Project Working Paper No. 4

KENYA/JAPAN

SOCIAL FORESTRY TRAINING PROJECT

CHARCOAL PRODUCTION

AND

RELATED STUDIES

Ginji Sugiura

Consultant in Charcoal

Senior Research Scientist, Institute for Promotion

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FOREWORD

Charcoal is a very important but sensitive subject in Kenya. A great deal of charcoal flows into towns every day and is sold in the market, but no reliable statistics on quantity, price, producers, consumers, etc., exists. Most importantly, nobody knows how much is a "legal" produce and how much is not.

One of the findings of another project survey ("A Survey of Social Forestry Training Needs in the Semi-Arid Area": Project Working Paper No. 2) shows that the purpose of charcoal production by farmers is overwhelmingly to obtain cash income and not for their domestic use. In other words, farmers seem to be compelled to produce charcoal when they are desperately in need of cash for survival, i.e. to buy food.

It is commonly observed in the semi-arid areas of Kenya that the number of charcoal bags stacked and sold along the roadside increases after a poor harvest in a drought-stricken year. The price goes down accordingly by this "over-production". A good harvest brings down the production level and makes the price higher; in 1989, an exceptionally favourable year, the price of a bag (90 kg) of charcoal in the Kitui area jumped to Kshs. 80 from Kshs. 40, the previous year.

Production of charcoal is, thus, closely linked with the life of the farmer, particularly in the semi-arid area. Conservation of natural environment in the area that is very difficult to rehabilitate once the ecosystem has been destructed will entirely depend upon the question as to if and how the social and economic problems facing the farmer can be solved. It is clear, therefore, that the problems related to charcoal production are more on the economic, political and institutional side than technical.

Then, why was Mr. Sugiura called in to advise on the technical aspects of the charcoal production? It is because of the following reasons:

(1) While awaiting political and institutional solutions, research capability of the Karura National Research Centre of KEFRI in this field needs to be developed well in advance to eliminate production loss estimated as pretty high.

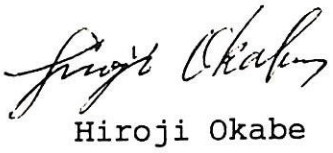
(2) Improved charcoal production methods developed in Japan would serve as a hint to the current situation in Kenya and the Japanese research experience in this area would also be useful.

It might be added in this connection that charcoal used to be by far the major domestic fuel in Japan and the annual production mostly by farmers amounted to as much as 2 million tons until late

1950s. Research efforts had been made in such subjects as management of fuelwood plantation, small-scale charcoal production etc. for the farmer. Since around 1960 fuel consumption pattern in Japan changed drastically and, losing its position to electricity and a gas (LPG), charcoal production level has fallen to only 35,000 ton. Research experience is being lost too and it was another reason for this consultancy to be carried out as early as possible before such expertise represented by a few including Mr. Sugiura might disappear.

Therefore, the content of this paper should be treated with caution. It will be obvious that recommendations are not for immediate applications, but for advance study and preparatory research build up. Probably the best way to apply these techniques is the charcoal production on the basis of the new resource created by social forestry activities.

August 1990



Hiroji Okabe

Chief Adviser

Acknowledgement

I am pleased to have had an opportunity to work in this project of which main objective is the promotion of social forestry in Kenya, particularly in the semi-arid areas.

Charcoal making is widely practised in the semi-arid areas, but skills in production are not quite satisfactory. Subjects dealt with during the consultancy were various, i.e. construction of several kilns, different production methods, procurement and use of different raw materials and utilization of charcoal bi-products, mainly wood vinegar. I have tried to transfer the experience and knowledge gained in Japan so that at least some of them could be utilized for the improvement of charcoal production and more efficient use of woody resources in Kenya.

The project (SFTP) has kindly arranged the services of Ms. Tomoko Nakamatsu as an interpreter throughout this consultancy. Without her assistance it would have been difficult to accomplish my task in two months time. I am grateful for Mr. J.K. Githiomi's contribution to the task. His untiring efforts were invaluable.

Thanks are also due to Dr. J.A. Odera, Director, KEFRI, Mr. Ben Chikamai and the staff of the Karura National Research Centre, the Chief Adviser and Experts of SFTP, particularly Mr. N. Noda, for their support and assistance provided.

Ginji Sugiura

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1. Terms of Reference of the Consultancy

The consultant was given the following terms of reference:

(a) To advise on the charcoal production methods and efficient use of charcoal under the conditions of the rural areas of Kenya,

(b) To develop and manufacture model charcoal kilns suitable for the rural Kenya and train the counterpart staff on the whole process including the handling of the portable kilns,

(c) To train the counterpart staff on the analytical method for defining the quality of charcoal and bi-products,

(d) To train the counterpart staff on the production of improved charcoal briquettes and on the use of stoves designed for the briquettes and

(e) To carry out studies on the carbonization rate and quality of charcoal of the selected tree species.

2. Work Plans

In accordance with the terms of reference, broad work plans were prepared as follows:

(a) Advice on charcoal production methods and use

Availability of wood raw materials for charcoal production is determined by the forest resource situation of the respective areas. Production method and usage of charcoal are, therefore, different depending upon the quality of the material obtainable in the area.

Although it is desirable to widely review current operations in the rural Kenya, the consultant's observations would concentrate on the practices in the Kitui area due to time constraints and advice and/or recommendations would be offered specifically for the Kitui area.

(b) Development and manufacturing of model charcoal kilns

The following three types and six models were considered as appropriate and applicable kilns for Kenya and would be constructed at Karura National Research Centre of KEFRI. The kilns could be used for both demonstration and research at the site.

(i) Fixed kilns

(1) Brick kiln: As bricks are commonly available in rural Kenya, this should be one to be recommended.

(2) Flat furnace (kiln): To be used for the carbonization of so far unutilized materials such as sawdust, coffee hulls, nutshells, etc.

(ii) Portable kilns

(3) FFPRI-Model: This model was developed in Japan by the Forestry and Forest Products Research Institute. It is made of stainless steel to make it corrosion resistant as a wood vinegar and tar collection device is built in.

(4) Drum kiln: This would be locally manufactured using 200 1. petrol drums. This is good for a small-scale production and could also collect wood vinegar and tar.

(iii) Earth mound kilns

(5) Kenyan and Japanese Types: A comparative demonstration of both models would be carried out.

(6) Charcoal making by tree planting holes: This would be tried at the Pilot Forest area at Kitui. It is known that tree growth is enhanced when charcoal powder and ash are mixed with soils. In addition to improving the soils, it would also sterilize soils and could prevent insects and diseases. It is thought worthwhile trying in the semi-arid area.

(c) Assessment of quality of charcoal and bi-products, and utilization of the bi-products

To assess the quality of charcoal, methods of industrial analysis as well as charcoal quality standards (bark adhesion, colour, hardness, etc.) would be introduced.

For the bi-products, wood vinegar and wood tar, of which extraction, distillation and refining are to be demonstrated, assessment of acidity, specific gravity and colour would be demonstrated.

Among many uses of charcoal and bi-products rarely known is there effectiveness as soil improvement materials. To demonstrate this, an experiment would be carried out by sowing pasture grasses and/or vegetables in wooden crates with soils either mixed or unmixed with charcoal powder, wood vinegar and ash.

(d) Production of charcoal briquettes and demonstration of a specially designed stove

A briquette manufacturing method out of charcoal powder left in kilns and of carbides produced by a flat furnace kiln [Ref. (b), (i), (2)] from such materials as coffee hulls, nutshells, rice husks, sawdust, pruned tree branches and maize stalks would be demonstrated.

For the demonstration two types of briquette making tools, one for a cylinder-shaped and the other for a stick-shaped briquette, and two kinds of binders one of which is of alkaroidic plant mucus (Kenyan original) and the other made of starch (developed by FFPRI Japan) would be used.

A burning test of briquettes produced would be carried out using stoves specially designed and made for the two types of briquette.

(e) Carbonization rates and quality of charcoal produced from selected tree species

It is not possible to carry out detailed experiments under this subject as no pyrolysis research equipment including an electric furnace is available at Karura National Research Centre. Therefore, the work would be limited to rather general measurement of carbonization rates and assessment of quality of charcoal produced from selected three species of which important are Eucalyptus saligna, Acacia mearnsii and Grevillea robusta.

3. Points of Importance for Charcoal Production and Application

After a quick review of the situation in Kenya the following points emerged as important points to be borne in mind during this consultancy. Therefore, these points were emphasised in investigating all the subjects covered by the broad work plan.

(a) Utilization of resources so far unutilized

It would be essential to utilize so far unutilized resources existing everywhere in order to ensure an adequate supply of wood energy to the Kenyan national economy and the people. Such unutilized resources are, for example, sawdust, piled up or just burnt by the saw-millers, and coffee hulls, only a small amount of which is used as green manure, fuel or for mulching by the coffee estates. Nutshells of macadamia trees, another subject for JICA's cooperation with Kenya, have not been utilized until now. As much as 60% in weight of the macadamia fruit could be an excellent raw material for activated charcoal or for fuel. Other materials such as rice husks or pruned tree branches could also serve for charcoal making. Furthermore, not only charcoal but also bi-products produced out of these materials, could be used for the benefit of the nation.

(b) Improvement of the skills in the use of earth mound kilns

A traditional technique of earth mound kilns exists in Kenya. It is fortunate that considerable resources are saved by this technique, but a wide range of skills in using this technique leaves much room for improvement. In order to further economise the use of wood resources, training of charcoal manufacturers would be urgently needed. An additional point is that the Kenyan type earth mound kiln cannot produce bi-products, wood vinegar and tar, and could be improved after the Japanese type to accommodate a simple device for this purpose.

(c) Effects of charcoal in improving the performance of tree planting

To produce charcoal in the tree planting holes would be effective in improving the survival and growth of the trees

planted. It will utilize so far unutilized thorny shrubs or Commiphora spp. which possesses excessive water and not liked for charcoal making. Charcoal that remains in the holes will enhance water storage capacity of the soil (this would be a research subject to be pursued in line with an investigation as to how much water would ensure survival of various trees), ashes would fertilize the soil and the burning would sterilize and decompose the soil making it more resistant against insects and diseases while producing more minerals. Application of this method would be tried at the Pilot Forest area at Kitui, but may be more widely done in other semi-arid areas. The same could be said for the growing of fruit trees in ASAL, including the target areas of the JICA assisted Horticulture Development project.

4. Work done and Results Obtained

(a) Charcoal production and utilization in the rural Kenya

It should be noted that the following is the advice formulated after a two months consultancy which is not long enough to undertake a thorough review of the present situation in various parts of Kenya. Therefore, the advice would be taken with this limitation in mind.

Earth mound kilns are commonly in use all over the world for charcoal making and prove to be the simplest and rational means. This technique is also prevalent in Kenya, but it has been observed that skills in charcoal making vary widely causing concern over the wastage of precious wood resources. The skills need to be upgraded as a matter of urgency. It would be necessary for solving this problem to establish a charcoal research unit in the Karura National Research Centre in order to advance research with due facilities and train extension workers specialized in charcoal.

It is assumed that Kenya will depend upon substantially on wood energy in the foreseeable future. Although the production of wood energy is simple and does not need capital intensive techniques, suitable lands for the bio-production are limited, therefore, efforts would be made to carry out research into the improvement of soil and productivity of fuelwood plantation. In this connection, charcoal production using tree planting holes seems to be able to play a key role in promoting tree planting activities in the semi-arid areas.

Population of Kenya is concentrated in about one third of the total land, the rest being arid or semi-arid. As the woody fuel is bulky and transport cost is high, the supply base must be located within the reasonable distance from the market. Raw materials are the secondary consideration and could be any unutilized woody resources. Agricultural residues are said to feed animals, but at least part of them could be used for charcoal making. Equally, coffee hulls, coffee and tea trees to be replaced, nutshells and so on are renewable and yet unutilized resources of Kenya.

Charcoal could be stored for a long time without any decomposition or deterioration in quality. Its calorific value is twice of that of fuelwood and exudes no smoke. Although it seems to be almost exclusively for cooking in Kenya, charcoal could be used for multiple purposes on its merits; it contains minerals necessary for plant's growth; content of impurities such as ash or sulphur is insignificant; absorptive capacity is high therefore can be used as decolorant and gas absorbent. In Japan these days, it is becoming common to spread charcoal under the floor for, as they call it, "healthy housing". Apart from domestic use, charcoal is purchased and used by hotels, butcheries, bakeries, coffee and maize retailers, schools, hospitals and prisons. Charcoal using industries are tobacco, tea, sugar and tannin factories. For information, various uses of charcoal in Japan are described in Appendix.

It would be advisable to maintain on a permanent basis the following kilns [Ref. (b) below] at Karura National Research Centre for both research and demonstration purposes with a view to application in the rural Kenya:

Earth mound kilns;

- Traditional type
- Improved type (can collect wood vinegar)

Portable kilns;

- Drum kiln (locally manufactured and can collect wood vinegar)
- FFPRI model kiln (shipped from Japan, can collect wood vinegar)

Fixed kilns;

- Flat furnace kiln (Japanese model for carbonization of residues, can collect wood vinegar)
- Brick kiln (Japanese model, can collect wood vinegar)

(b) Development and manufacturing of kilns suitable for Kenya

Charcoal is being produced widely all over the world using various methods. The largest producer is Brazil, where the major use is for iron production, followed by Thailand. In these countries large-scale brick kilns are used for charcoal making. As bricks are commonly available even in the rural area, it is foreseen that brick kilns would occupy a dominant position in Kenya. Therefore, an emphasis was put on the brick kiln during the work.

(i) Earth mound kilns currently in use:

The Kenyan model differs from the Japanese model by providing 4-6 smoke outlets on the bank above the ground. This is due, presumably, to reduce the work load to fill back earth. As the area (Kitui) is semi-arid, charcoal is produced during the rainy season because it is difficult to make the dry soils air-tight or cool them down quickly. This technique, once mastered, proves to be the cheapest and is capable of carbonizing various materials and/or such agricultural residues as coffee, rice, maize, sugar cane, pineapple, etc. For example, carbonization of macadamia nutshells was tried successfully by the Japanese model during this consultancy also collecting wood vinegar from smoke exhaust. It is recommended to upgrade the skills in the use of this technique in view of its popularity already gained. It would also be advisable to gradually shift an emphasis to the use of more durable kilns while carrying out training in efficient charcoal manufacturing.

Results of a trial by the Kenyan type earth mound kiln (4m x 4m) was as follows:

- Raw materials; Eucalyptus paniculata logs, weight 1,400 kg, moisture content 18%, piled horizontally up to a height of 1m.
- Cover; dry grasses, etc. 30 cm thick, soils up to 20 cm thick.
- Ignition; burn well at the entrance, the same as the practice in Japan. It was easy because the trial was done in the dry season.
- Duration of carbonization; 6 days, it takes more time to cool down in Kenya than in Japan. Normally produced charcoal is collected early in the morning.
- An estimated of charcoal produced was 350 kg.

Results by the Japanese type earth mound kiln (2m x 1.2m):

- Raw materials; E. paniculata logs, weight 380 kg, moisture content 18%, plus some macadamia nutshells.
- Smoke outlet; one. Wood vinegar collected by a chimney.
- Duration of carbonization; 3 days.
- Charcoal produced; eucalyptus charcoal 102 kg, 26.8% of the original weight. Charcoal of macadamia nutshells also produced in good quality.

(ii) Charcoal manufacture using tree planting holes:

The purpose of this trial is to see firstly the effects of charcoal powder, ash and other bi-products on the water storage capacity and sterilization of soils, and secondly to test a very simple method to obtain charcoal in the rural area where people cannot afford substantive materials. Useful characteristics of charcoal, i.e. absorption, moisture absorption, water storage capacity and permeability would be utilized to help re-afforestation in the semi-arid area. However, as this is an initial trial, more detailed experiments should be carried out at a later stage after observing the growth of seedlings planted in the used holes. The operation took place from 2 to 4 March 1988 at the Pilot Forest site at Kitui.

Design and Operation: Considering the normal wind, two additional small holes (10 cm x 10 cm x 60 cm) are dug, on the windward as a chimney and the leeward as a draft hole, to the tree planting hole (60 cm x 60 cm). Small branches are laid vertically around the edge of the planting hole and horizontally in alternate directions at the bottom. When igniting a small amount of kerosine may be used. Seeing that the branches are burning well, charcoal materials are thrown in from the thinner ones first and then gradually the larger. Continuing this for about an hour, the planting hole is filled with materials and ready for a final operation to lay grasses and leaves up to 20 cm thick and on top of it earth up to

10 cm to cover the hole. A skill is needed to keep proper burning and ventilation, and also to measure amount and timing for earth cover. 50 holes were used for the trial producing about 10kg of charcoal per hole.

The operation could be deemed as 90% success and good charcoal was produced in the following morning. Failed cases were probably caused by excessive earth cover and insufficient initial burning (Ref. photos Nos. 3 and 4 and reference material).

(iii) Portable kilns:

(1) Drum kiln

With a view to the development of appropriate technology in Kenya, a model kiln developed by the author using a set of two drums was introduced. Angled iron bars were attached to stabilize the drums. A chimney was set up, iron mesh built in at the bottom (actually, side of the drum) and a pretty large opening was welded to the lid of the each drum. Manufacturing cost of the kiln was Kshs. 1,000. (700 for two drums and 300 for welding) and could be cheaper if mass-produced. Corrosion from wood vinegar is unavoidable, but the kiln would be more durable in arid Kenya than in rainy Japan (Ref. photos Nos. 5).

Operation: 117 E. paniculata logs weighing 175.4 kg were used as raw materials which were stacked in two drums densely, smaller ones to the bottom and larger ones upper. Then, the lid was reset and well dried ample igniting material was placed at the opening. An initial burning of about two hours would ignite whole kiln. It would take 12 - 15 hours for carbonization and 5 - 8 hours for cooling. It is desirable to ignite in the evening, carbonized during the night and take out charcoal in the morning. All four times of charcoal production showed the same recovery rate of 28% which is considerably higher than that in Japan (normally 18 - 20%). Reasons for the high recovery seem to be a low moisture

content (18%) of the eucalypts logs, well balanced initial burning and an appropriate combination of a small draft hole and the position of a chimney. The charcoal produced was of a good quality with barks intact.

During the carbonization process the drums are covered with earth which is taken away at the time of cooling to speed up the process (this is important in the tropics). The earth taken away could be used for sowing beds of a tree nursery as sterilized soil. The upper surface of the drum in operation is heated up to 350°C and could be used for cooking. Collection of wood vinegar is made possible and the vinegar could be used as insecticide or soil sterilizer. Ashes could be used as fertilizer, desiccate or for keeping warmth.

(2) FFPRI model kiln

Although this model was first made of iron, corrosion from wood vinegar was a serious problem and stainless steel is now being used. It is quite durable equipped with two wood vinegar collectors on top and at the bottom of the chimney. One of the merits of this model is easiness in dismantling, transporting and assembling. Anybody can deal with it after practicing once. Needless to say it is the most efficient way of charcoal making to bring a kiln to the place where the material is.

The kiln consists of a cylinder shaped wall which could be dismantled to three parts, a cone-shaped top, a bottom with four chimney holes and four draft holes and four chimneys. Raw materials could be any solid woody substance and need not be of fixed shape, but normally the logs of 4-10cm diametre and 50-100cm length are the best and easiest for carbonization. Larger logs of 20cm diameter or more would be split into the above size for better carbonization.

Operation:

The kiln should be located in the dry area with good drainage and near the water where the smoke exhaust would not cause trouble to the residents considering the normal direction of winds. When the location is decided and the kiln placed, stakes would be put in circles around the centre to make an ignition room. Out of raw materials, some are placed on the ground first, thinner logs for the lower part and larger logs to the middle and upper parts. They must be stacked very close together. Finally, on the top of all these raw materials, well dried wood (could be valueless or less valuable crooky ones) are to be placed and ignited with paper or kerosine. After the ignition it would take about 40 minutes to make a core of the fire and about two hours until the whole materials start carbonization. After 40 minutes, the top would be attached and smoke exudes from the central chimney hole. After two hours when the lower wall becomes warm, but still touchable by hand, chimneys are attached and, if white smoke comes out briskly, the ignition is perfect. Connecting borders of the parts of the wall must be sealed with sand and clay mix. When the smoke becomes bluish, red hot charcoal can be seen through the draft hole. As the smoke gets thinner the chimneys should be closed one after another, draft holes also sealed with clay and cooling starts. When the wall is cold enough by touching, remove the top and place a hand inside the kiln in order to make sure that the fire is completely extinguished. If not, one can feel the heat coming out from the inside. Ensuring no fire is remaining, produced charcoal is taken out and left for the night. It is accumulated, it may start fire. The time needed for the operation is two hours for ignition, six to ten hours for carbonization, six to eight hours for cooling and two hours for taking out; less than 24 hours in all. The actual trial used as raw material eucalypts logs stacked in two stages and weighing 332kg. Charcoal produced was 67 kg, giving a normal recovery rate of 20%.

This is a model called No. 1200 (meaning diameter 1200 cm at the

bottom) developed for the use by a family or for lease within a community. For a large scale production, use of four to five No. 1900 models to be handled by a group of three workers is recommended. This kiln can also be made of iron sheet in Kenya and could be utilized to carbonize utilized resources.

(iv) Fixed Kilns:

(1) Japanese type brick kiln

Strictly speaking, this is a Japanese type kiln, usually constructed with clay in Japan, built with bricks. The reason is that clay of appropriate quality is not always available, whereas bricks are popular construction material and obtainable even in the rural area. So far charcoal making by brick kilns has not been practised in Kenya.There seem to have been a trial by a German technical co-operation project of a "orange half kiln" with a number of smoke outlets on top, but did gain popularity because the operation is not easy.

The kiln is of the convenient size for research, training and demonstration. It has a circular bottom and measurements are; external diameter - 3m, internal diameter - 2.4m; height - 2 m; kiln wall - 1.5m; a chimney - 18 cm X 18 cm X 2.5 m; an ignition room cum opening width 50 cm X depth 50 cm X height 60 cm (Ref. Fig. 3).

Design and construction methods were discussed with the counterpart staff and the construction took ten days with four workers. Two kinds of brick, a large (29 cm X 17 cm X 17 cm) and a small (23 cm X 11 cm X 6.4 cm), were used for the kiln; large ones for the wall, small ones for the top and chimney. Quality bricks in the market cost KShs. 3 for a large one and KShs. 2.80 for a small one (23 cm X 6.3 cm X 6.4 cm). In order to economize the cost, cheaper bricks

were purchased from Thika prison, but they were poorly burnt and were not strong enough. Clay was also obtained at the prison and a mixture of clay, burnt soil from the previous trial of the earth mound kiln and cement in equal amount (1:1:1) was used as mortar. For the wall of the kiln, however, a mixture of clay and burnt soil only (1:1) was used. To construct the top (ceiling) was the most difficult and needed utmost care. After laying two layers of bricks, a circle wire (size No. 8) was pierced in the centre of each new brick and tied at every 40 cm intervals to stabilize the bricks. Raw materials are stacked as if inside an overturned bowl and it makes the building of the ceiling easier even for an inexperienced person when he/she stands on the materials and do the job. The very top of the ceiling is to be built with bricks cut off to a wedge shape. A finish by a mixture of cement and burnt soil (2:1) was applied to the constructed kiln. A chimney was constructed with a wooden frame (18 cm X 18 cm) around which brick was to be laid. The frame needs not be removed as it will be carbonized in the first operation. The roof was designed to lead smoke there and provide for a smoking and/or drying room, but was not completed during the consultancy. Wood vinegar was also collected.

(2) Flat furnace (Kiln)

This is a simple device to carbonize residues, but requiring a skill to operate well. This model is used in Japan for charcoal making from sawdust, tree barks and other fine materials. As it is important to utilize sawdust, nutshells and barks in Kenya, a furnace of the smallest type was designed and constructed. The size is 1.5 m X 2.5 m, wall thickness 30 cm, two smoke outlets at the bottom and a square chimney of 6 m high (this is a minimum required). The point is to make a strong flow for carbonization to be controlled by a damper. Although it was not possible to operate it during the consultancy, advice as to how to operate, ignite and

extinguish the kiln and how to handle the products was offered. Elements for quality assessment are ash, volatile matters and moisture.

Operation:

To prevent raw materials to stick to the bottom, small logs are laid on the floor roughly. Barks and fine wooden residues are then laid up to 10-30 cm thick. Sawdusts are laid up to 5-10 cm thick on top of both and whole materials are ignited from the opening with waste paper or kerosine. When smoke goes through the ducts on the floor and comes out from the chimney like white vapour, it is a sign that carbonization is going on well. When the smoke is bluish or transparent, it is a sign that ashes are being produced or the materials are just burning. To observe the colour of the smoke is, therefore, important to see the process of the carbonization. After a week or ten days of operation, a layer of carbides, 50-60 cm, will be obtained. After uncarbonized materials are taken out by a rake, the carbides are extinguished with water. Moisture content of the final produce should be about 20%. Carbonization temperature of this method is 400-500°C.

It could be emphasised again that, Kenya being an agriculture based country, utilization of residues such as bean hulls, coffee and rice husks, fruit nutshells, sugarcane, maize stakes, pineapple hulls and woody matters of sawmills carpentries is essential. If these are carbonized and make into charcoal briquettes, the current pressure on the forests can greatly be reduced.

(c) Quality Assessment of Charcoal and Bi-Products:

As noted earlier, the Karura National Research Centre lacks analytical research equipment necessary for detailed assessment of the quality of charcoal and bi-products as desired. However, use

of a charcoal kiln thermometer, a charcoal refining metre, a specific gravity metre (for wood vinegar) and a pencil hardness measuring guide (H, HB, B etc.m., for measuring hardness of charcoal) was instructed and practised.

Research institution and facilities related to wood energy should be strengthened and improved in general, but the following equipment items would be provided as soon as possible:

(i) Items for Industrial Analysis of Charcoal:

- Two electric furnaces with temperature control (normal temperature 1,000°C)
- Two to four platinum crucible furnaces (to measure volatile matters)
- Ten instruments ("boat"s) to measure ash content and an electric furnace (normal temperature 800°C)

(ii) Items for Basic Research Including those of Charcoal Quality and Carbonization Rate:

- A set of items for dry distillation
- A set of items for distillation of wood vinegar
- A set for wood gas analysis
- A charcoal briquette testing equipment
- A crusher and a churner for experiments
- Six automatic thermometers (1 - 1,200°C)
- A desiccator (moisture tester)
- Cameras
- Microscopes
- A viscosity metre (for binders of briquettes)
- Chemicals
- Glassware

(d) Carbonization Rates and Charcoal Quality of Selected Tree Species:

Dominant raw materials in Kenya for charcoal are Acacia spp. and Eucalyptus spp., but are different by regions. It was, therefore, advised to carry out trials on carbonization, quality test, like temperature measurements, kiln operations and utilization of smoke exhaust by using several tree species and the different types of kilns constructed during the consultancy. An aim of the trials is to develop guidelines on charcoal making by separative regions. Result of the trials would be recorded on the form "Charcoal Making Record" (see annex 5). In this connection methods to measure carbonization rate, volume weight, hardness, refined degree, construction rate, calorific value, ash content and so on were instructed.

General Points of Importance are as follows:

(i) Quality of charcoal is affected by moisture content of materials used, meaning that a season for harvesting is to be selected with care.

(ii) The kiln constructed have different characteristics which will give different qualities to the charcoal produced. Use of a kiln should be decided taking the circumstances into consideration.

(iii) The lower the degree of carbonization, the faster the burning speed in use in general. Therefore, charcoal of low carbonization is not suitable for use for a long time e.g. for cooking, but is good for getting heated quickly.

(e) Charcoal Briquettes and Use of Stove:

Briquettes production method and use of binder made from starch were demonstrated at the Karura National Research Centre on 19th and 25th February. It was noted that various materials, grasses and fruits, are locally available for the production of binders, and would be tested for developing economical, effective and easily available binder.

Briquette production was also demonstrated during the charcoal making trial using tree planting holes, In this case, charcoal of twigs which are valueless was used to make briquettes together with the charcoal powder produced by the drum kiln. Use of a briquette (Rentan) stove was shown to the Kitui people who participated (Ref. Fig. 5)

5. Conclusion and Recommendation

(a) The consultancy, though short, achieved most of the expected results in two months according to the carefully planned schedule.

(b) Equipment items brought in (Ref. Annex 3) were selected on the basis of local needs and with a view to future application to the charcoal technology in Kenya. The delivery of items was slightly delayed, but did not cause crucial stoppage of the work.

(c) The Kenyan staff would carry on the work started by the consultant, master the techniques by accumulating research results and try to extend the improved techniques to the nation.

(d) In order to encourage the staff to achieve the above task, the Karura National Research Centre would be provided with better facilities and equipment.

Main People Met

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Mr. B. Chikamai, Chief, Karura National Research Centre
Mr. J.K. Githiomi, Charcoal Research, Karura

Ministry of Environment and National Resources (MENR)

Mr. W.K. Maluki, Principal Planing Offer

Japanese Embassy

Mr. Y. Nishitani, First Secretary

JICA Kenya Office

Mr. K. Kumagishi, Resident Representative
Mr. M. Suemori, Assistant Representative

Social Forestry Training Project (SFTP)

Mr. K. Watanabe, Chief Adviser
Mr. Y. Yanagihara, Expert/Training Leader
Mr. M. Hori, Expert
Mr. T. Niino, Expert
Mr. M. Arai, Expert
Mr. O. Edazawa, Expert
Mr. N. Noda, Expert

Annex 2

Work Diary

Date:	Remark:
Tuesday, 19th January	Departure, Narita (BA 008)
Wednesday, 20th January	Arrival/Departure, London (BA 005)
Thursday, 21st January	Arrival Nairobi Visit JICA Office, Japanese Embassy, Ministry of Environment
Friday, 22nd January	Visit KEFRI (Muguga). Briefing by Chief Advisor (CA)
Monday, 25th January	Discussion on work plan with Mr. Githomi (Accompanied by Mr. Noda, Expert, and Ms. Nakamatsu, Interpreter)
Tuesday, 26th January	Collection of data and kiln construction materials
Wednesday, 27th January	Collection of materials for charcoal briquette binder
Thursday, 28th January	Discussion on work plans and admin. matters with CA
Friday, 29th January	Collection of macadamia nutshells. Visit to JICA Horticulture Development Project
Saturday, 30th January	Exchange of ideas with JICA team
Monday, 1st February	Supervision of drum kiln construction
Tuesday, 2nd February	Supervision Completed
Wednesday, 3rd February	Advice on operation of drum kiln
Thursday, 4th February	Trial of drum kiln. Comparison of Japanese and Kenyan earth mould kilns.
Friday, 5th February	Drum kiln trial completed and results recorded

Date:	Remark:
Saturday, 6th February	Charcoal production survey in Nairobi area
Monday, 8th February	Charcoal production survey in Kitui area an collection of kiln materials
Tuesday, 9th February	Charcoal production survey in Kitui area and collection of kiln materials
Wednesday 10th February	FFPRI portable kiln (shipped from Japan) delivered
Thursday, 11th February	Advice on operation of the above
Friday, 12th February	Visit to Thika. Procure bricks, sand and clay
Saturday, 13th February	Re-arrange work plans, provision of raw materials
Monday, 15th February	Procured a manual mill, tools for kiln construction Sowed vegetable seed in control as well as charcoal powder plots
Tuesday, 16th February	Advice on operation of FFPRI kiln. Started ignition at 1600 hrs.
Wednesday, 17th February	Carbonization completed at 0600 hrs. successfully. Bricks purchased and transported
Thursday, 18th February	All large and small bricks obtained Remaining equipment items from Japan arrived
Friday, 19th February	Advice on how to make briquettes and starch binder
Saturday, 20th February	Study of information collected
Monday, 22nd February	NATIONAL HOLIDAY (Election)
Tuesday, 23rd February	Advise on how to collect and assess quality of wood vinegar
Wednesday, 24th February	Supervision on use and refining of wood vinegar

Date:	Remark:
Thursday, 25th February	Advise on briquette production and use of binder
Friday, 26th February	Foundation of brick kiln completed and drainage installed
Saturday, 27th February	Study of collected information
Monday, 29th February	Construction of brick kiln wall
Tuesday, 1st March	Construction of brick kiln wall Prepared materials for instruction at Kitui
Wednesday, 2nd March	Instruction on operation of drum kiln and Japanese type earth mound kiln at Kitui
Thursday, 3rd March	Instruction on carbonization by open hole method and wood vinegar collection at Kitui
Friday, 4th March	Instruction on briquette production. Kitui people also participated
Saturday, 5th March	Arranged information
Monday, 7th March	Brick kiln walls completed. Construction of flat furnace kiln started
Tuesday, 8th March	Preparation of materials for ceiling of brick kiln
Wednesday, 9th March	Supervision of construction of brick kiln ceiling
Thursday, 10th March	Brick kiln ceiling and flat kiln smoke outlet completed
Friday, 11th March	Brick kiln chimney finished and whole kiln completed, Flat kiln wall construction started
Saturday, 12th March	Preparation of report
Monday, 14th March	Reporting at JICA Office. Flat kiln chimney constructed.
Tuesday, 15th March	Reporting at Japanese Embassy. Ignition of brick kiln.

Date:	Remark:
Wednesday, 16th March	Brick kiln operation continued. Flat kiln completed
	Reporting at Karura, KEFRI
Thursday, 17th March	Submission of draft report
Friday, 18th March	Departure, Nairobi (via London, Anchorage - BA 054, BA 005)
Saturday, 19th March	Arrival, Narita

Annex 3

List of Equipment Items Procured for the Consultancy

1.	FFPRI Portable Charcoal Kiln, 1,200 Model (Stainless Steel)	1 set
2.	Charcoal Refining Meter	1
3.	Dial Scale (150 kg)	1
4.	Digital Thermometer (small, for experiment)	1
5.	Thermometre (glass) 100	3
	200	3
	360	3
6.	Floating Gravity Metre (for wood vinegar)	5
7.	Briquette (Rentan type) Pressing Machine	2
8.	Briquette (Stick type) Pressing Machine	2
9.	Briquette (Rentan No. 3) Stove	2
10.	Charcoal Stove	2

Equipment Items Provided for the Consultancy

Photo 1 FFPRI Portable Kiln 携行機材一式

Photo 2 Other Items

Use of Charcoal by Characteristics

1. **Physical Use**

(a) Use by porosity:
Activated charcoal, water purifier, air cleaner, exhaust absorbent, filter material, fish gathering device, microbe culture material, dew preventing material for housing

(b) Use of abrasion:
Polishing material for lacquer ware, coisinne ware, copperplate, zinc plate, etc.

(c) Use by light absorption
Solar water heater, snow melting, soil temperature raising

(d) Use by Electric Specificity:
Earth for current, electro-micro wave cut off, electrode carbon filament

(e) other uses:
Heat insulation, sand insulation

2. **Chemical Use**

(a) Use by reaction:
Metal refine, ignition material, black gunpowder, chemicals, charcoal gas

(b) Use of Energy:
Domestic fuel for hating and cooking, business use (baking/roasting of foodstuff), powder

(c) Use by inorganic matter:
Fertilizer, mineral supply drug, pottery glaze, ceramic manufacture, dyeing

3. **Use for Hobbies**

Flower arrangement, tea ceremony, ornamental charcoal

Photo 3　Kenyan type Earthmound Kiln

ケニア式焼法

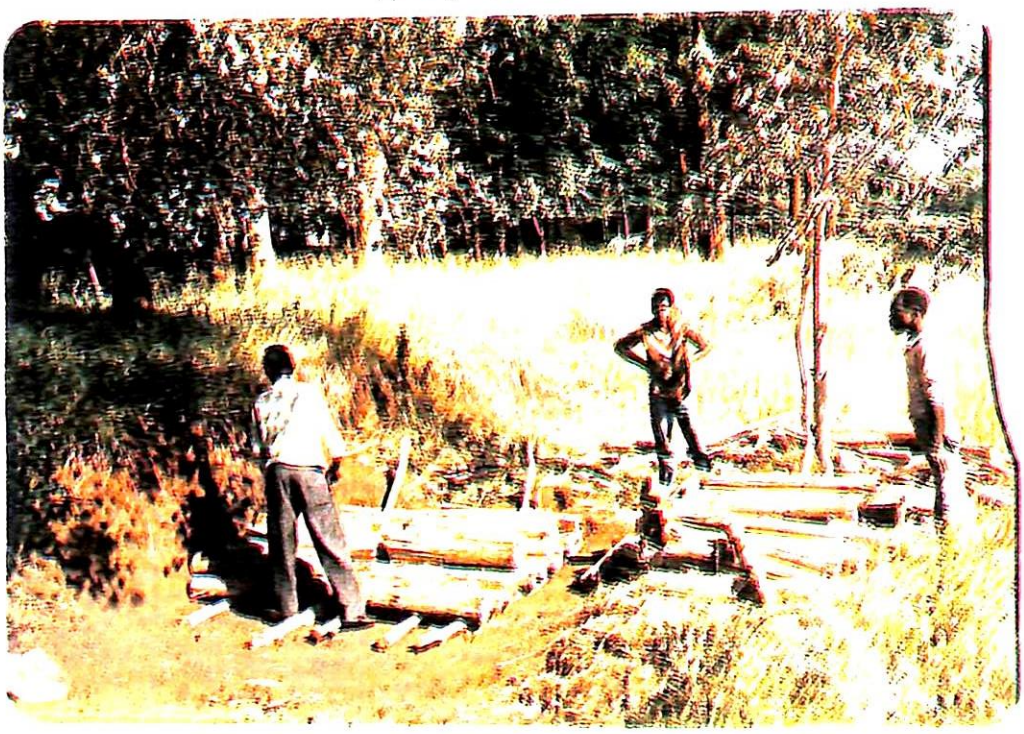


Photo 4　Stacking the Raw Material

炭材の積み方

Figure 1

FIG. 1 DRUMS KILNS

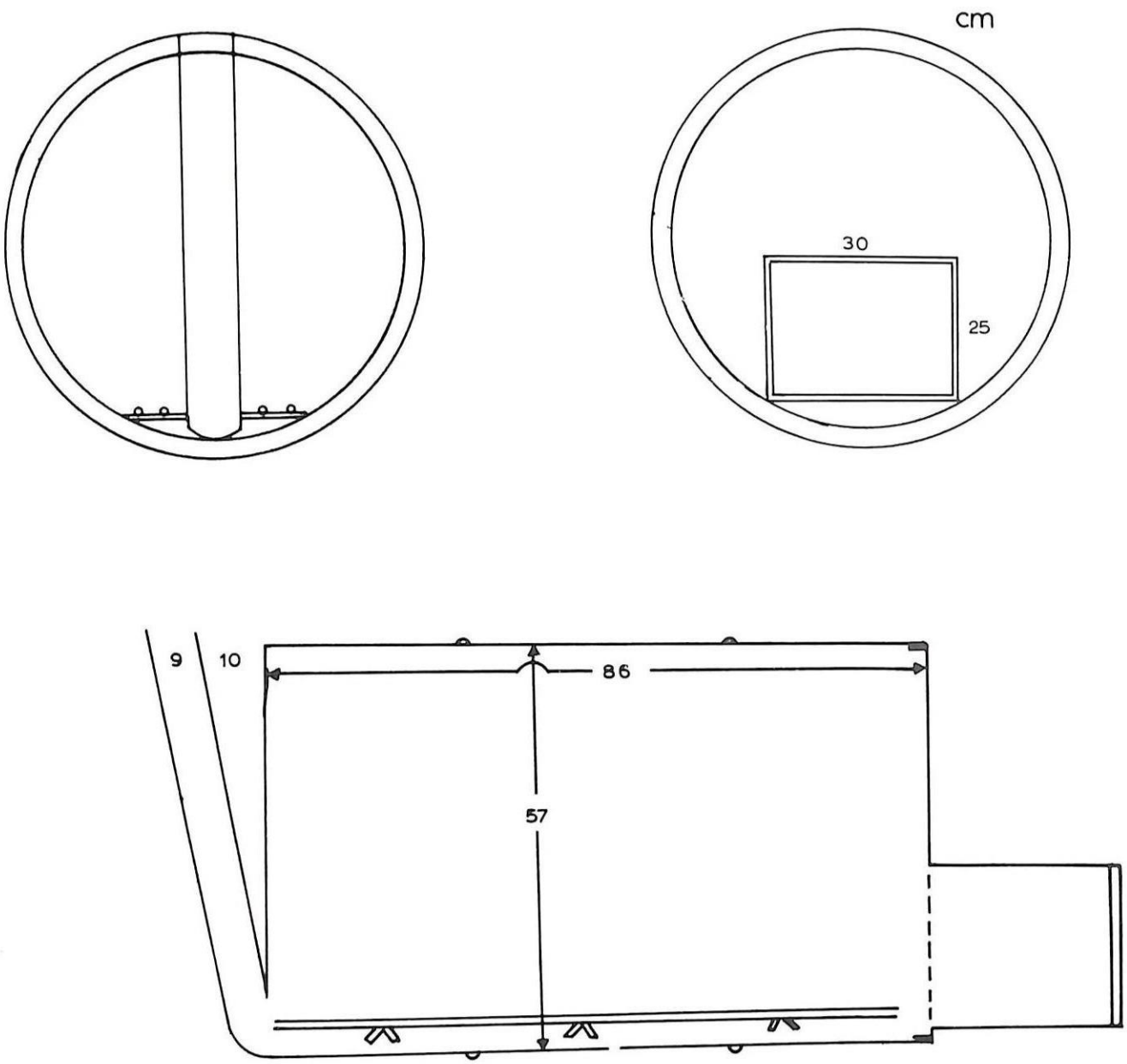


Photo 5　Completed Drum Kiln

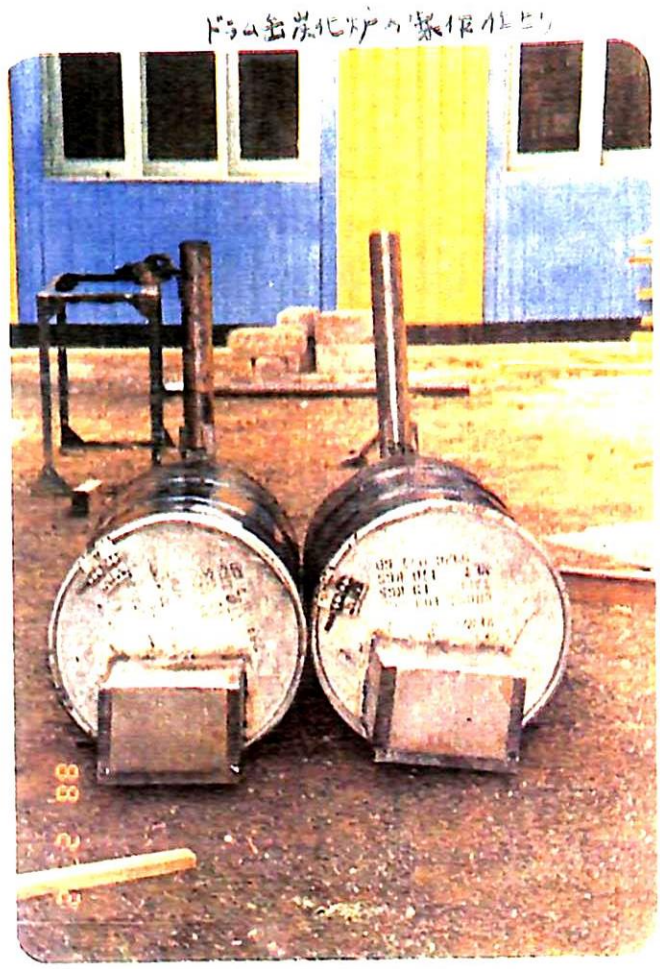


Photo 6　Ignition

Figure 2

FIG. 2. PORTABLE KILN (FFPRI TYPE)

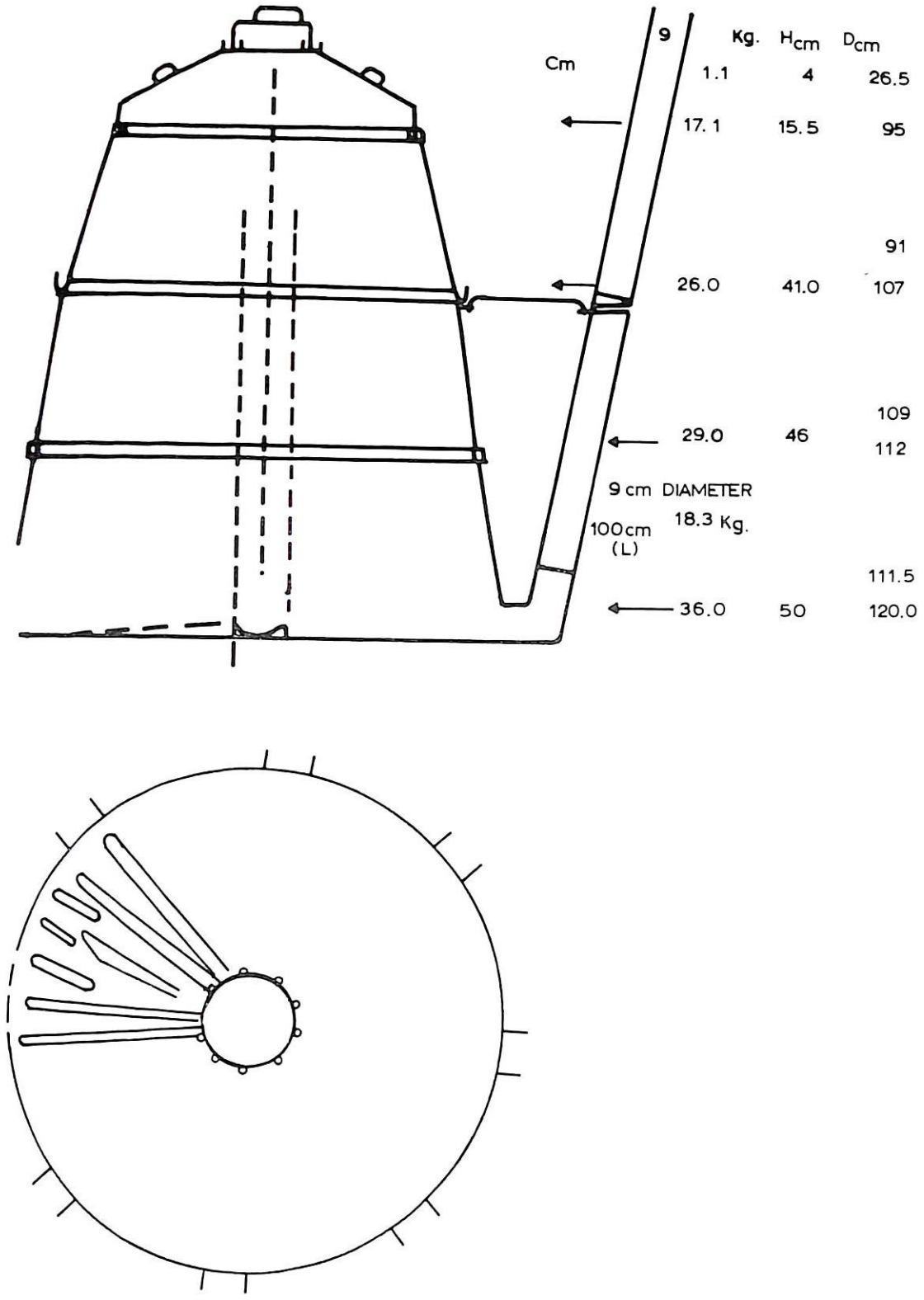


Photo 7 FFPRI Type Portable Kiln being ignited

林試式移動炭化炉 点火中

Photo 8 Taking out produced charcoal (A case of double-column system) 出炭 (2段組の場合)

Figure 3

FIG. 3. BRICK KILN

Cm.

63. 3. 15

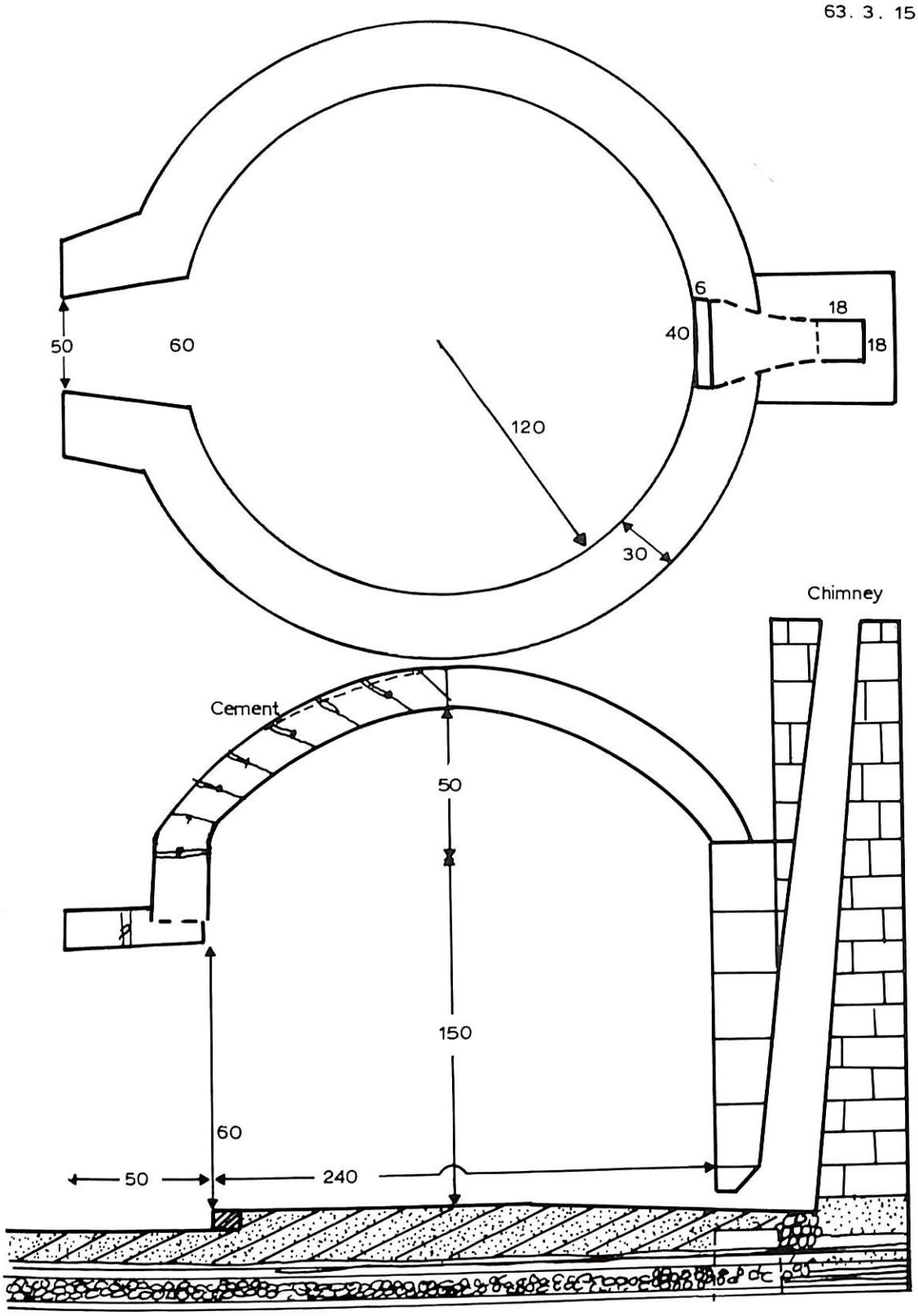


Photo 9 Operation of the foundation of the brick kiln

窯底づくり

Photo 10 Making the ceiling of the brick kiln

天井築窯

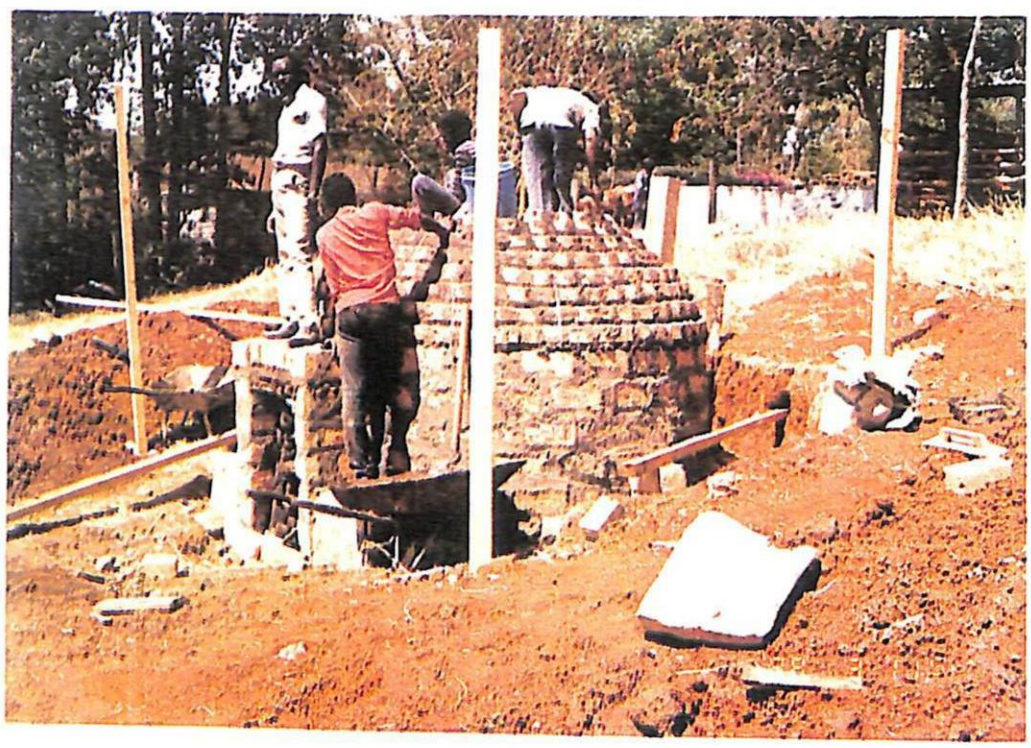


Figure 4 Saw dust Carbonizing kiln

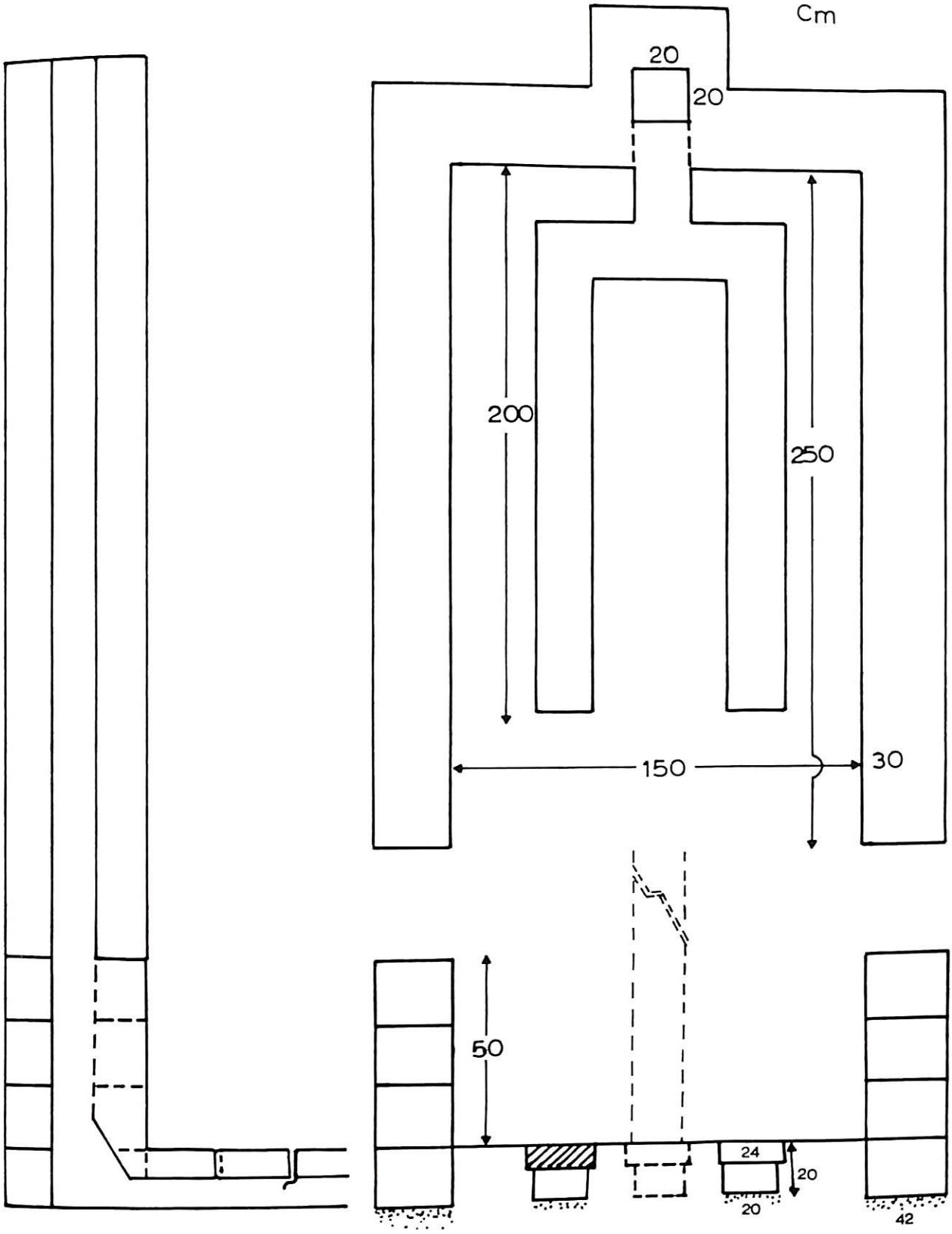


Photo 11 Brick kiln in operation and flat furnace (kiln) being constructed

レンガがま炭化中と平炉

Photo 12 Flat furnace nearly complete

平炉の完成近し

Annex 5

CHARCOAL MAKING RECORD

(No.)

Date:

Trial by (Tick one)

Portable kiln ( )

Drum kiln ( )

Earth mound kiln ( )

Brick kiln ( )

Flat furnace kiln ( )

Foreman's name: _____ No. of Years of Experience _____

Charcoal making: From (date) _____ To (date) _____

Ignited at (time): _____ on (date) _____

Weather: _____

Temperature: _____

Extinguished at (time) _____ on (date): _____

Raw Material (log)

Species: _____ Date of harvest: _____

Moisture content: _____% Weight of logs: _____kg

Diametre of logs: _____ cm _____ cm/Ave. _____ cm

Length of logs: _____ cm Weight of firewood: _____kg

2. Carbonization

Stacking time: _____hrs. _____mins.

Ignition time: _____hrs. _____mins. Maximum temperature

Carbonizing time: _____hrs. _____mins. Inside the kiln

Extinguishing time: _____hrs. _____mins. Top:(ceiling)____°C

Taking out time: _____hrs. _____mins Bottom: _____°C

3. Wood vinegar

Quantity: _____ litre Specific gravity: _____

Colour: of liquid: _____

4. Single log test

	Before	and	After operation
Weight:	_____ g		_____ g
Diametre:	_____ cm		_____ cm
Hardness:			_____
Lustre of cross section:			_____
Bark adhesion:			_____
Crack:			_____
Moisture:			_____

5. Produce

Weight of charcoal:	_____	kg
Recovery rate:	_____	%
Hardness:	_____	
Refining degree:	_____	%
Calorific value:	_____	
Volume weight:	_____	kg

6. Sate of Ash

General situation (_____ cm from the opening):

_____

Production and Marketing of Charcoal Briquette

Carbide=Crushing=Screening=Weighing=Mixing=Kneading=Moulding=Drying=

Various mills	Rotating or vibrating	Scales	Fret mill	Fret mill	Press machines	Natural or artificial

= Inspection = Packing (= Final Product) = Market

Standards	Paper	For barbecue
Special	Plastic	home fuel
1st	Box	industrial fuel
2nd	Bag	smelting
Strength	2kg	water filter
Ash %	5kg	others
Moisture %	10kg	

Briquette making by hand

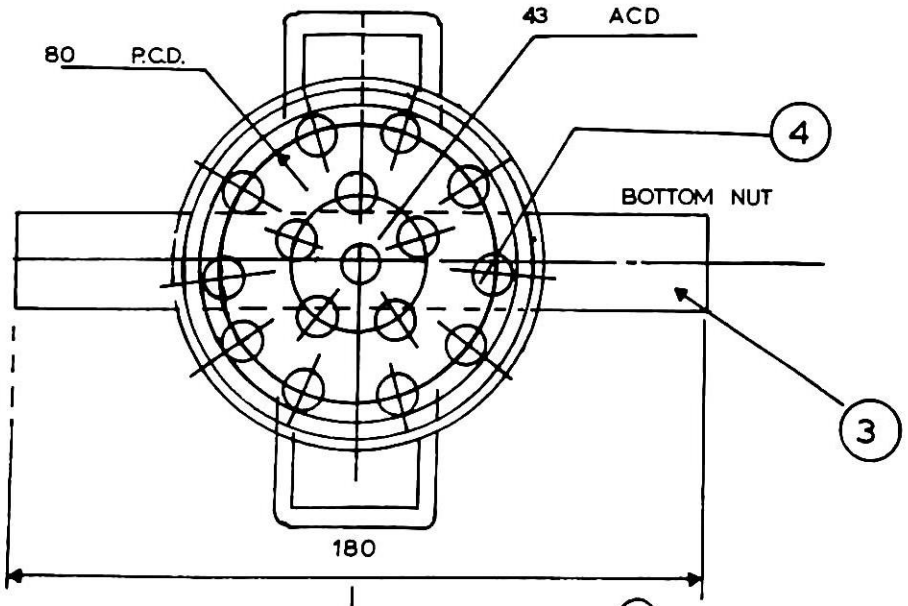
Carbide=Screening=Crushing=Mixing=kneading=Moulding=Drying=Product

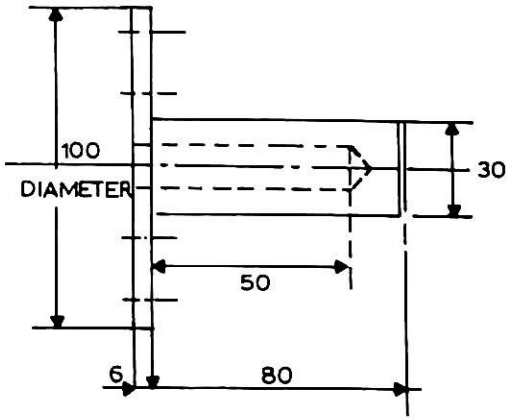
Husks	Sieves to	Hand mill	Soft (3)	Starch	"Renatan"	Natural Inspect
nutshells residues	exclude materials > 3mm	to crush materials > 3mm	& hard(1) ideal	binder 3-5% of all raw material	or stick type	ash moisture and strength

Standard Distribution
Coarse 2
Medium 3
Fine 5

N.B. When using also inspect smell, ash, colour and durability

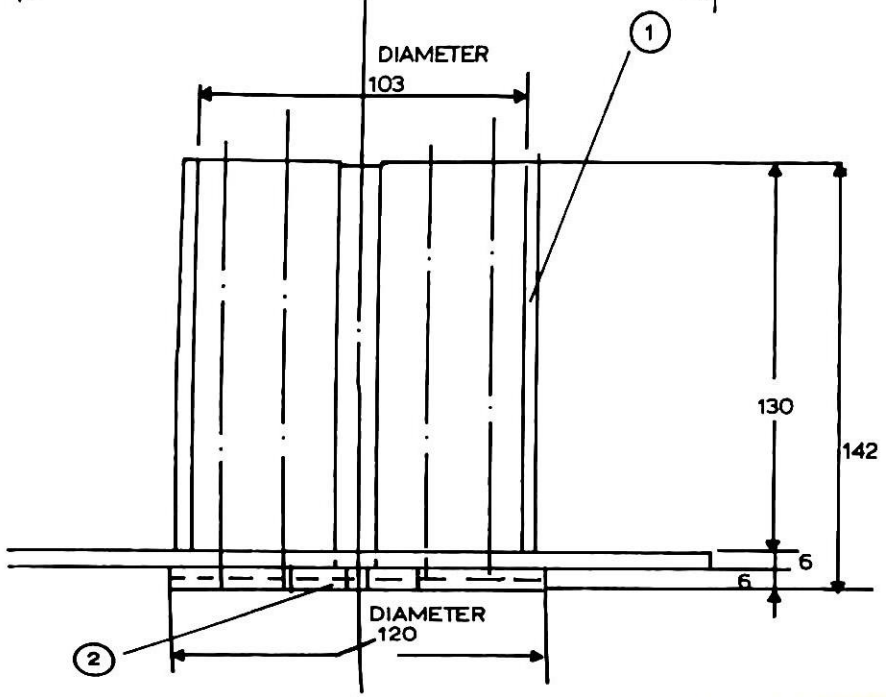
FIG. 5. MANNUAL BRIQUETTE PRESSING MACHINE





PRESS

5



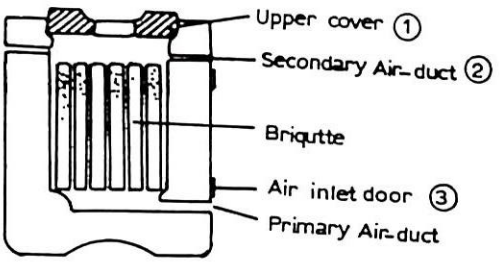
PRODUCTION COST ¥ 60,000 x 2

Number of parts

part no.	parts	material	Weight	
5	press	5541		1
4	bar	505 304		11
3	detachable board	5541		1
2	base board	5541		1
1	main body	505 304		1

How to use Briquette (Rentan) Stove
Read carefully before using

This is the stove you can ignite from upside



STOVE

(1) Ascertain that secondary airduct - 2 - is not clogged before using

(2) Be sure to put upper cover - 1 -

(3) Adjust heat and duration by air inlet door - 3 -

(a) Ignite outside the room, put upper cover - 1 -, fully open air inlet door and keep in an airy place for about an hour. Then, bring it into the room.

(b) Place upper with its protruded part upside, so that a space can be made when a pan, etc., is put on.

(c) While using, do not make the room-air-tight to let fresh air inside.

(d) When used for a long time with air inlet door - 3 - closed, emission of carbon monoxide increases. Therefore, make sure to have enough ventilation.

(e) Before sleeping, take stove outside the room.

(f) Bottom of stove becomes hot. Do not put it directly on inflammable materials such as mats or carpets.

(g) Stove should be checked regularly. If upper cover(1) and the stove body are heavily damaged, do not use it any more.

Photos 13, 14
Charcoal making at Kitui
Earthmound Kiln (Japanese type)

キトイ地区での製炭技術指導
伏焼法（日本式）

Photo 15 Drum kiln

Stacking of raw material

ドラム缶炭化炉 詰込完了

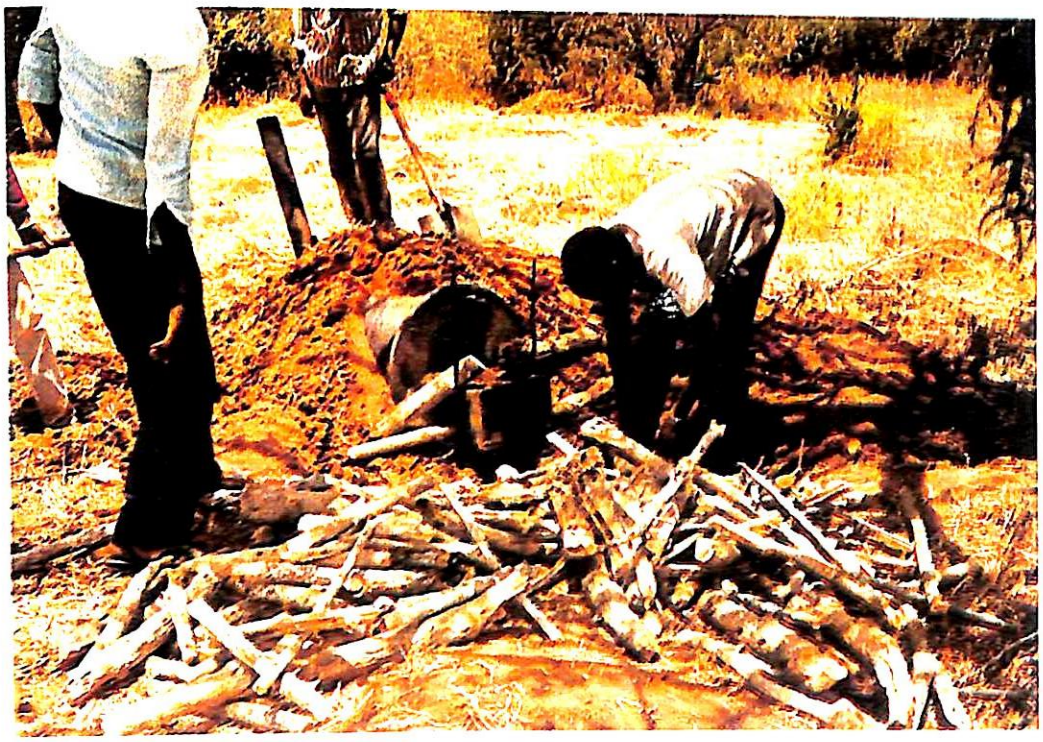


Photo 16 Collecting wood vinegar during operation

炭化中 木酢液採取

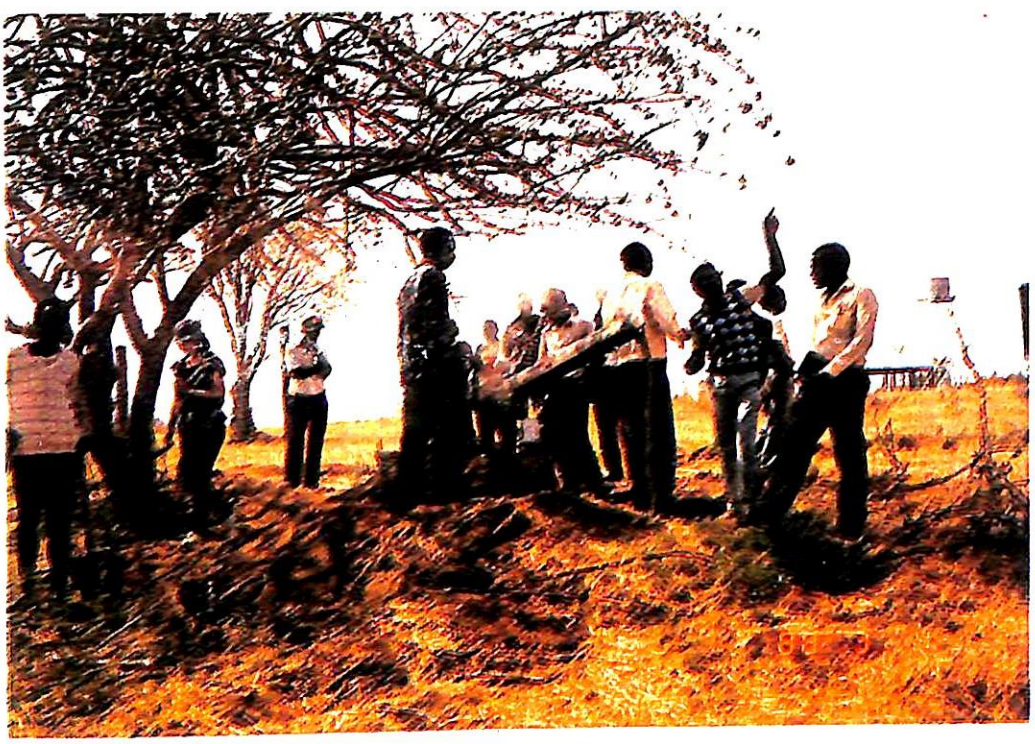


Photo 17 Kitui: Charcoal making by tree planting holes

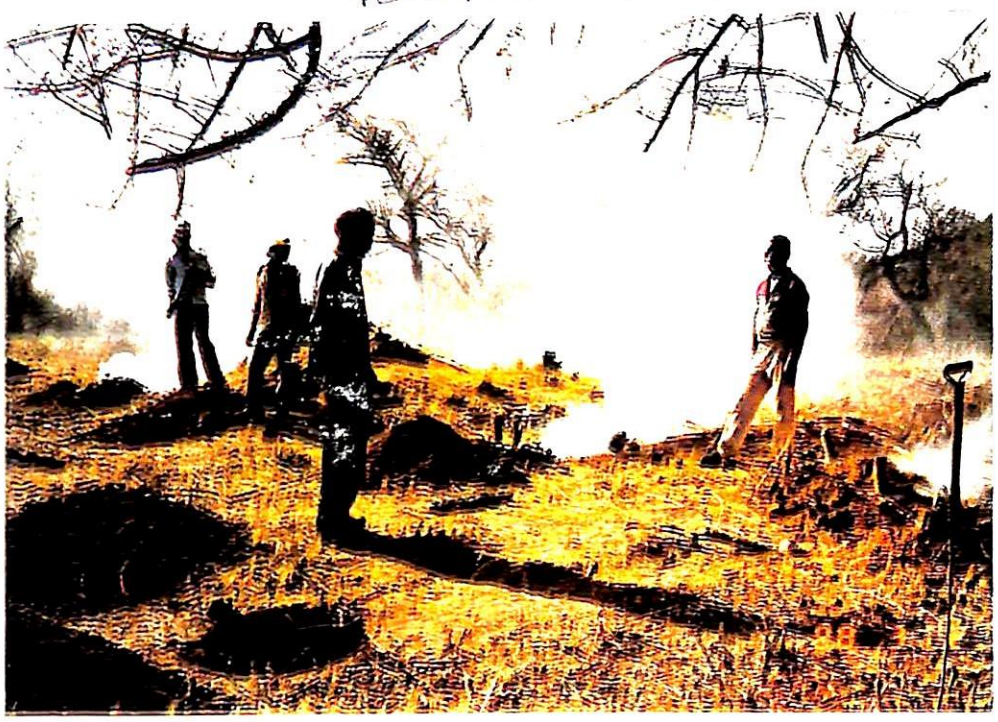


Photo 18 - ditto -
Taking out charcoal the following morning.

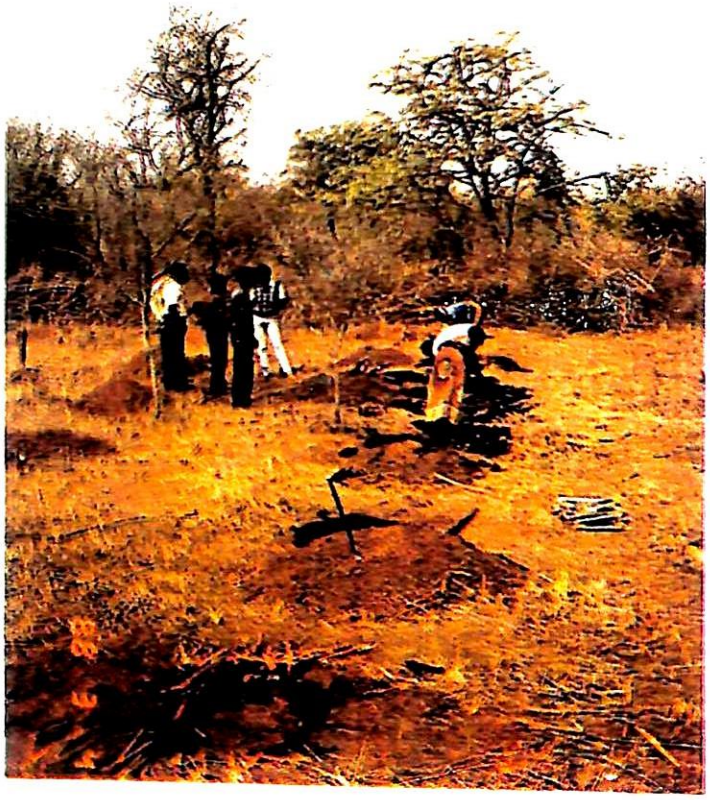


Photo 19 Experiment on the use of charcoal powder for soil improvement

木炭施用試験

Photo 20 Charcoal and Red Soil Contrast Burnt soil and charcoal

(赤土) (対照区) (焼土と木炭区)

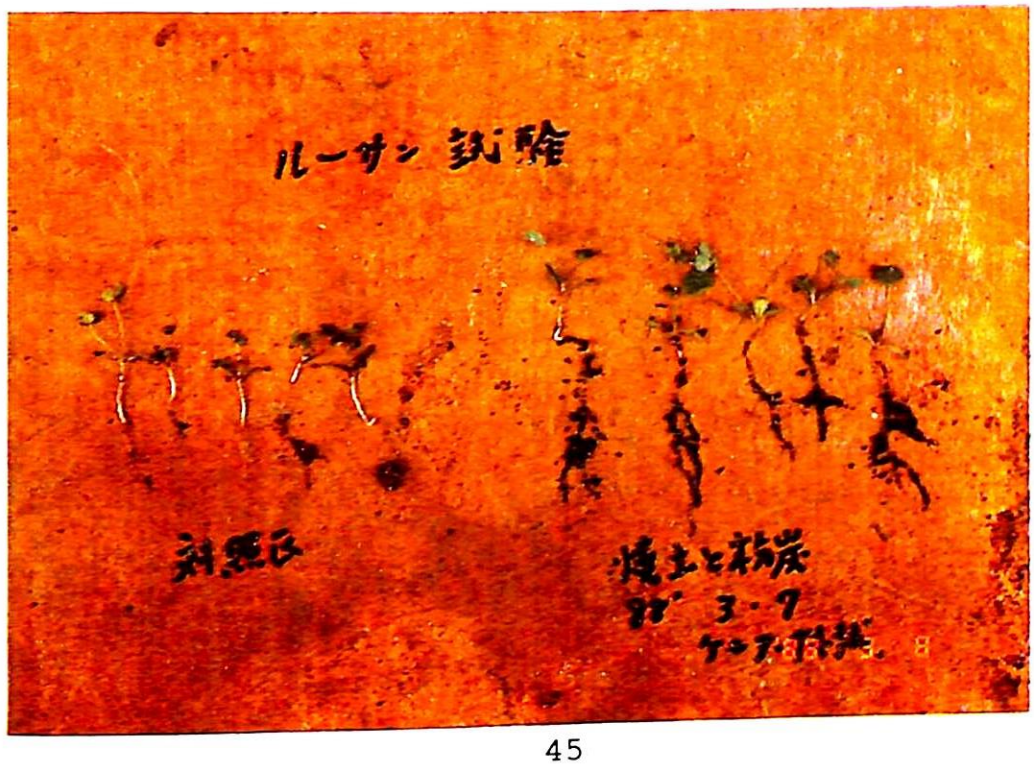


Photo 21 Location of Karura and Kitui (Main areas of consultants' activities)

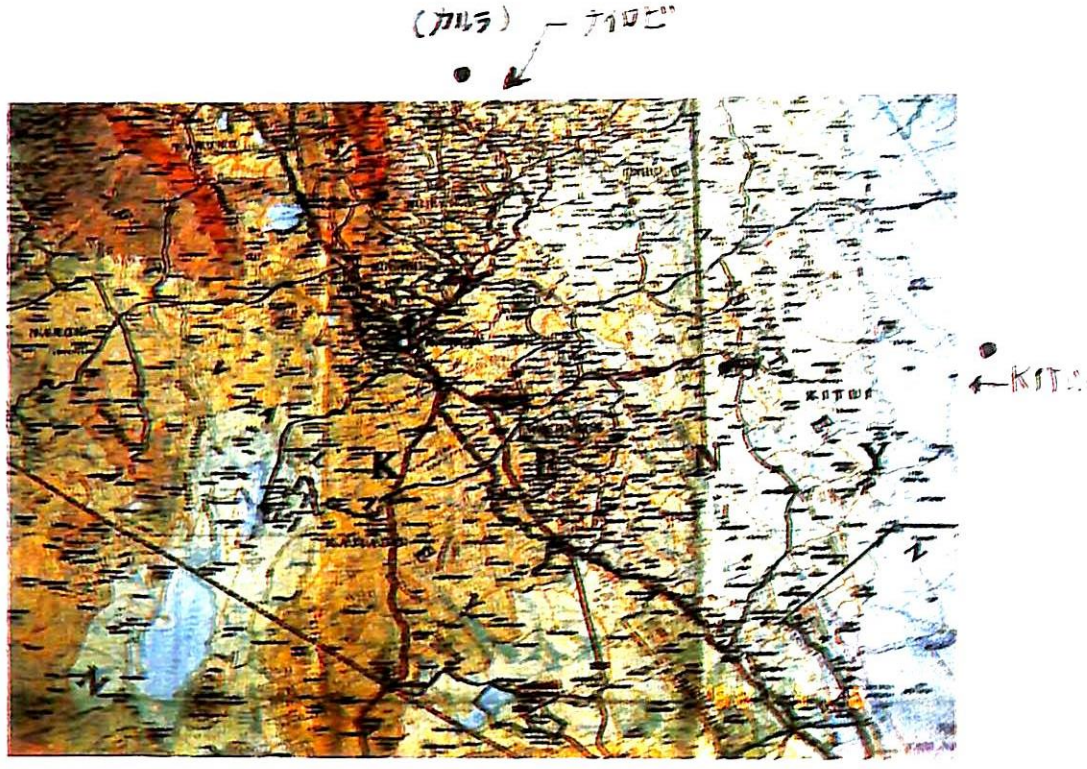


Photo 22 JICA Horticulture Development Project Macadamia Nuts and Carbonized nut shells

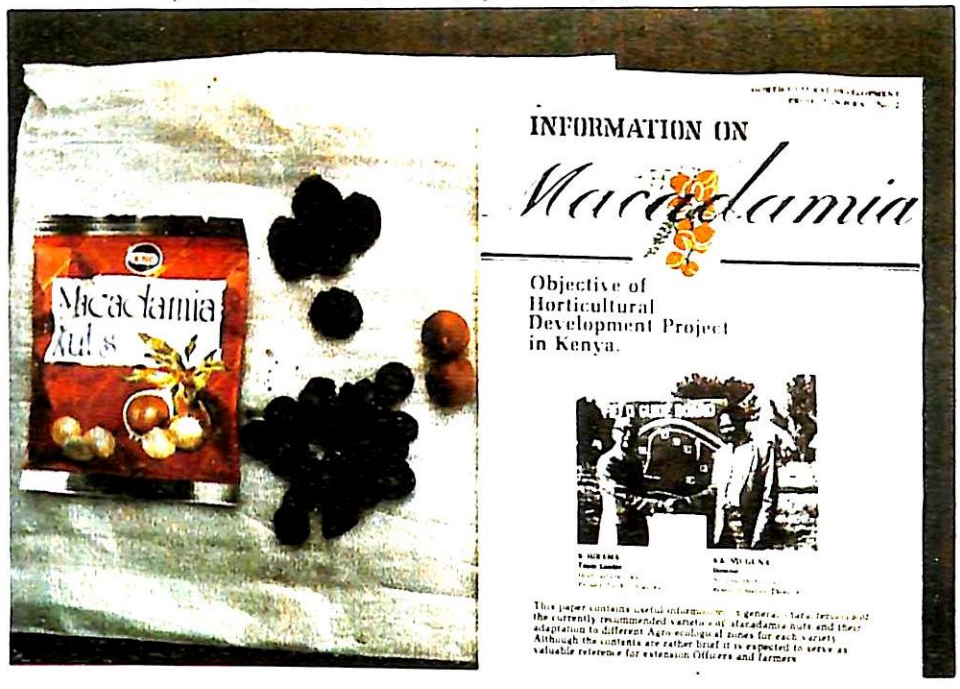
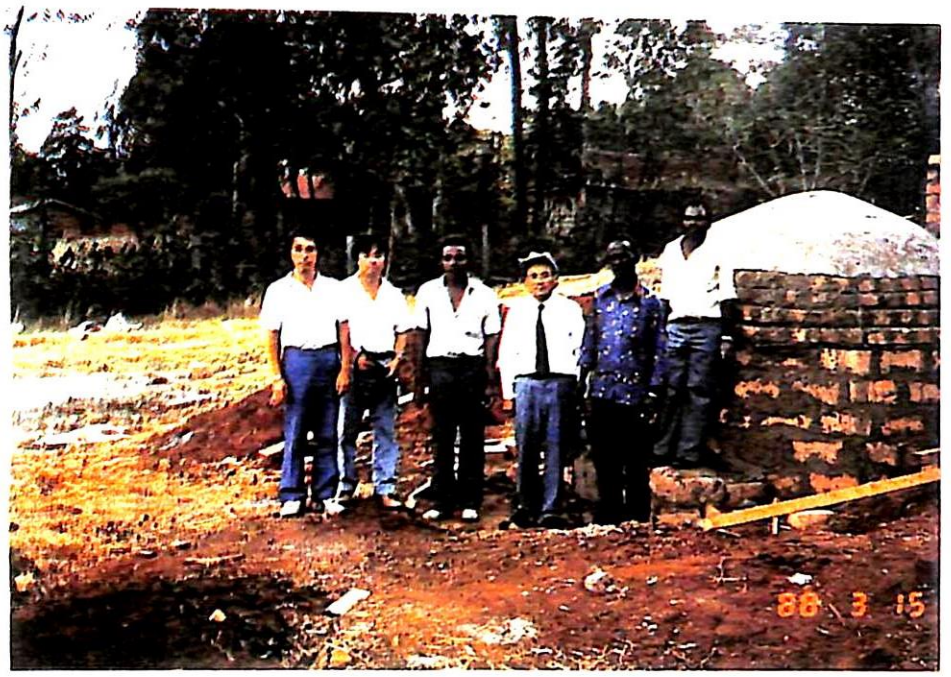


Photo 23 People involved in this consultancy.



From left: Mr. M. Arai, Mr. N. Noda, Mr. J.K. Githiomi
Consultant