UNIVERSITY OF NAIROBI
HOUSING RESEARCH AND DEVELOPMENT UNIT

MAKUTI ROOFING FOR FARMER'S HOUSING

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1. Introduction

1.1. Aim of the exercise

HRDU has been requested by the National Irrigation Board to investigate the possibilities of the use of Makuti roofing (palm leaf thatching) for the 5200 farmer's houses to be erected in the Bura Irrigation and Settlement Scheme situated on the Tana river at a distance of about 240 km. from Malindi.

Data on present and potential future production capacity, production cost and transport cost, marketing system, and technical details of the product were to be collected.

1.2. Sources of information

Information on the number, geographical distribution and characteristics of coconut palms in the coast area were obtained from Professor C.L.M. van Eijnatten (Dept, of Crop Science, Fac. of Agriculture, University of Nairobi) whose department has recently surveyed the coconut "industry" in Kenya.
Information on production, marketing, transport and application of Makuti was collected during a survey in the coast area by two technicians of the HRDU (Mr. G. Ochola and Mr. J. Hang'alla). Architects, contractors, dealers and manufacturers (village women) were interviewed during two surveys of one week each, one covering Mombasa and the area south of Mombasa, one covering the area between Mombasa and Malindi.

2. Coconut palms in the coast area of Kenya

2.1. Quantity and distribution of palms

2.1.1. Number

Total estimated number of coconut palm in the coast area of Kenya: 2 million trees.

2.1.2. Distribution

The palms are concentrated in four main areas:

a. South coast
South of Mombasa (from Waa) to Lunga Lunga (Tanzania border) from the coast line up to 10 km. inland.

b. North coast
From Mombasa-Miritini to Kilifi creek in a narrow strip along the coast and a second strip further inland along the line Mazeras-Kaloleni.

c. North of Kilifi creek.
From Kilifi to Malindi and from Malindi inland up to Kakokeni.

d. On Lamu and the adjoining islands.

2.1.3. Concentration

As the depth of the strip of coconut plantations is greatest at the south coast, this region contains the largest number of palms.
The two strips north of Mombasa (up to Kilifi creek) are narrow, and the inland strip (Mazeras - Kaloleni) is influenced by unfavourable dry conditions.
North of Malindi there are no further plantations of any importance.
On Lamu and the other islands climatic conditions are more favourable for coconut palms than in the other areas which results in high concentration and better palms (more leafs per palm; see also para 2.2.1).

2.2 Characteristics of coconut palm in Kenya

2.2.1. Number of leafs per tree

As, in general, rainfall in the coastal area of Kenya is lower than the optimum for coconut palm cultivation, the number of leafs per tree is lower than normal, i.e. 20 - 24 leafs per tree. Conditions on Lamu are more favourable and it is likely that the number of leafs comes closer to 40 (normal number for higher rainfall areas).

2.2.2. Growth pattern

A new leaf is formed every six weeks, 9 - 10 leafs are formed per year. The efflorescence ("blossoms") develops under the leaf and results in full-grown nuts after about 14 months. When the nuts are fully developed the leaf starts drying out and will drop to the ground when dry (or can be removed when still partly green and can be dried before production of Makuti starts).

2.2.3. Characteristics of leafs

Length of mid-rib: 6 to 7 metres.
Number of blades per leaf: 200 to 300.
Length of blad3s: 0.90 to 1.50 metre.

2.2.4. Requirements for Makuti production

Due to the fact that the length of the blades is reduced towards the ends of the leaf (leaf more or less lens-shaped) not all blades are suitable for Makuti making. Although large leafs may yield 3 Makuti mats or more, as an average 2 Makuti mats of about 600 x 600 mms. can be made out of one palm leaf.

2.2.5. Makuti production potential

The total palm stock yields 20 million palm leafs per year, or enough material to produce 40 million Makuti mats yearly. With 2200 mats needed to cover one farmer's house (NIB figure) the total available number of leafs would be sufficient to cover 18,000 houses per year. It is obvious that only a fraction of the available leafs are at present used for Makuti making. From the above figures it is clear, however, that material resources allow for considerable increase of production.

3. Makuti production and application

3.1. Characteristics of Makuti mats

3.1.1. General

Makuti is a "traditional" roofing material which is older than the "industrial" development in the building sector in Kenya. It is produced and used over a large area (East African coast from the Somali-Kenya border to the south of Mozambique), but sizes and characteristics differ from location to location.

3.1.2. Description of Makuti mats

Makuti mats consist of palm leaf blades which are tied to a rib (part of the stem of the palm leaf) thus forming mats which are used for roof covering. Laying of the mats resembles the laying of slates or timber shingles. As, apart from the tying to the top rib (stem) the palm leaf blades are loose strands, waterproofness is obtained by multiple overlapping (in the direction of the roof slope). The difference with a slated roof is that the mats are laid with a side lap also.

For the tying of the blades to the stem the traditional material is dried fibre of Doum palm leafs, but sisal twine (industrially produced) is sometimes used as well.

The mats are laid on rafters (round poles or branches) and the stems tied to the rafters with sisal twine.

The way the blades are tied to the stem is shown in figures 1. and 2. below:

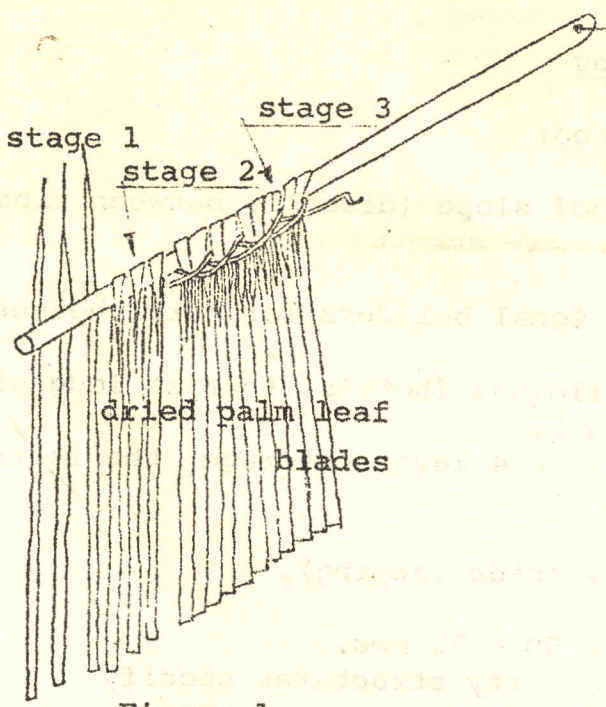

Figure 1

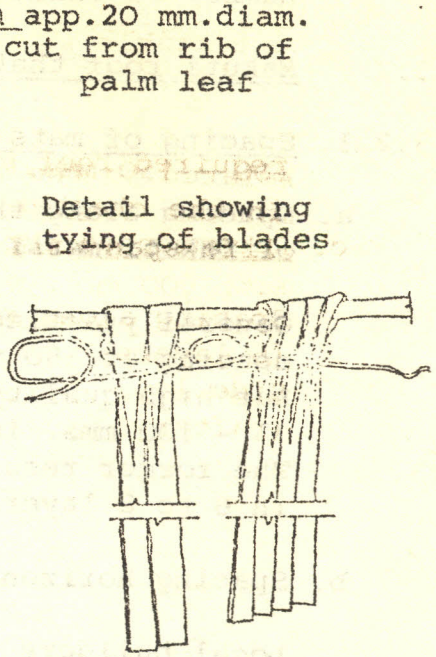

Figure 2

Differences in size have an influence on the support structure. In order to arrive at the optimum side lap of the elements (minimum 100 mms, often larger because of irregular width of the mats)., rafter spacing must be adjusted to the width of the mats. As, in traditional circumstances, a builder will use mats produced in or near his own location, this adjustment does not cause any difficulties. When Makuti is to be used far from the production sites, efforts must be made to enforce a standard width in the production process (e.g. 600 mms.) so that a standard spacing of the rafters can be adopted.

3.1.3. Size of Makuti mats

The survey team measured a large number of Makuti mats in a number of production centres. Both width (measured along the "stem") and length (length of palm leaf blades) varied greatly, not only from location to location but also in stocks produced by each individual producer (village woman).
In general the minimum size produced is 600 x 600 mms. and the design of the support structure should be based on this size.*)

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*) at the south coast mats of 500 x 500 mms. are produced also.

The number of palm leaf blades per Makuti mat is related to the width of the mat, but no direct mathematical relation can be observed, as the width of the blades is not constant . For a good quality mat, 600 mms. wide, the average is 75 blades. Obviously a larger number of blades produces a better mat, but good quality mats with a smaller number of blades occur.

3.2. Makuti roof thatching

3.2.1. Spacing of mats on roof

a. Spacing along the roof slope (distance between ribs of Makuti mats).

General practice of local builders for rural houses: spacing at 150 mms.
For high quality buildings (hotels, tourist lodges) 75 - 100 mms. is usual.
The former results in a 4 layer coverage, the latter in 6 to 8 layers.

b. Spacing horizontally (side lapping).

Local builders allow 50 - 75 mms.
Architects of high quality structures specify 100 - 150 mms.

c. Recommended for low-cost structures:

Spacing along roof slope: 100 mms.
(6 layers)
Side lapping: 100 mms.
(rafter spacing at 500 mms.)

The above results in 20 mats per square metre.

3.2.2. Roof slope

For good quality work roof slopes should not be less that 45° (1:1 slope ratio).

As a steeper slope results in a larger roof area and consequently increases the cost (more mats, longer support timber), local builders tend to choose roof slopes below 45° . This result in waterproof roofs but reduces the life span of the roof cladding.

"Breaks" in roof slopes should be avoided as rapid deterioration will occur at the junction of the two slopes. Different slopes for lean-to verandahs are acceptable as these roof extensions can be easily repaired or replaced.

For high quality work where a longer life span is required roof slopes of 55° - 60° are recommended.

In the chapter on costs the relation cost - roof slope - life span will be reconsidered.

3.2.3. Life span of Makuti roofing

All professionals interviewed (architects, contractors and small builders) agree on the general principle that steeper slopes and closer spacing (larger number of layers) extend the life span of Makuti roofing. It remains difficult, however, to make definite predictions as high quality structures where the designers aimed at longer life span are still a fairly recent development.

It can be assumed, however, that when the roof slope is 45° (1:1 pitch) with 100 mms. end lap (6 layer coverage) the life span will be not less than 4 years. (5 years more likely)*)
With a roof slope of 60° (1:0.58 pitch) and an end lap of 75 mms. (8 layer coverage), doubling of the life span can be expected (8 years or more).

4. Makuti production and marketing

4.1. The production process

4.1.1. General

Makuti making is a typical traditional "cottage industry". Producers working outside their own houses are found in all areas where coconut palms are available.

No successful group activities (beyond housewives working with younger family members) have been noticed by the survey team.**)
Questions asked about potential increase of output per person when the job is done on a full-time basis did not yield useful answers.

4.1.2 The producers

Makuti producers are housewives who collect the material (palm leaf) and make the mats in their "spare time" (time left over between the normal domestic activities). Sometimes delivery to dealers is also done by the women themselves.

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*) Several roofs under construction were surveyed with slopes between 40° and 30° and end lap of 150 mms. The local builders still expected a life span of 4 years.

**) The survey team interviewed the chairman (female) of a recently formed women's cooperative at the south coast (3 villages: Chaii, Makundi, Pongwe) but results were disappointing.
(impression: lack of leadership, members too young and inexperienced)

4.1.3. Working days

Makuti making is always done during the day time in between domestic activities (washing, cleaning, food preparation and cooking). When the shamba needs attention no, or little, time is available for Makuti making. The survey team tried to find out how much time was spent on material collection but data obtained are not conclusive and vary greatly (depends on distance to coconut plantations).

4.1.4. Daily production

As the time available per day is not constant daily production varies. Low daily production is 10 to 20 mats, the maximum is around 40 mats per day.

4.1.5 Period of production

Makuti is mainly made during the dry season (leafs must be dry), and to a lesser extent during the rains (when demand, for repairs, may exceed available stocks).

Probably due to the fact that most producers are (semi-) illiterate, information obtained on the length of the period varies greatly. It can be assumed that the production period stretches from November to May, with the highest production during December, January, February, March.

4.2. Marketing of Makuti mats

4.2.1. General

Although direct sales from producer to user occur on a small scale (repair work) the majority of the production is sold by the producers to dealers who stock the material in their stores from where it is sold in retail (per bundle of 20 mats; in some areas in bundles of 10 mats). The larger dealers also supply on contract (orders for large quantities supplied to building contractors).

4.2.2. Relation dealer-producer

Dealers collect (by lorry of pick-up) from producers in their district. Bundling (in 20's, sometimes in 10's) is done by the producers. Producers living near the dealers store carry the product to the store. In the north coast area small dealers are established in each market centre so that each producer regularly supplies to the same dealer. The south coast producers are served mainly by dealers from the Mombasa area and producers may supply to several dealers.

4.2.3. Supply capacity of dealers

Most dealers have limited storage capacity. Capacity of 2,000 to 3,000 bundles (40,000 to 60,000 mats) is indicated by a number of dealers. A few large dealers could stock more, but large quantities are normally supplied on contract, not ex stock.

Information on supply capacity (on contract basis) obtained from the dealers is not conclusive and cannot be used in a cumulative sense, as dealers covering the same area may rely on the same producers. Therefore, when one dealer obtains a large supply contract, the other dealers in the area may not be able to collect material.

4.2.4. Dealer's price versus producer's price

Price information collected by a survey team differs from prices negotiated by contractors. Producers sometimes quote sales prices of the dealers (in order not to "spoil the market") and dealers do not like to discuss prices with non-clients. It is clear, however, that the price paid by the dealer to the producer equals 50% of the dealer's sales price.

4.3. Storage of Makuti mats

4.3.1. General

Dealers and professionals interviewed are of the opinion that Makuti can be stored for a period of 6 to 10 months without causing deterioration of the material provided certain precautions are taken.

If application for a large housing project is considered where the construction works are spread out over the whole year, storage facilities must be created to form a "buffer stock" from which the material can be drawn during the periods which are unfavourable for Makuti manufacturing.

4.3.2. Requirements for Makuti storage

Makuti in storage should be protected from rain and sun shine. Open storage sheds (roofed area only) are sufficient.

Makuti must, preferably, be stacked free from the ground on timber poles or battens. The battens must be termite proof (either termite proof timber or impregnated soft wood) and, especially for long term storage, the soil in and around the sheds must be "poisoned" with suitable chemicals.

1000 Makuti mats require a storage space of 2.5 - 3 cubic metres. As about 2,000 mats are required to cover an average farmer's house, the storage space per house amounts to 5 - 6 cubic metres. Assuming a stacking height of 1.50 metres, net covered storage area per house would be 3 - 4 square metres, gross covered area say 5 square metres.

5. Cost of Makuti roofing

5.1. Cost of Makuti thatching for "standard" roof slope

5.1.1. Cost of Makuti mats

The average retail price of a bundle of 20 Makuti mats ex dealer's store is KShs.8.- or KShs.0.40 per mat.
For large quantities most dealers indicate a reduced price of KShs.7.- per bundle or KShs.0.35 per mat.

5.1.2. Cost of transport

Only a few dealers have, in the past, supplied large quantities at sites far from the production areas. Information gathered on transport cost is, therefore, not as accurate as could be desired.

Although the weight of each mat can vary between 700 and 900 grammes (depending on size and number of blades in the mat) it seems to be usual practice to load one thousand mats per ton carrying capacity of a lorry (i.e. 7,000 mats on a 7 tons lorry, 10,000 mats on a 10 tons lorry).

Different rates are applied for transport on tarmac roads and on murram roads. Transport rates are reduced when a return pay-load is available.

Normal rates per ton-km. are:

- on tarmac roads	KShs. 1.--
- ditto with return pay-load	0.70
- on non-tarmacked roads	1.20
- ditto with return pay-load	1.--

When Makuti is transported from Malindi to Bura the transport cost would add
240 x 1.20 = KShs. 288.-- to the cost of 1,000 mats.
This would result in a total cost per mat of app. KShs.0.65 (based on price of mats at Malindi of KShs.0.35).

When a regular supply system could be organised and some return pay-load could be found, a sales price at Bura of KShs. 0.60 might be possible.

5.1.3. Labour cost

The daily output of a skilled Makuti layer (fundi) with one helper (unskilled labourer) is 500 mats. Assuming pay rates of KShs.30.- per day for the fundi and KShs. 15.- per day for the labourer, the net labour cost input would be KShs. 90.- per 1,000 mats.

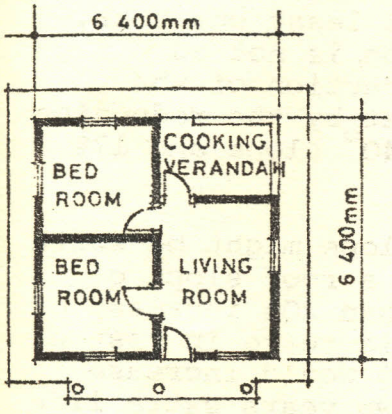
5.1.4. Total cost of Makuti thatching

For a roof with a slope of 45° (1:1 pitch), end lap 100 mms., side lap 100 mms., the cost of one square metre of roof surfacing would be:

	at the coast KShs.	at bura KShs.
Cost of 20 Makuti mats (including quantity discount)	7.--	13.--
10% allowance for waste	0.70	1.30
Net labour cost	1.80	1.80
Total cost per square metre roof surface KShs.	9.50	16.10

For a typical farmer's house with one living room, two bedrooms and a verandah, the plan of which is shown below, the total roof surface is 100 sq.m. The total cost of Makuti roofing to such a house would thus be:

at the coast KShs. 950.--
at Bura KShs. 1,610.--



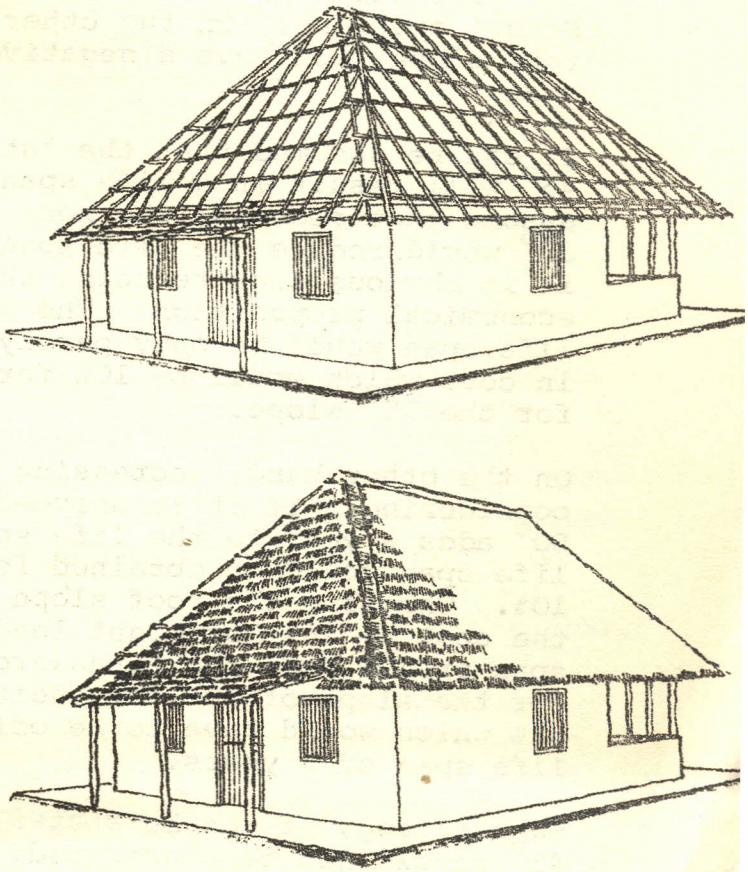


Figure 3

Plan and perspective views of farmer's house *)

*) Architect : O. Kaszner

5.2. Relation between cost and roof slope

For the typical farmer's house shown in figure 3 the total roof area has been calculated for different roof slopes, based on the following assumptions:

roof overhang (horizontal projection) 0.750 m.

roof slope to end elevations 15° steeper than main roof slope (i.e. for a main roof slope of 45° the slope to the ends of the roof will be 60°)

Results of these calculations are:

Roof slope	Total area of roof
30°	77 sq.metres
35°	83 sq.metres
40°	90 sq.metres
45°	100 sq.metres
50°	110 sq.metres
55°	128 sq.metres
60°	152 sq.metres

As mentioned in chapter 3. (para 3.2.3), increasing the roof slope will increase the life span of the Makuti covering. On the other hand, reducing the roof slope will have a negative effect on the life span.

It can be assumed that the "standard" roof slope of 45° will result in a life span of 5 years. If we assume that reducing the roof slope to 40° or even 35° would reduce the life span by at least one year, it is obvious that reducing the slope is not an economical proposition. The 20% reduction of the life span would be only partly offset by the reduction in cost which would be 10% for the 40° slope and 17% for the 35° slope.

On the other hand, increasing the slope might be worth considering. If it is assumed that a roof slope of 50° adds a year to the life span, than 20% increase of life span could be obtained for an increase in cost of 10%. Choosing the roof slope of 55% would increase the cost by 28% but might lead to two years extra life span or 40% over the "standard" life span.
For the slope of 60° the additional cost would be 52% which would have to be offset by an increase in life span of 3 years.

Summarizing, it can be stated that roof slopes below 45° should not be considered. Increase of the roof slope to 50° or even 55° might be an economical proposation in the long run.

6. Conclusions

Makuti roofing can be considered a suitable roofing material for farmer's houses in the Bura resettlement scheme.

In the coastal area it is, no doubt, the cheapest material available for roofing even when the comparatively short life span is taken into consideration. When applied at a distance of about 250 km. from the production area, the initial cost increase will be in the order of 60 to 70% which, at first view, still is competitive with other material (e.g. corrugated galvanised iron, corrugated asbestos-cement).

When considering the raw material situation, production capacity could be increased to cope with large increases in demand. As, however, the manufacturing of Makuti is a typical "cottage industry", a drastic increase in production will not be easy to organize. It is also doubtful whether the present transport capacity could cope with large increases in quantity. It seems, therefore, advisable to choose this material for a number of villages or certain categories of buildings within each village only, but not for the whole scheme.

In view of the fact that production is not evenly spread over the year, storage near the construction site of a "buffer stock" for about 6 months must be arranged for.

As the planned construction period more or less corresponds with the expected life span of the Makuti roofing, future maintenance and replacement does not involve major problems of supply and transport of material, and provision of specialized labour. Although maybe at a slightly slower rate, the regular supply of material could continue after the houses have been completed. At that time the houses constructed during the starting period of the scheme would be ready for maintenance works. This also means that specialized labour would find continous employment in the scheme.

In view of the relation roof slope - expected life span, the recommended roof slope is 45° (roof pitch ratio 1:1). Lowering the roof slope is not an economical proposition.
It might be considered to choose a steeper roof slope (50° or 55°) thus leading to an increase of life span which more than offsets the increased cost. As no accurate data can support this suggestion, a few houses could be designed with the steeper slopes as experimental structures. The performance of these steeper roofs should be properly monitored over a number of years.