D.) supervision, they are involved in the cutting, transporting and selling of the timber. The F.D. permits the local inhabitants to cut firewood only for their own consumption.

As described in Methods, the interview results were studied in depth during the last phase of the field work, when we could estimate (in quantitative terms) how important the mangrove cutting is for the families belonging to the three wealth classes (as shown in Fig.1). This activity is important as a cash generating source only for the poor and middle classes, representing an essential income supplement.

There is good agreement between the data obtained from the participatory discussions and the data from the specific interviews (150) of the last phase of the field work. For example, according to the interviews, the value in Ksh of building wood harvested in one year in the study site is 2,243,942 (corresponding to 2,656 m^3) and according to the participatory activities it is 2,384,185.

As seen in Figs. 1 and 2, the poor class is significantly more dependent on the mangroves than the other two (Tab. 1; $\chi^2 = 7.96$; df = 2; p = 0.0187, Wilcoxon Kruskal-Wallis test); crab harvesting, firewood collection, timber cutting and fishing are the main activities.

The surface area of the mangrove forest, covering the coast and the main island inside the creek, is about 1600 ha, of which 900 ha belong to our study site. The forest is not a pristine system and human activities are responsible for the present floral composition and forest structure. Unfortunately, in the course of our research it wasn't possible to asses the effect of tree cutting on natural regeneration and there are no studies that have assessed it. However, the results of a recent study by Kairo and Gwada (Kairo and Gwada, 1998) confirm that there is good regeneration but also a worrying decrease of large trees, due to intensive exploitation of the area.

During the survey activities carried out with members of the local community, they proved to be experts on the creek and the mangroves. They linked the presence of fish in the creek directly to the health of the mangrove system. Their knowledge of the relationship between the mangroves and the fish prompted them to initiate replantation schemes in two areas of the creek, managed by the community itself.

The matrix in Fig. 3 reports information such as the mangrove species present in the creek, how the locals perceive the changes in the numbers of big trees and different uses of the species (ranked with scores from zero to five). Finally, the informants ranked the price of each tree. Even a quick look at the matrix reveals that the decline of the present species can be attributed to the cutting of building timber to be put on the market, while the local consumption has had no effect on the presence of big trees.

The analyses and considerations that followed these first meetings gave rise to the development of the decisional matrixes. They were drawn separately for the two wealth

[8] Other items included are: crafts, such as carpentry or masonry, and for the rich class, income from the letting of property.

classes involved in timber cutting, because each class assigns different importance to the criteria.
In the analysis, we also considered the characteristics of the study site, divided into two areas: Dabaso and Mida-Majaoni. Dabaso was the first settlement and is populated by nearly 400 families, the majority of which have 12 acre farms. The farmers consider this size suitable to supply their family needs and to assure future security. The main problems of this area are related to young families without enough land. On the other hand, Mida Majaoni, populated by nearly 350 families, is a more recent settlement and both the area and fertility of the land are less than in Dabaso. Moreover, in Mida Majaoni, water sources are located on the borders of the area and are difficult to reach by most of the inhabitants. This means not only more difficulties for daily family tasks, but also a limitation of the development of activities requiring water, such as livestock husbandry or crop cultivation. Fig. 4 compares the income composition in the two areas.
Tables 2 and 3 show the DM and the criteria importance (subdivided according to the wealth classes and to the areas).
The results of the application of fuzzy logic (Tab. 4) reveal that there are no significant differences between the final preferences of the middle and poor classes, while there are marked differences between the two areas.

CONCLUSIONS

Both in Mida and Dabaso, the preferred alternative is a 1 acre plot of coconut cultivation. However, it is impossible to achieve this alternative in the short term because there is no land with productive coconut trees available. Nevertheless, these data are interesting because they confirm what emerged during the meetings, i.e. the significant priority of coconut cultivation for the Mida Creek community, and they explain that its importance cannot be ascribed to income alone but also to the other criteria considered in the matrix.
The second preferred activity is cutting for building timber. This is certainly not unexpected, considering how heavily mangroves are exploited nowadays. This statement seems to be disarming, because the maintenance of the present rate of mangrove exploitation is ecologically unsustainable. However, it does oblige us to consider alternatives that in the short term would not lead to the end of timber cutting but would result in long-term sustainable exploitation of the mangrove resources, together with improvements in the living conditions of the local community.
To analyse the situation in more detail, we will deal with the two areas separately. In Dabaso, dairy cow husbandry follows timber cutting as a preference. However, in the matrix we calculated the time required to generate the first income from dairy husbandry to be 1.5 years. If we were to compare these two activities after the cow starts producing, the preferences would be reversed, both for the middle and poor classes. From this point of view, the diffusion of dairy husbandry as a source of income alternative to the current exploitation of the mangrove seems particularly interesting.
An alternative for the Mida area would be the assignment to each family of 1 acre of land that could be cultivated with food crops associated with coconut, since coconut alone will not be productive. These scenarios for the future would be preferred to the current management of the area.
However, we must emphasise that until timber dealers from Malindi are banned from the mangrove, it will not be possible to conduct sustainable mangrove management, because they are the most important promoters of mangrove cutting. Moreover, to prohibit locals from tree cutting, without offering them a valid alternative, does not seem possible. This is because the government does not have the means to assure that the laws are respected and because this activity represents an essential source of income for the local community. Without this income, the inhabitants could not afford to satisfy some basic

needs such as paying for or maintaining their houses and having a small monetary income to pay for medical care and school fees.
At the end of the work, we would like to evaluate if the methodology we applied (the participatory approach and the fuzzy logic analysis) effectively fulfilled the purpose we set at the beginning.
As our work was limited to a relatively short period, it was not possible to include the participatory management of the development process. This would have entailed a deeper involvement of the community, which should have brought local Institutions into the process. However, during the research, the definition of problems and priorities and the outlining of possible solutions was carried out with a participatory approach. Basically, this meant focusing attention on the attitudes and behaviours of the people we were working with. This allowed us to integrate the scientific knowledge of the researchers with the knowledge of the local people (in a way that we would define as satisfactory) and to talk with the community in a "common language". This approach was fundamental for the success of the research; indeed, it is not possible to deal with the management of an area without the involvement of local communities.
On the other hand, the application of the fuzzy logic analysis seemed to be more suitable than other methods (both multi-criterion and optimisation analysis) to combine quantitative and qualitative data. Since most (but not all) of the parameters used to compare the alternatives were qualitative, the opportunity to apply this analysis was important for the positive development of the work. Thus, we could fully utilise the outcomes of participatory discussions and of the entire fieldwork. In fact, the results of the participatory meetings were used directly to fill in the decisional matrixes, preserving their feature of uncertainty and imprecision, while the quantitative data could maintain their numerical nature. Then, through the development of the decisional matrix, we could synthesise the judgements that emerged during the meetings and compare the various alternatives, also taking into account the quantitative data. Finally, by means of the fuzzy logic, we could try to predict how the preferences would change if some parameters were to vary; in particular, we analysed the influence of the parameter "time required to generate income". However, a similar assessment could be made for other parameters such as "environmental impact"; it can be expected that this parameter would change following a campaign to make people sensitive to the environment.
Therefore, this case study yielded a positive assessment of the fuzzy logic analysis, since it combined simplicity, flexibility and methodological rigour. Moreover, it was very appropriate to use the outcomes of the participatory activities which, as we have already mentioned, formed the basis of our methodology.

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Fig.1: **Annual Income composition in the three wealth classes**, standard errors are shown. The building wood data refer to the results of the participatory discussions and matrixes, while the other data refer to the results of the interviews.

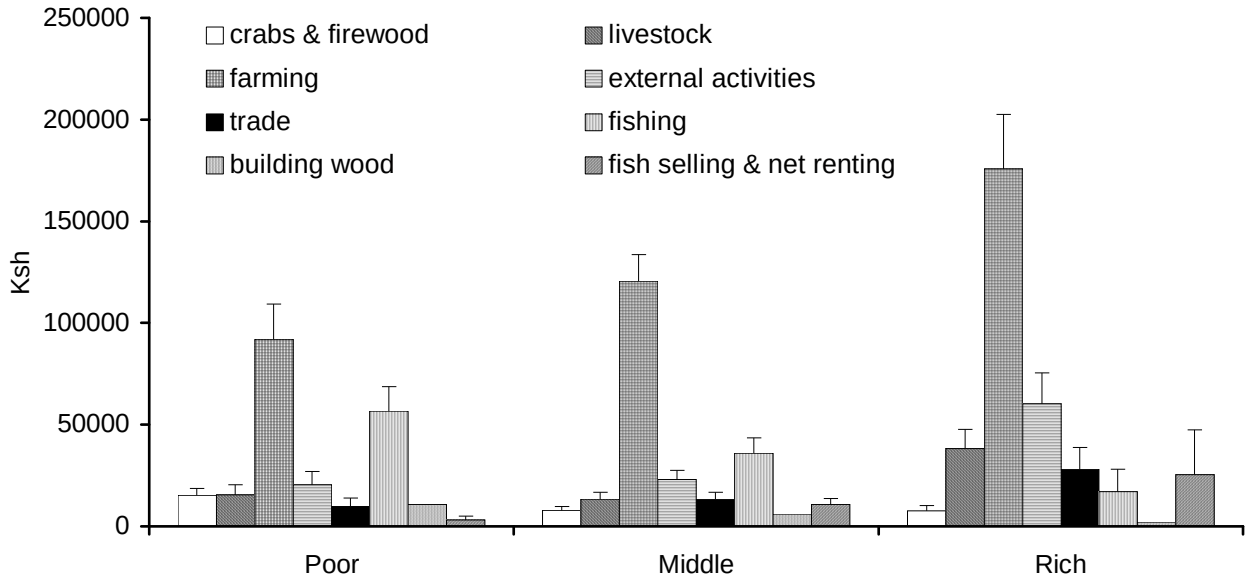


Fig.2: **Contribution of the mangrove to the total income in the three wealth classes**

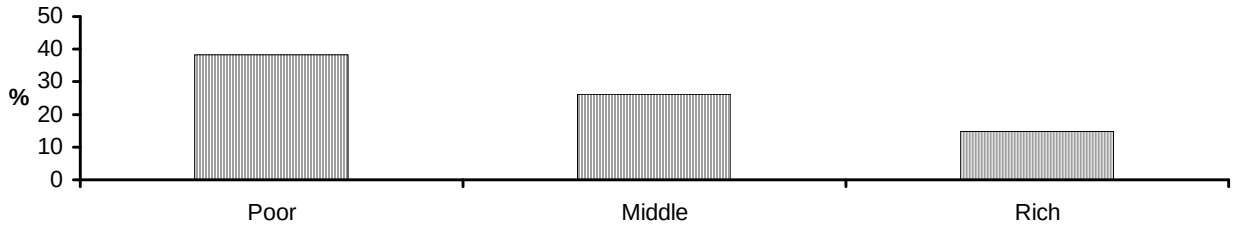


Fig.3**:Participatory matrix of mangrove uses**

NAME OF TREES	*LOCAL NAME*	*TREND*	*BUILDING TIMBER*	*FIREWOOD*	*CHARCOAL*	*FISHING MATERIAL*	*PRICE*
Sonneratia alba	*Mlilana*	↔		•••			
Avicennia marina	*Mchu*	↔		••	•••		•
Xylocarpus granatum	*Mkumafi*	↔		••	••		
Rhizophora mucronata	*Mkoko*	↓	•••	••	••	••	•••
Ceriops tagal	*Mkandaa*	↓	•••	••			•••
Bruguiera gymnorrhiza	*Muia*	↓	•••	••			•••

Sita, 14/03/1998

Elaborated by: Amos Kenga, Kaingu Kenga, Kwicha Mwamure, Katana Jefwa, Benson Tsuma

Fig. 4a: **Income composition in Dabaso area**

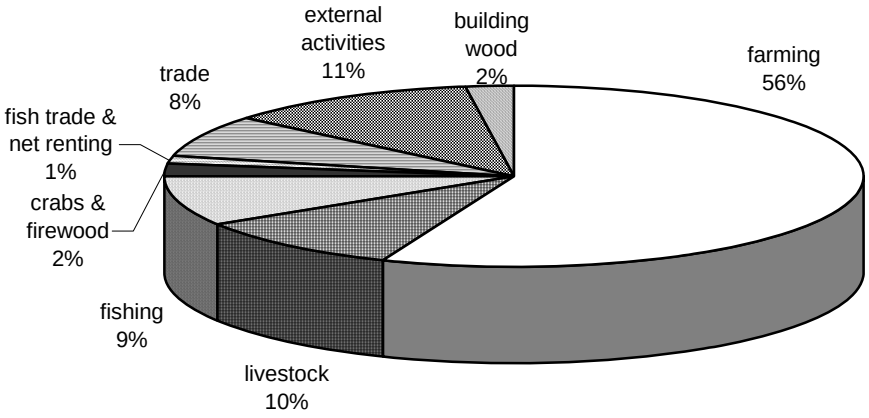
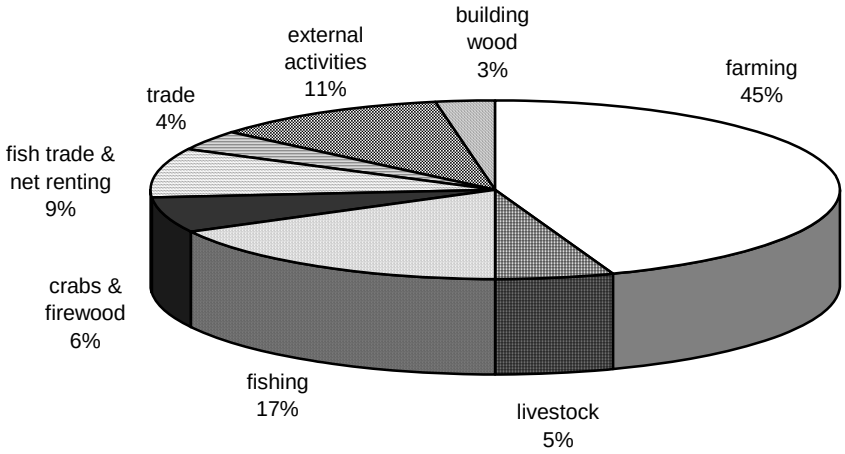


Fig. 4b: **Income composition in Mida Majaoni area**



Tab. 1**: Average annual income (total, farming and mangrove) for the wealth classes, in Kenyan Shillings** (± standard error)

classes	total	farming	mangrove
rich	354586 ± 36606	175788 ± 26901	52283 ± 24187
middle	230716 ± 15485	120552 ± 13126	60476 ± 8462
poor	222984 ± 18966	92079 ± 17143	85455 ± 12665

Tab.2: **Decisional Matrix**

criteria			alternatives								
	max min	scale	building wood	casuarina (1 extra acre)	productive casuarina (1 extra acre)	coconuts (1 extra acre)	productive coconuts (1 extra acre)	diary (1 extra head)	ecotourism	improved fishing	food crops (1 extra acre)
annual income (Ksh)	max	No	10667	36000	36000	10322	10322	22000	5000	22050	17704
environmental impact	min	3	very high	low	low	low	low	low	very low	low	low
family production for consumption	max	3	high	high	high	very high	very high	very high	very low	very high	very high
fertiliser requirement	min	2	low	medium	medium	low	low	low	low	low	low
income security (against price fluctuation)	max	3	very high	very low	very low	very high	very high	very high	low	medium	very high
income security (against yields fluctuation)	max	3	very high	medium	medium	very high	very high	medium	very high	medium	high
quick cash generation	max	3	very high	high	high	very high	very high	very high	low	medium	very low
seasonal income fluctuation	min	2	low	low	low	low	low	low	high	medium	medium
time required to generate income (years)	min	No	0	3	0	7	0	1.5	0	0	0.33
water requirement	min	2	low	high	high	low	low	high	low	low	low
work effort	min	2	high	medium	medium	low	low	low	low	high	medium
work seasonality	min	3	very low	high	high	medium	medium	very high	high	medium	high
work time requirement	min	3	high	high	high	low	low	low	low	very high	medium

Tab.3: **Criteria importance**

criteria	poor class in Mida Majaoni	middle class in Mida Majaoni	poor class in Dabaso	middle class in Dabaso
annual income (Ksh)	high	high	high	high
environmental impact	low to very low	low to very low	low to very low	low to very low
family production for consumption	medium	medium	medium	medium
fertiliser requirement	medium high	medium high	medium high	medium high
income security (against price fluctuation)	high	high	high	high
income security (against yields fluctuation)	high	high	high	high
quick cash generation	medium high	medium high	medium high	medium high
seasonal income fluctuation	medium high	medium high	medium high	medium high
time required to generate income (years)	maximal	maximal	maximal	maximal
water requirement	maximal	maximal	low	low
work effort	low	medium	low	medium
work seasonality	low	medium	low	medium
work time requirement	low	medium	low	medium

Tab.4: **Fuzzy logic results**

Mida Majaoni area			Dabaso area		
Possible alternatives	poor class	middle class	Possible alternatives	poor class	middle class
productive coconuts (1 extra acre)	0.83	0.84	productive coconuts (1 extra acre)	0.82	0.81
building wood	0.76	0.71	building wood	0.75	0.72
food crops (1 extra acre)	0.68	0.69	diary (1 extra head)	0.70	0.68
improved fishing	0.67	0.67	food crops (1 extra acre)	0.66	0.67
diary (1 extra head)	0.60	0.61	improved fishing	0.64	0.61
ecotourism	0.57	0.58	productive casuarina (1 extra acre)	0.59	0.58
coconuts (1 extra acre)	0.57	0.58	ecotourism	0.54	0.54
productive casuarina (1 extra acre)	0.53	0.54	coconuts (1 extra acre)	0.53	0.54
casuarina (1 extra acre)	0.45	0.46	casuarina (1 extra acre)	0.50	0.49