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Charcoal Production in Blue Nile Province

Dr. Hassan Osman Abd El Nour
Kamal Satie

Edited by
Gaafar El Faki
and
Matthew S. Gamser

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FORWARD

This report represents SREP's first field research into charcoal production. Much was learned during this research about methods of analyzing this industry. Because of this learning process, the quantitiative data obtained on conversion factors should be treated as an initial estimate of the state of the industry, not as a final statement on this subject.

SREP is undertaking a follow-up study on charcoal conversion factors to check the findings here in. The report on this second study is expected in June 1985.

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EXECUTIVE SUMMARY

The Sudan Renewable Energy Project, in cooperation with the Khartoum Polytechnic, Forests Administration, and the FAO Fuelwood Development for Energy in Sudan Project, studied the charcoal production industry in the Blue Nile Province from January through June 1984. Work began with a qualitative survey to ascertain the general nature and location of the production system. A more quantitative study of the wood-to-charcoal conversion process and the resource base in some 41 selected production sites followed.

Although charcoal is made in earth kilns in Sudan, it is by no means produced by "primitive" methods. The charcoal production system in the Blue Nile Province, the principal source of this vital resource for the Central Region and Khartoum, is a highly developed network of entrepreneurs, agents and workers that achieve high efficiencies in wood-to-charcoal conversion.

Charcoal in Blue Nile Province is produced in a private sector that has a well established division of labour and responsibility. About 25 entrepreneurs employ 50-100 workers and 1-2 agents each in their operations. A production operation entails labour recruitment, mess provisioning, water supply, and tool repair in addition to technical supervision and equipment supply.

About 80 per cent of the charcoal burners come from Western Sudan. Most have years of experience and perhaps a family tradition in producing charcoal. They are methodical in their work, with wood stacking and kiln loading, as well as carbonization which follows a strict pattern.

The typical charcoal kiln ("Simbiryia") is cone or pyramid shaped. It is formed by stacking wood billets outwards from a central tripod. The largest billets are put in the centre, and the smallest on the outside of the cone. Drying is precisely timed to optimize carbonization and avoid insect damage to the wood resource.

A tunnel is left heading away from the prevailing wind. The kiln is covered with grass and then with fine soil that sometimes has to be brought in by lorry.

Carbonization takes 4 to 14 days, depending on kiln size. All but one of the kilns studied produced over 100 sacks, with the largest yielding 817 sacks (almost 32 tonnes) of charcoal.

This was the first attempt in Sudan to take detailed measurements within the charcoal production sector. To the maximum extent possible, specific weights and volumes were recorded. The calculation of certain parameters in the production process required estimations, and the methods used for these and their reliability are discussed herein. Lessons learned from this first investigation will allow more accurate and objective measures to be obtained from future studies.

Notwithstanding this qualification, the results of this study differed so profoundly from previous figures that a major reassessment of the charcoal production sector is called for. The organization and, in particular, the efficiency of this industry is far higher than that pictured in previous analyses.

The fuelwood-charcoal conversion process as measured in this study required less than half the amount of fuelwood previously reported to produce one tonne of charcoal. The average charcoal sack measured contained roughly 20 per cent less charcoal than its official content requirement.

Charcoal Production Statistics

	(Previous Studies)	(Inis Study)
1. Cubic meters fuelwood (stacked) required per tonne of charcoal produced	17-18[1]	6-9
2. Weight of charcoal sack (kg)	45-50[2]	35-43
3. Mean annual increment (cubic meters/feddan), *Acacia seyal*	0.5[3]	1

[1]Jackson, 1960; Sanai, 1974; Foggie, 1965; NEA, 1982; Bayoumi, 1983; World Bank, 1983.

[2]Foggie, 1965.

[3]Sudan Forests Administration estimate used for royalty determinations, and Foggie, 1965.

The study estimated the mean annual increment for Acacia seyal at twice the rate used by the Forestry Department in assessing royalty payments. These calculations need to be checked in more detailed surveys, but they suggest a need to examine the present royalty system to insure that payments reflect true stand value and costs of reafforestation.

Charcoal production is a major industry in Sudan, worth over 15 million pounds per season at present in the Blue Nile Province alone, and expanding each year with growing consumer demand. Yet it is very little understood, and no planning has been made for the future of the fuelwood resource on which it depends. The smoothly running system of today could soon come to a halt if new fuelwood supplies are not developed.

INTRODUCTION

The Blue Nile Province:

Sudan has a population of 21.6 million persons. Twenty per cent of the population is urban, 69% is rural and 11% is nomadic. Of the total population, 8.7% reside in the Three Towns making up the capital (Khartoum, Khartoum North and Omdurman). The total population grows at an average of 2.8% per year. The country is administratively divided into 18 provinces which are grouped into eight regions besides the capital.

A third of the total population resides in the urbanized fuelwood deficient provinces of Gezira, White Nile, Khartoum, Red Sea, Nile and Northern. Their total fuelwood consumption in 1980 was 20,187,000 m^3 (30% of the country's total), and their charcoal consumption accounts for 16,416,000 m^3 (37% of the country's total). The wide area from which they draw their fuelwood (referred to by Foggie, 1976) extends from Gedaref in Kassala, across the Blue Nile, White Nile and N. Kordofan provinces. Forests in this area are being depleted and the distance of haul is increasing.

The Blue Nile Province (BNP), with administrative Headquarters at Damazine, is one of the three provinces making up the Central Region, the other two being Gezira and White Nile. It is the main source of forest products, particularly fuelwood and charcoal, for the Khartoum and Gezira areas.

BNP has a population of 1.06 million persons and an area of 63000 square kilo meters.

It is bordered on the north by the Gezira Province, on the east by Kassala Province and the Ethiopian border, on the south by Upper Nile and on the west by White Nile Province.

Except for the Ingessina Hills in the south east and a few inselbergs, the terrain in most of the province is flat, gently sloping north and north east. The most salient feature in the province is the Blue Nile and its tributary, the Dinder River.

In the flat uniform plains making up the greater part of the province, the soils are dark cracking clays (cotton soils). These appear to be alluvial in origin, from soils transported by the Blue and White Niles, but some may have been formed in situ from basalt rocks. Those soils are alkaline (pH 9) and have a high clay content (60%). On drying, these soils shrink considerably and a network of wide and deep cracks are formed. At the onset of the rains, water penetrates the soils through these cracks which then close up so that the soil, when moist, is practically impermeable. On and around the rocky hills, the soils are of clay formed in situ together with boulders. Along the Blue Nile and its tributaries, the soils are deep, alluvial sandy loams and silt. Rainfall, which mostly occurs between July and October, varies from 300 mm per annum in the north to 800 mm in the south.

Ecologically, the province falls within the woodland savannah with three distinct vegetation associations:

i) Acacia mellifera thornland on dark cracking clays alternating with grass areas (rainfall 400-570 mm). Associated with the dominant A. mellifera are

Cadaba sp., Boscia seneglensis, B. aegyptiaca and A. seyal only on water receiving sites.

ii) Acacia seyal/Balanites Savanah alternating with grass area (rainfall 570 mm). Associated with A. seyal and B. aegyptiaca are A. senegal and A. campylacantha.

iii) Anogeissus - Combretum hartmannianum Savannah wood land (rainfall 600 mm). Associated with Anogeissus and Combretum are A. seyal and Sterculia setigera

On the clay soils formed in situ, usually associated with small inselbergs such as the Ingessena Hills, an association of A. mellifera, Commiphora africana and Boscia senegalenisis occurs and with it are found Adansonia digitata, Lannea sp., Albizia sericocephala, Dalbergia melanoxylon, Terminalia brownii and Pterocarpus lucens.

Along the Blue Nile and its tributaries Acacia nilotica is dominant. On the soils near the river (azaz), the acacia Savannah is replaced by non-thorny woodland in which Combretum hartmannianum, Sterculia setigera and Adansonia digitata are dominant (Jackson and Harrison, 1958).

The economy of the area is largely agricultural, with some forestry and livestock production. While the province has one of the highest per capita animal populations in Sudan, it is principally a site for extensive agricultural activity. Some 500,000 feddans are under irrigated agriculture mainly for cotton, kenaf and sugar production. Approximately 6.2 million feddans are under rainfed agriculture, mainly for the production of dura (Sorghum) and sesame. Of these, 4.4 million feddans are under licensed mechanized farming (implemented or under implementation), 1.6 million

feddans are under traditional shifting cultivation. These are in the form of individual schemes (1000-1500 feddans), mechanized schemes (10,000-5000,000 feddans) and plots of shifting cultivation (5-100 feddans). Another 1.5 million feddans are earmarked for further agricultural expansion.

The total area of reserved forests and those under various stages of reservation is 1.1 million feddans. Of these, only 32,000 feddans are under management plans and another 35,000 feddans were mechanically seeded with A. senegal. The rest of the area is natural forest.

The province is also rich in wild life and is home for the most important game reserve in the country-the Dinder Game Reserve with a total area of 100,000 feddans.

Charcoal Production Study: Terms of Reference

This study consisted of two consultancies arranged and supported by the Sudan Renewable Energy Project and the FAO Fuelwood Development for Energy in Sudan Project. The principal field investigators during both studies were Dr. Hassan Osman Abd El Nour, consultant, and Mr. Kamal Satie, General Forestry Administration. The first consultancy took place during January-February 1984. It utilized a two-week study tour to the principal charcoal production areas to determine:

1) the locations of existing and potential production operations and their physical relationship to past production sites;
2) the different types of people and positions involved in all aspects of the production process; and

3) incremental yields of the Acacia seyal resource base used for charcoal production.

The findings of this initial field work were used to formulate the methodology for the second consultancy, a more detailed quantitiative assessment of the fuelwood resource base and the wood/charcoal conversion process. Field work for this second consultancy took place between March and June 1984. Analysis focused on:

1) quantity of wood required to produce 1 tonne of charcoal;
2) weight and composition of charcoal sacks; and
3) incremental yields of the Acacia seyal resource base used for charcoal production.

This field work also permitted some revision of the more qualitative data obtained in earlier field work.

It should also be noted that Dr. Hassan Osman had considerable prior experience in charcoal production activities as a result of his years of service as Conservator of Forests for Blue Nile Province.

2. CHARCOAL PRODUCTION - LOCATION, PEOPLE AND METHODS

Locations and Production Levels:

The Forest Policy for 1932 calls for the concentration of all commercial wood cutting inside forest reserves, where regeneration is assured.

Of the 1.1 million feddans of forest reserve in BNP, only the riverain forests with an area of 32000 feddans are covered by management plans. These mostly carry sunt (*Acacia nilotica*) and bamboo (*Oxytenanthera abssinica*) in the Gertland. In accordance with the declared policy, the large size sawlogs go to the government sawmills, the smaller logs are sold to the private sector sawmills, and branchwood is chopped into firewood. The annual production of 50-80 thousand cubic meters of sunt firewood is hauled mainly to the Three Towns. The local bakeries and brick kilns are either content with small branchwood or rely upon dead Talh (*A. seyal*) wood obtained on permit from outside forest reserves.

The forest reserves which carry tree species suitable for charcoal production (the Dahara forests) are not covered by management plans and are left as a stand-by for the future with very few exceptions.

Contrary to the declared forest policy, however, the Blue Nile Forests Administration (FA) wisely concentrates all production of charcoal and industrial wood outside forest reserves. Logging of Heglig (*B. aegyptiaca*) for bentwood chair and other furniture factories and for charcoal production is concentrated in areas destined for agricultural expansion. The idea is to salvage the wood there rather than leave it to be burnt into ashes as land is cleared for cultivation.

To instill this concept, an understanding was reached with the Mechanized Farming Corporation (the government bureau which allots 1000-1500 feddan schemes) that scheme approval is complete only after the FA has certified that the prospective proprietor has paid royalty on the estimated standing tree crop on the plot. Royalty is charged per sack of charcoal at a flat rate of 30 sacks per feddan. An estimate is made if the proprietor disputes the rate. The minimum chargeable royalty is on 5 sacks per feddan. This is not the case, however, with schemes in excess of 1500 feddans which are approved centrally in Khartoum. A lot of charcoal is produced in these schemes, but the proprietor is not obliged to wait for salvage operations or pay royalty.

The parties involved in rainfed agricultural expansion in BRP include the World Bank, the Sudanese Agricultural Bank, the Mechanized Farming Corporation, the Investment Bureau and proprietors. So far, none of the involved parties have observed measures to sustain perpetual land productivity. With the exception of a very few, no proprietor has adopted a tree fallow system and none has preserved any tree belts to act as wind breaks or as mother trees to seed the particular holding if ever abandoned.

The negative consequences of these practices are bound to be felt, and soon. Land fertility will decrease, as has happened in Ghadambalia in Kassala, and Dali in Blue Nile Province. The resultant gully erosion is likely to lead to siltation of the Damazine Dam Basin. This would affect the volume of irrigation water and further aggravate the energy crisis by impairing hydropower generation.

The clearfelling process has also curtailed the

amount of land suitable for pasture. This has already led to conflicts between animal herders and farmers.

Throughout most of the past two decades, charcoal production in BNP came from the sites detailed in Tables 1, 2 and 3.

Table 1: Charcoal Sources in the Blue Nile Province

Portion of Total Annual Output	Site/ Uses
65%	Areas earmarked for imminent or future agricultural expansion in the form of macro rainfed schemes. These are individual, company or multi-national holdings approved centrally (from Khartoum) by the Investment Bureau (e.g., Sudanese Saudi, Sudanese Egyptian Integration, etc).
20%	1000/1500 feddans rainfed mechanized farming schemes approved by the Mechanized Farming Corp. at Damazine, mostly for individuals but could be for corporations, firms or institutions.
5%	Rotation areas of irrigated schemes such as B.N. Agricultural Corporation. These areas are left fallow for periods ranging from 5-10 years.
10%	Small hodlings for rainfed traditonal agriculture (shifting cultivation). These used to be 5-10 feddans. Now they may reach up to 500 feddans and are mechanized.

Table 2: Charcoal Production Levels in Blue Nile Province[1]

Year	Total (Charcoal Sacks)
73/74	1,184,228
74/75	1,716,454
75/76	1,846,454
76/77	1,764,368
77/78	1,317,899
78/79	1,218,959
79/80	1,552,000
80/81	2,460,660
81/82	2,337,654
82/83	3,150,966[2]

1. BNFA
2. Estimate

Table 3: Charcoal Production Levels in B.N. Province by Forest circles [1]

YEAR	FOREST CIRCLE, PRODUCTION %					TOTAL %
	Singa % [2]	Damazine %	Dinder % [3]	Sufi %	Other Circles %	
80/81	57	7	30	5	1	100
81/82	51	8	27	12	2	100
82/83	50	10	26	12	2	100

[1]Source: Present study.

[2]The percentages are based on royalties collected. These depend largely on the strategic position of checkpoints, irrespective of the charcoal source. Wad El Hail and Abu Hugar checkpoints on the west bank command all the charcoal hauled from the south and southwest which could include charcoal produced in Damazine circle. The same goes for Karkuj and Kardus on the east bank. Royalties levied there could be for charcoal produced in Damazine or Dinder. The percentages therefore do not necessarily indicate the exact level of production in the particular circle.

[3]Before 80/81 Karkuj checkpoint was administratively part of Dinder circle.

It is likely that by the mid 1990's, existing agricultural schemes and projected schemes will place virtually all the existing charcoal resource base under the plough. Charcoal and other industrial wood will then have to come from forest reserves.

The entire present forest estate in EEP is not sufficient to sustain current charcoal production levels. Half the area of present forest reserves (500,000 feddans) is situated in remote areas (Kurmuk), does not carry tree species suitable for charcoal making, and was not intended for charcoal production. The proportion of the present forest estate which is accessible and potentially carries tree species suitable for charcoal making (500,000 feddans) is not under management plans. Although trees suitable for charcoal making, such as A. seyal, regenerate readily and prolificly inside and outside forest reserves if given the chance, information on their yield per unit area has not been available.

Producers and Production Organization:

Charcoal in Blue Nile Province is produced entirely by the private sector. It is an institutionalized business with well established division of responsibility and work relations.

Approximately 150 producers obtained permits for the current season (1983/84). Seventy-five per cent of them obtained the permits either as part of the process of acquiring a mechanized farming scheme or on behalf of established charcoal production entrepreneurs. In either case, the permit will end up with practicing entrepreneurs. There are roughly 25 "permanent" entrepreneurs (those who have been in the business for 20 years or more). A handful of new entrepreneurs (3-5 years experience) have recently ventured into the business.

For most entrepreneurs, charcoal production is one of several occupations. They are invariably traders, own one or more lorries, and practice some form of agriculture (mechanized and/or pump irrigated orchards).

Entrepreneurs obtain permits and start work immediatel after the onset of the dry season (November-December). The permit fee is LS 100 and covers an area of 500 feddans assumed to produce 15000 sacks.

Entrepreneurs employ agents to act as supervisors and to serve as a link between them and the charcoal burners. The agents are usually experienced, trustworthy former "charcoal burners". The agent is paid a commission of 20-25 Piasters

per bag produced. His responsibilities include recruitment of workers, supervision of operations, running of the provision shop on the site, and bearing of risk for any losses resulting from his conduct of duties. He can be penalized by deduction from his commission for sums of money owed by fleeing or sick workers, for poor quality charcoal produced, and for other disruptions and damages.

Each entrepreneur employs 1 to 3 agents according to business volume. Each agent supervises some 50 workers. Agents and entrepreneurs get together early in the season (October/November). Agreements are written but not necessarily legally documented. Agents are issued with an advance for labour recruitment. Some entrepreneurs have a "semi-permanent" lot of workers in the sense that the same workers are employed each season. The agents travel to the labourers' areas where they pay the travel cost to gathering centres such as Sennar or Damazine. Here lies one of their fragile risk areas. Besides the advance the "charcoal burners" receive at home, they are fed, perhaps clothed, and provided with tools (on loan) until their kilns come into production. The agents therefore have to recruit people they know and trust.

From their side, the agents appoint mess leaders on a commission basis of 2-5 piasters per sack. Messes usually comprise 7-10 men from the same family, village, district or ethnic group. The mess leaders receive and issue rations, repair and sharpen tools, and keep empty sacks and sewing gear.

The greater majority of charcoal workers (some 80 per cent) come from Darfur and Kordofan. The rest are Blue Nile Province locals and people from White Nile. Of the westerners, the Fur are a majority, followed by Zaghawa, Tama

Burgo, Masalit, Kawahla, Buzzam and Shiwaihit. Most of the ones interviewed are 20-50 years of age and have been practicing charcoal production for three or more years. Approximately 50% of the workers interviewed were illiterate. The other 50% have either been to Koranic school or received primary education. According to most entrepreneurs, the "westerners", even if less productive than the locals, are most devoted to this harsh business. Also, because their homelands are distant, they have no social ties to urge their visits to nearby settlements.

There is no particular bias against local Arabs. These are basically nomads or shifting cultivators. They are usually not interested in charcoal making and thus not available. However, the best quality charcoal seen during this research was made by Arabs near Haroon.

The arrival time at the gathering points and start of charcoal production depends on the workers harvest of their crops back at home.

Upon arrival at the gathering points, the mess leaders get in touch with the entrepreneurs. A lorry is usually sent to transport them to the entrepreneur's domicile or centre of activity. There they are supplied on credit with food, domestic utensils and tools. Utensils noted at most messes include cooking pots, metal plates, pails, mugs, teapots and glasses. These are bought communally as part of the mess. Water containers, usually 44 gallon metal drums, are the property of the entrepreneurs. Working tools include light locally made axes, locally made rakes, spades, and hoes.

The workers are then transported to the sites, which are usually marked by Forest Administration representatives. There they start by building their huts from local materials

such as building poles and straw. They also hand hew their own beds and weave them with ropes made from Dom palm fibers.

At some point shortly after the workers' arrival, the agent arrives and sets up camp, usually a hut serving both as shop and living quarters. The shop contains such items as dura (Sorghum) flour, salt, sugar, tea, onions, dried fish, dried beef, edible oil, soap, bleach, torch batteries, dom robes, string, axes, sandals made of old motor car tyres, snuff, cigarettes, and a set of scales.

Each charcoal burner keeps a notebook at the shop where the value of personal effects borrowed by him are entered immediately in his presence. Communal effects such as mess items are entered in the mess leader's book. This double entry arrangement, in charcoal burner's book and the agent's book, is a safeguard for both parties.

Charcoal workers are provided with water free of charge at the rate of 4 gallons/man/day. Entrepreneurs who employ more than 70 workers need to devote a lorry with driver and assistant to providing water for his squad.

Workers are paid a piece rate per bag produced and packed. This varies with locality and entrepreneur and ranges from LS 1.35-1.80 per packed bag.

Production Methods:

Charcoal burners work individually. Each cuts enough wood to fire one kiln at a time. They cooperate on a reciprocal basis in difficult tasks such as the transport of heavy billets and kiln guarding over the first few days.

The tree species preferred by all parties is the Talh (*Acacia seyal*), followed by Kitir (*Acacia mellifera*) and Heglig (*Balanites aegyptiaca*). Some charcoal is produced from Habil (*Combretum hartmannianum*) and Sailek (*Anogeissus leiocarpus*). The former has a high conversion ratio but produces light charcoal and is generally rejected by the entrepreneurs, and the latter is not very common.

Most kilns contain only one species of wood, probably to facilitate even carbonization. Some 80 per cent of the kilns encountered contained pure Talh. However, in the Dinder area, some kilns of pure Heglig and even Siddir (Zizyphus spina-christi) were seen. These woods are very valuable for construction and furniture making, and their use in kilns indicates a serious fuelwood supply problem in this area.

The large trees are either felled by axe or by burning their root collar zone in the fashion preferred for areas destined for mechanized farming. Medium size trees (20-30 cm diameter) are felled by axes about 30-40 cm from ground level. Haskab (A. senegal) and small trees (5 cm diameter) are spared by charcoal producers.

Except for a few central billets which are cut to about 2 meter length, the rest of the wood is cut into 1-1.5 meter billets. Branch wood is utilized down to 2 cm diameter. The billets are left to sun and air dry for a 4 week period determined by many factors:-

1) Entrepreneurs concerned with charcoal quality, especially for storage, do not allow drying for more than 4 weeks.
2) Others prefer the 4 week duration in order to catch the "hot" market especially at the beginning of the season.
3) The short duration serves the purpose of the small entrepreneurs. The shorter the period from the start of work to production the less advance is owed by workers and the greater are the chances for repaying their loans.

Drying periods in excess of 6 weeks are observed for large size kilns which produce 500-1000 bags. These are usually produced at the end of the season. Certain factors may impose drying periods of many months. Examples include land clearance, and sickness or desertion of some workers. In such cases, the wood is left over for the following season.

The conditions of sunshine and wind prevailing in the Sudan induce rapid wood drying. Moisture content determined for specimens collected from various charcoal production stages indicated that, during the dry months (January-May),

freshly felled Talh has a moisture content of around 35%. After drying for a few months this wood had a moisture content of 5-20%. One year of drying had produced Heglig and Talh at equilibrium moisture content of 6-10 %.

Talh, Heglig and Kitir are very susceptible to attack by Brochid borers such as Sinoxylon senegalense and termites. Talh is attacked immediately after felling and small wood can perish within two months.

While the wood is drying, the kiln site and cover grass are being prepared. Sites average 10-15 meters diameter for small and medium kilns and 20-30 meters diameter for large size kilns respectively. Cracks are filled in and compacted. The thoroughness in which this is done has a great bearing on the charcoal recovery and quality. If soil for kiln burial is not available, it has to be brought in by lorry. Transported soil could be fresh or that used for a previous kiln. The entrepreneurs and the workers prefer poorly stocked areas that have good soils to well stocked areas that have no suitable soils for kiln covering.

Wood billets are then transported to kiln sites using wooden stretchers. The charcoal burners are generally very methodical. All the wood is stacked round the kiln site. Twigs are stacked at the bottom followed by medium and large sized billets respectively. In this way sufficient wood to make a kiln is stacked at the site in an arrangement ready for kiln construction.

At this stage the kiln owner may enlist outside help, more frequently on a reciprocal basis but sometimes as paid assistance.

Charcoal burners speak of three distinct kiln shapes and

sizes. The only shape seen around the blue Nile Province is the cone shape which they call "simbiryia" (Abdim stork) type. The other two are the square bottomed or "um kursi" (the one sitting on the chair) and the "Tumsahiia" (the corcodile) shape. These were not seen. Smaller kilns which produce less than 200 sacks are called "kilatoon" (small locomotive). Charcoal burners regard kilns producing 200-500 sacks as medium size, and kilns producing more than 400 sacks as large.

The cone shaped kilns are stacked starting from the centre outwards. A few large billets are stacked as a tripod, filling the space between the legs with dry grass. Larger billets are stacked next followed by medium and then small billets to the outside. An open tunnel is left away from the wind direction, leading to the central haystack inside the tripod. The experienced burners prefer shorter, straighter billets and very close stacking.

The entire shape is draped first in dry grass or straw and then with 10-20 cm of earth. A heap of earth and wooden pegs are always kept as a standby to plug in outlets discovered in the burning process.

A piece of cloth or sacking dipped in diesel is ignited and introduced to the central haystack through the tunnel using a long pole or piece of bamboo. No vent is used. Combustion is through direct draught.

After 15 minutes or so (to make sure that the kiln has "caught"), the tunnel is closed with earth. The kiln is then closely watched for several days, the exact time depending on the size. This is another example of reciprocal cooperation:the owner actually moves his bed close to his kiln.

Complete charring may require from 4 to 14 days depending upon the kiln size. Longer charring times are felt to be better. Well-charred billets remain whole, with charred bark, and produce rustling metallic sounds.

When no more smoke is being emitted, the kiln is gradually opened in concentric circles starting from the outside and moving inwards. Each day, charcoal is withdrawn from a circle cut from the earth covering the kiln surface. Earth covering or other fire extinguishing methods take care of any glowing bits that appear while the charcoal is conditioning.

The cold charcoal is packed progressively. Each burner manually packs his own sacks. He uses a hook hanging from around his neck to keep the sack open. The sacks are then turned over to a lorry operator and his loading squad, hired especially for charcoal transport.

3. CHARCOAL PRODUCTION - QUANTITATIVE ANALYSIS

Field work took place from 15 March to 30 June 1984. Commercial charcoal production at this time was concentrated in 5 areas of Blue Nile Province: Wad El Nail and Haroun on the West Bank of the Blue Nile, Daiwa on the East Bank, Khor AL Agalieen and Dinder River. Some 41 earth kilns at 23 sites were selected for analysis. They were chosen to represent as diverse a population as possible with respect to production site, kiln size, constituent wood, and origins of entrepreneurs and labourers.

Only kilns whose final dimensions could be quantified were chosen. Of these, most were completely stacked and awaiting grass and earth cover. Others were partly stacked, with all their component wood already present at the production site.

The Computation of conversion factors consisted of a combination of measurements and estimations. Kiln height and circumference were measured, and sample wood stacks and charcoal sacks were weighed. Kiln volumes and wood input were then estimated from these figures, and conversion efficiencies calculated. More detail concerning this methodology and the results is presented below.

Potential error in this analysis stemmed primarily from stacked volume: weight content determinations for the fuelwood input. Error sources and their implications for data reliability are discussed below.

Kiln Volume Estimation:

3.2.1 Methodology: Kiln volume was estimated as the volume of a cone of corresponding height and base circumference to those measured. A cone was chosen as the closest geometrical approximation of the actual kiln volume, as wood is stacked in roughly conical fashion radiating outwards from a central point at the top of the kiln.

Estimated volume (V), therefore, was expressed in the following equation

$$V = \frac{C^2}{4\pi} \times \frac{h}{3}$$

where C = measured circumference of base, and h= measured height.

3.2.2 Results: Kilns were divided into 3 groups according to volume.

Small	0-59	Cubic meters
Medium	60-120	Cubic meters
Large	121+	Cubic meters.

The largest kiln measured had a circumference of 63.5 meters, a height of 3.15 meters and an estimated volume of 337 cubic meters.

Kilns varied more in circumference than in height, the latter being limited by log availability. Trees with clear boles that produce logs over 3.5 meters are rare in charcoal production areas. Charcoal burners prepare as many logs as possible in the 2.5-3.0 meter range to form the kiln's central structure, and accommodate the intended volume by

increasing kiln circumference.

Kilns are stacked vertically with the biggest billets at the bottom and the smallest at the top. While charcoal burners do not fill in the spaces between billets with small billets or twigs, they utilize small branches of as little as 2 centimeters in diameter in their kilns. More experienced burners seemed to achieve closer stacking within the general form used by all.

Wood Input Assessment:

Two systems were used to assess the volume and weight of kiln wood input. At sites where all wood had not yet been cut and made ready for carbonization, sample trees were felled, and all their component wood (down to 2 centimeters in diameter) recorded. At sites where wood was all cut and ready for loading, a sample of the prepared stock was taken.

In both cases, the chosen sample was then cut into 1 meter lengths and stacked in firewood trader fashion (all wood in one direction, with the largest billets on the bottom, and the smallest on top) in ½ to 2 cubic meter stacks. The proportions of different sized billets (2cm, 5cm, 10cm, and 20cm diameter) in the stacks were estimated, and billets were measured for length and midpoint diameter. Their volumes were computed (as the volume of a cylinder of similar length and diameter) and the total solid volume of the stack estimated (Table 4). At this stage samples were collected for moisture determination (Table 5).

The sample stacks were then weighed on a flat balance, the total solid volume and weight of wood per kiln was estimated, using the stacked/solid volume and stacked volume/weight ratios derived from estimated kiln sizes, stack volumes, and stack weights.

Table 4. Stacking factors (solid/stacked volume ratios)

Tree species	Stacking factors (Minimum Diameter)				
	2 cm	5 cm	10 cm	20 cm	w.s.f**
Talh-Acacia seyal	0.3490	0.4375	0.4650	0.670	0.528
Heglig-Balanites aegyptiaca	0.4533	0.5050	0.530	0.630	0.559
Habil-Combretum hartmannianum	0.4350	0.450	0.460	0.630	0.517
Layon-Lannea fruticosa	0.270				0.270
Sunt-Acacia nilotica*		0.5150	0.5760	0.660	0.596
Sahab-Anogeissus leiocarpus	0.40				0.400
Mixture (Layon, Heglig, Talh, Habil, Sahab)	0.230				

* The Sunt specimen studied was firewood that was stacked at Wad El Nail Railhead for several years. Firewood produced for or by Forest Administration is chopped down to 2 inches (5 cm) diameter, and is stacked to 1 m length x 1 m width x 1.2 m height. This is to allow for biodeterioration during storage.

** Weighted stacking factor-Stacks were estimated to contain 5,10,50 and 35% billets of 2,5,10 and 20 cm diameter respectively.

Table 5. Species Density

Tree specie	Weight in kg of one stacked c.m. at moisture content			
	Green	15-20	10%	Kilnwood
Talh A. seyal	476.3	448.5	436.5	442.5
Heglig- B. aegyptiaca	548.0	502.0	451.0	131.0
Leyon- L. fruticosa	306.0			
Habil- C. hartmannianum	502.0	468.0		
Sahab- A. Leiocarpus			392.0	
Mixture(Layon, Heglig, Talh, Habil, Sahab)				443.0

On average, some 2.3 stacked cubic meters of wood comprised one tonne. The smallest kiln (25.7 cubic meters) was estimated to contain 11.4 tonnes of wood, while the largest (337 cubic meters) held an estimated 151 tonnes (Table 6).

Table 6. Stacked Volume/Weight Ratios

Kiln	Estimated volume (M^3)	Estimated Weight (tonnes)	V/W
1	38	17	2.2
2	38	17	2.2
3	26	11	2.4
4	97	43	2.3
5	44	19	2.3
6	49	22	2.2
7	58	26	2.2
8	47	21	2.2
9	98	43	2.3
10	72	32	2.3
11	94	42	2.2
12	68	30	2.3
13	118	53	2.2
14	152	68	2.2
15	100	44	2.3
16	123	54	2.3
17	219	99	2.2
18	337	151	2.2
19	55	24	2.2
20	61	27	2.2

continued

Table 6. Contd:

kiln	Estimated volume (M^3)	Estimated Weight (to)	V/W
21	96	43	2.2
22	108	48	2.3
23	188	84	2.2
24	80	34	2.4
25	181	79	2.3
26	109	47	2.3
27	140	61	2.3
28	118	53	2.3
29	46	20	2.2
30	88	39	2.3
31	105	46	2.1
32	75	34	2.3
33	69	30	2.3
34	79	34	2.3
35	31	13	2.4
36	31	13	2.4
37	30	13	2.3

As both kiln size and stacking density figures were based on estimates, the net wood content of each kiln, based on both these figures, is itself an approximation. Researchers attempted to reflect to the maximum extent possible the species and billet size content of each kiln, and weight and volume measurements were carefully checked. Further analysis, in which total wood input to kilns is weighed, would provide a useful check on the reliability of the estimates made in this study (see below for further discussion).

Charcoal Output:

It was planned to count the number of sacks produced from all the kilns, and to take 10 sample sacks from each kiln for weight and composition analysis. In practice this was not possible, as sacks had already been removed from several sites by the time the researchers arrived to record this data.

At 20 sites all sacks from the kilns studied were available for analysis. At 12 other sites the research assistants had kept an accurate count of total sacks produced. At 2 other sites and at the charcoal office in Dumazine, other charcoal sacks were available for analysis. In sum, there was data available on total sacks produced for 33 kilns, and charcoal sacks available for content analysis from 24 sites.

Content analysis consisted of weighing 10 randomly chosen sacks from each site (in one case only 6 sacks remained on site, so all were selected), then emptying half of them and dividing their contents into 3 fractions:

1) pure charcoal;
2) dust, soil and bits;
3) unburnt wood.

Each fraction was weighed and its proportion of the total sack recorded. Some 220 sacks were weighed, and the contents of 118 were analyzed.

Results of these measurements are summarized in Table 7. The mean sack weight was 39 kilograms, significantly lower than the supposedly standard sack weight of 45 kilograms (100 pounds). This discrepancy is in large part due to the changeover from cotton to dura sacks which took place in the charcoal industry between the mid 1960's and mid 1970's. Two Hessian cotton sacks could be retailored to produce 5 charcoal sacks. Dura sacks are narrower and lack the top closing flap of Hessian cotton sacks. Unlike the cotton sacks, they cannot be packed high with charcoal and sealed. The Hessian sacks were able to carry 45 to 56 kilograms, but only 12 of the sacks measured during this study contained more than 45 kilograms (of which 6 were lentil sacks belonging to one entrepreneur).

Table 7. Sack Weight

	Number of Sacks measured	Mean Weight (kg)	Std.Deviation
Wad el Neil			
1) Abd El Rahman El Siddig	20	34.2	2.8
2) Ahmed El Nour	40	40.6	4.1
3) Mohd. El Rizzigi	20	39.3	3.9
4) Sharaf El Din El Beshir	10	37.9	3.9
Harun			
1) Unknown	10	34.2	1.6
2) Ahmed Suleiman	40	34.4	3.2
3) Khamis Idris	10	38.3	2.8
4) Mohammed Omer	10	40.9	2.7
Daiza			
1) Unknown	40	40.4	2.6
2) Rahimtalla	10	41.5	4.0
Damazine			
1) Seized at dept	10	41.1	2.5
TOTAL/Average	220	39.3	4.4

Charcoal quality varied greatly from sack to sack. While the mean content of pure charcoal was 32 kilograms (82 per cent), some sacks had as little as 23 kilograms, and some as much as 37 kilograms.

The large kilns produced sacks with a higher pure charcoal content than smaller kilns (see Table 8 below). However, the sample size was small, and more extensive analysis is needed in this area.

Table 8. Charcoal Quality

Kiln Size	Number of kilns	%Pure Charcoal	Std. Deviation
Small	6	74.9	6.5
Medium	12	80.1	8.3
Large	2	89.8	2.8
TOTAL	20	79	8.4

Wood/Charcoal Conversion:

The total weight of charcoal produced in each kiln was compared to the original kiln volume to obtain a ratio of stacked cubic meters of firewood per tonne of charcoal product.

Table 9. M^3 Wood (Stacked): Tonne Charcoal

Kiln Size	Number	Conversion Ratio	Std. Deviation
Small	12	7.7	2.0
Medium	15	7.4	1.3
Large	6	8.7	1.2
TOTAL	33	7.7	1.6

While the mean conversion ratio for large kilns was somewhat higher than for others, there was little significant difference between kiln sizes when standard deviations were taken into account.

Some 6-9 cubic meters of wood, on average, were required to produce one tonne of charcoal, with no kiln requiring less than 5 or more than 11 cubic meters. This figure substantially differs from the previously used 17-18 cubic meters/tonne, based on the Jackson report of 1960. It also compares very favorably with the 5-5.6 cubic meters of firewood/tonne of charcoal standard of brick kilns (see FAO, 1983). At the mean sack weight of 39 kilograms, 1 cubic meter of fuelwood produces 3.5 sacks of charcoal.

Some variation in kiln performance may be attributable to differences in skill among the entrepreneurs and production teams studied. Well controlled air flow during carbonization and careful unloading of the kilns could have contributed to the differences observed in the table below.

Table 10. Entrepreneur Kiln Performance

Entrepreneur	Number of kilns	Mean conversion Ratio	Std.Deviation
Ali Eisa	2	5.5	0.5
Mohamed El Rizaigi	2	6.2	0.8
Ahmed Balloula	6	6.4	0.7
Mohammed Omer	1	6.5	-
Ahmed Babiker Hago	2	7.7	0.2
Ahmed Suleiman	9	8.0	1.5
Ahmed El Nour	4	8.8	0.8
Khamis Idris	1	8.9	-
Sharaf El Din Beshir	4	9.1	0.9
Abd El Rahman Siddig	2	10.1	1.3
TOTAL/Average	33	7.7	1.6

FAO (1983) states that yields of 1 tonne of charcoal from 4 tonnes of air-dried fuelwood represents good practice. At a mean of 2.3 stacked cubic meters per tonne of fuelwood, all the entrepreneurs achieve this level when standard deviation is taken into account.

Potential Error

Measurements of kiln volume and stacking density described in previous sections are based on certain approximations and interpretations, and hence could deviate from the actual values in each case. Kiln volume was based on the volume of a cone of identical base and height:

$$V = \frac{1}{3} \pi r^2 h$$

Where r is derived from measured kiln base circumference. Larger kilns, however, resemble cones less than smaller, as stacked wood ceases to radiate linearly from an apex. These kilns, it can be argued, become more like a spherical section, whose volume would be expressed as

$$V = \frac{1}{6} h (3r^2 + h^2)$$

Where r again is derived from kiln base circumference.

The volume of the largest kiln is 55 per cent greater if calculated by the latter formula. This would indicate a corresponding increase in the stacked cubic meter/tonne of charcoal output ratio, from 7.7 to 11.9. As this higher figure is still over 70 per cent below the previously accepted average, the potential error does not diminish the significance of the principal findings of this study.

Stacking density was calculated by measurements of sample stacks erected in firewood trader fashion. This is a horizontal cross-hatched technique, while wood in kilns is stacked vertically and is not cross hatched. No comparison of horizontal and vertical stack densities was made, but it is conceivable that the uni-directional, vertical stack could contain up to 20 per cent more wood by weight for a fixed volume.

This discrepancy does not affect the above conversion factor, which is based on volume calculation only. However, it would raise the tonnes of fuelwood/tonnes charcoal ratio from an average of 3.4 to 4.0. The larger figure still represents efficient kiln performance by FAO world standards.

During the next charcoalling season measurements of total wood weight input (including moisture content analysis) and total charcoal output should be performed on a smaller number of kilns, perhaps using the same entrepreneurs. Such measurements would provide an indication of the reliability of the data derived from these approximations.

4. WOOD STOCKING

The field work carried out was concerned with the estimation of two parameters for the A. seyal growing in charcoal producing areas in the Blue Nile today. These parameters are stocking and volume per feddan.

The scope of work was limited and no attempt was made to actually measure current and mean annual increments (CAI & MAI). All figures for CAI and MAI in the following tables were calculated from volume and age estimates. Thus it is not possible on the basis of this work to define a rotation for A. seyal. By definition the rotation of maximum volume production lies at the point in time where CAI and MAI are equal.

Lacking any records as to age or silvicultural treatment of the stands surveyed, the study based its estimates for age gradations on the knowledge of local people, forest guards and foresters in the region.

A. seyal (Talh) forests within the charcoal production zone were classified by age into nine age gradations (see table II). Thirty-four plots of 0.01 hectare (10x10 m) were then randomly laid out in the different age gradations. For each plot measurements of height, basal area and estimates of volume were made and entered in form 3 shown in Appendix 1.

In addition to these plots, another 26 random plotless sweeps were made using a metric spiegel relascope. Tree volumes were estimated directly from readings of the relascope.

Volume estimating for the 34 plots was made through carrying a stem analysis on 40 trees representative of all tree sizes and forms in the different age gradations. Stem analysis as a method entails the chopping down of all stem and branchwood of individual trees into one meter billets. The mid-diameter of each billet is measured and its volume computed. By acting up all billet volumes the actual tree volume is attained.

Once the actual volumes were attained the next step was to equate them with the volume of the corresponding cylinder using Pressler's and Kitamura's dendrometric formulae (see Table11). This will result in the form factor (FF). Since this form factor is based on stem analysis on the bole and central shoot, a modification was necessary to calculate what is referred to as the Charcoal Burner Form Factor (CBF). The basic difference here is to calculate actual volume on the basis of the branching nature of the A. seyal species, on the one hand, and the fact that charcoal burners utilize the whole tree down to twigs of 2 cm diameter.

The results shown in Table 11 can be summarized as follows:

1. The resultant form factor varied between 0.4 and 0.8 with a mean of 0.6, while the charcoal burner form factor varied from 0.5 to 1.8 with a mean of 0.9.

2. The stands measured are naturally regenerated and are subject to maltreatment by man and beast. Those near human settlements are cleared for building poles and fuelwood and are topped off by animal herders for fodder. Reserved forests too do not escape this treatment. There is no way, therefore, of determining how much was removed from these stands in the course of their development. What was measured can cautiously be taken as the main crop.

Table 11. Stocking-cubic meters (stacked) obtained using different methods.

Age class	V=GHF	Stocking per Ha pressler's V=Gx2/3h	cm stacked Kitamura's deckpanel	Actual stocking stacked cm/fed.	M A I cm/fed/annum
-5	8,73			1.37	0.55
6-10	30,05	22.92	45.30	11.36	1.51
11-15	54.50	36.81	54.78	16.11	1.29
16-20	91.66	31.15	66.02	16.86	0.96
21-25	125.79	36.16	40.52	15.75	0.70
26-30	79.31			14.67	0.53
31-35	79.31			13.99	0.43
36-40*	141.66	46.99	48.60	20.91	0.56
+40*	170.17			22.53	0.53

Actual stocking was directly read as cubic meters stacked, outside bark. The three other methods of volume determination gave solid volumes, which were converted to stacked volume by multiplying by a stacking factor (0.349 from table 4).

V = Volume 1 Ha
G = Mean basal area 1 Ha
H = Mean height 1 Ha
F = Mean form factor (should be f)
* Encountered only in Forest Reserves.

3. The early culimination of MAI (6-10 years) is perhaps induced At this stage stocking as high as 700 stems/feddan is not uncommon and very little human interference usually occurs. The crop has not reached a useful state for poles and is still within reach of animals.

4. The progressive decline in M A I with age is perhaps reflective of the maltreatment Talh is subjected to as its age increases and hence its utility.

5. The rise in M A I at the 36-40 age class is reflective of the relative protection afforded by forest reservation. But even there, the progressive decline with age is evident. At 40 years, the M A I dropped to 0.53 c.m. stacked per feddan per annum.

6. The calculated MAI and CAI are expected to intersect (i.e., become equal) between 15 and 25 years.

7. At 20 years the present study estimated an MAI of 1 stacked cubic meters/feddan from natural stands. This is twice the figure quoted by Foggie (1967). Thus a feddan when clear-felled should yield 20 cubic meters. Using 3.54 sacks/cubic meter conversion factor (see Chapter 3) a feddan is expected to yield 70 sacks and not 30 sacks (the figure used by the Blue Nile forest authorities when levying royalties)

8. Based on these estimates and the 1983 production figure of 2.5 million sacks, the total annual area designated for clear felling is around 38,000 feddans.

9. The importance of estimation of volume and stocking parameters of A. seyal in fuelwood planning deem it necessary to carry out a more detailed study to confirm and refine these findings. It is within the context of such findings that any cropping tree/fallow systems should be planned and analysed.

5. Production Costs:

Researchers attempted only to obtain rough data on production costs through interviews with entrepreneurs and agents. Their goal was to identify major cost components, rather than to precisely quantify them.

Entrepreneurs incur a sizeable expenditure before they start production. The business involves considerable risks. Incidents of burners fleeing away with loans, falling sick, dying or just not producing enough, are common.

The entrepreneur first has to obtain a "charcoal burning permit", issued by the FA at circle H.Q. The permit fee is Ls 100 and it is limited to an area of 500 feddans and a quantity of 15,000 charcoal sacks. Any extra quantity produced has to be covered by another permit.

He also has to pay royalty at the rate of Ls 0.250 per sack produced besides any local tax, as is the case when charcoal is produced in areas of micro schemes. However, if charcoal is to be produced in a 1000/1500 feddans scheme, he has to reach an agreement with the proprietor, and one of them has to pay royalty on the estimated standing tree crop. No burning permit or removal pass will be issued until these matters are resolved.

Three entrepreneurs and one agent discussed their production with the researchers. Findings are presented in table 12 below.

Table 12. Charcoal Production Costs

Item	Cost Range (LS) per sack
Labour per packed sack	1.55 - 1.80
Water	0.20 - 0.40
Agent	0.20 - 0.25
Empty sacks	0.60 - 0.75
Transport to depot	0.55 - 1.30
Royalty & local tax	0.27 - 0.30
Sudries including deficit from repacking	0.10 - 0.30
Total at Depot	3.47 - 5.10

Total cost at the depot does not include interest on investment or entrepreneur's supervision cost. Entrepreneurs estimate both factors as to equal to 20% of the cost at the depot. If sales take place at the kiln site (which rarely happens) then transport cost to depot would be omitted.

Appendix 1. Data Collection Forms

1. Production Site Questionnaire

LOCATION: _____

NUMBER OF KILNS: _____

SIZES: _____

NUMBER OF PERSONNEL:

Foremen: _____

Labourers: _____

Other: _____

EQUIPMENT PRESENT:

For cutting _____

For Transport _____

For Water _____

Other _____

WOOD SPECIES USED _____

DRYING METHOD AND TIME _____

STACKING METHOD _____

KILN VENTING (IF ANY) _____

AVERAGE CYCLE TIME (ESTIMATE) _____

AVERAGE YIELD (ESTIMATE) _____

Places of Origin of Personnel _____

Place of Origin _____

Education Level _____

Number of Production Teams _____

Years in this business _____

Ultimate End-Use of Land to be cleared _____

_____

2. Forest Administration Regional Headquarters Questionnaire

Entrepreneurs Obtaining Permits

Number: _____

Names: _____

% Regulars: _____

% Nes: _____

Areas allowed for Production: (Location and Total Feddans, Plantation or natural forest)

_____

_____

Past Years 1982:

Entrepreneurs: _____

Total Production: _____

Transport Permits _____

Lorry No. & Type: _____

Distances (estimate) _____

Areas Allowed for Production: _____

(1972) (or about 10 years ago) _____

(same as above) _____

_____

Long-Term Projection for Production Areas

Feddans: _____

Locations: _____

Present Land Use: _____

Projected Land Use After Felling: _____

_____

_____

SREP:

3. Weight/Volume Ratios

Kiln Location: ..... Date: .....
Kiln Operator: .....
Entrepreneur: .....

Sample Stacked volume: L x h x w ..... = m^3 (A)
Sample solid volume : ..... = m^2 (B)
Equivalent of one m^3 stacked in the solid: (B) ÷ (A) ..... = m^3 (K)
Weight of stacked sample: ..... = kg (C)
Weight of one m^3 stacked (C ÷ A): ..... = kg (D)
Weight of one m^3 solid (C ÷ B): ..... = kg (E)
One metric ton equivalent of stacked wood: 1000 ÷ (D) ..... = m^3
One metric ton eqivalent of solid wood: 1000 ÷ (E) ..... = m^2

(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)

Estimate

Talh %

Heglig %

Kitir %

Habil %

Sahab %

Other:

%

%

%

TOTAL=100%

Billet volume (5) : = ½(3) x ½ (3) x π x (2) = cm^3
sum of columns (5) = cm^2 ÷ 1000000 = m^3 (B)

1 = billet No; 2 = length (cm); 3 = diameter at mid point (cm);
4 = mid point-cross-sectional area cm^2, 5 = volume of billet cm^3

Compiled by: Checked by:

4. Kiln Analysis

Wood to Charcoal Ratios

No. sacks per stacked m^3 = $S \div V$ = sacks

No. sacks per solid m^3 $S \div V_1$ = sacks

tons of stacked wood per ton charcoal = $Q \div R$ =

Charcoal Quality:

% charcoal (per sample sacks) = %

% bits (per sample sacks) = %

% dust (per sample sacks) = %

% unburnt wood (per whole kiln) = %

Date:

Kiln Location:

Kiln owner: domicile tribe

date felling started date felling ended

entrepreneur:

Wood Content:

Kiln circumference (c) = m

Kiln height (h) = m

Kiln volume-stacked (v)

Kiln volume-solid (v). = v x k (form 2) = m^3

Weight of wood in kiln (R) = V x D (form 2)

Moisture Content determination:

Moisture content (m.c.) determined in the field = %

Weight of sample weighed in the field (x) = kg

Oven dry weight of sample (y) = kg

M.C. as determined in the laboratory = $\frac{x-y}{y} \times 100$ = %

Charcoal Yield:

No. of charcoal sacks produced (s) = sacks

Average weight of sack (w) = kg

No. of sacks per metric ton (P) = $1000 \div (w)$ = sacks

Weight of charcoal produced by kiln (Q) = $s \div p$ = m.t.

5. Acacia Seyal Stocking

Age Class:/ - years.

Locality	G m^2/ha	h m	f.f.	c.ff.	Stocking in solid m^3/ha			Actual stocking stacked m^3/ha	S.F.	Adopted stocking m^3/ha stacked	MAI m^3/fed/an.
					V=Ghf	Pressler's $\dot{V}$=Gx2/3xh$_1$	Kitamura's deckpunkt				

f.f: form factor; c.f.f.= charcoal burners' f.f.; S.F.: Stacking factor

G= mean basal area; h: mean height; h^1=height where d ≐ ½ dbh

MAI = mean annual increament.

Appendix 2. Conversion Factors

Entrepreneur	Location	Kiln No.	Stacked Volume (c.m.)	Sacks produced	Sacks weight (kg.) average	Kiln Production (m.t. charcoal	Sacks per stacked (c.m.)	Stacked c.m. wood per Tonne charcoal
Abd El Rahman El Siddig	Wad El Nil	1	37.78	115	35.07	4.11	3.04	9.2
" " " " "	" " "	2	37.91	105	35.75	3.14	2.77	12.1
Ahmed El Nour	" " "	3	25.70	74			2.80	
" " "	" " "	4	96.86	247	39.93	9.86	2.55	9.8
Mohamed El Rizaigi	" " "	5	43.61	177	36.75	6.50	4.06	6.7
" " " "	" " "	6	48.84	207	41.90	8.67	4.24	5.6
Sharaf El Din El Deshir	" " "	7	58.31	155			2.66	
" " " " "	" " "	8	46.70	127			2.72	
Ahmed El Nour	" " "	9	98.03	282	44.30	12.49	2.88	7.9
" " "	" " "	10	71.87	220	37.15	3.17	3.06	8.8
Sharaf El Din El Beshir	" " "	11	94.46	240	40.86	9.81	3.54	9.6
" " " " "	" " "	12	67,98	230	37.98	8.74	3.38	7.8
Ahmed Sulieman	Haroun	13	117.69	394	38.57	15.19	3.35	7.8
" "	"	14	151.70	480	40.75	19.56	3.16	7.8
" "	"	15	100.36	446	36.40	16.24	4.44	6.2
" "	"	16	122.53	412	38.17	15.73	3.36	7.8
" "	"	17	219.15	602			2.75	
" "	"	18	337.10	817			2.42	
Khamis Idris	"	19	55.07	162	38.32	6.21	2.94	8.9
Mohamed Omer	"	20	60.58	229	40.86	9.36	3.78	6.5
Ahmed Sulieman	"	21	96.06	382	42.15	16.10	3.98	6.0
" " " "	"	22	108.41	403			3.72	
" " " "	"	23	187.86	508			2.70	

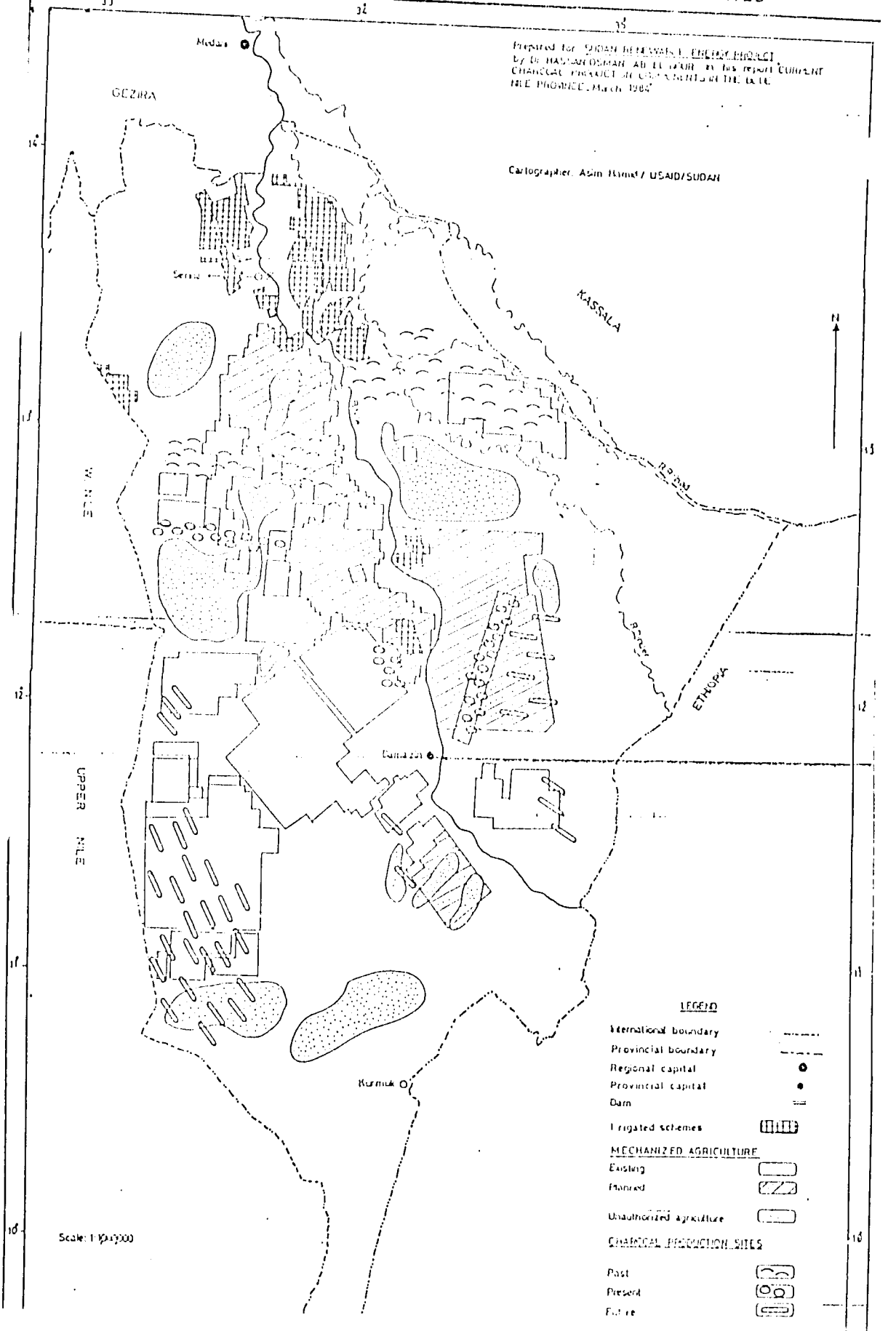
Appendix 2. Conversion Factors Continued)

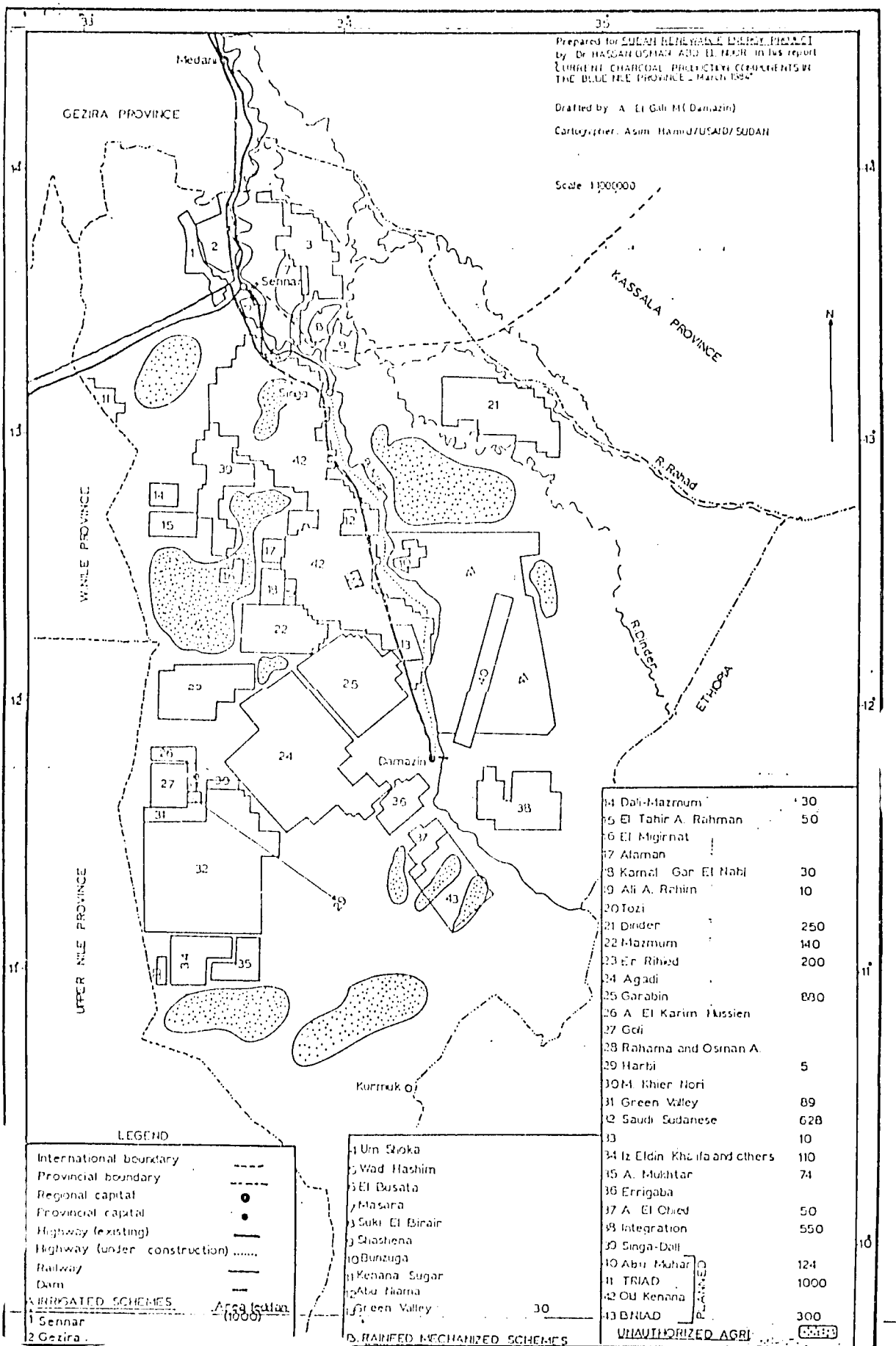
Entrepreneur	Location	Kiln No.	Stacked Volume (c.m.)	Sacks produced	Sacks weight (kg.) average	Kiln Production (m.t. charcoal	Sacks per stacked (c.m.)	Stacked c.m. wood per Tonne charcoal
Ahmed Babiker Hago	Daiwa	24	80.10	265	38.85	10.29	3.31	7.8
" " " "	"	25	181.41	613				
" " " "	"	26	109.31				2.95	
" " " "	"	27	139.64	412			2.95	
Rahimtalla	"	28	117.71	530	41.46	21.97	4.50	5.4
Ali Eisa	"	29	45.57	217	41.10	8.92	4.76	5.1
" " "	"	30	83.02	401	38.18	15.31	4.56	5.4
Ahmed Balloula	"	31	104.83	342			3.26	
" " " "	"	32	75.20	275	41.40	11.39	3.66	6.6
" " " "	"	33	69.22	236			3.41	0.31
	Dinder	34	79.39	353			4.45	
	Khor Alqualim	35	30.76	138			4.49	
	" "	36	31.02	120			3.87	
	" "	37	29.71	125			4.20	
					40.40			
					39.38			
					41.10			
Nour of Samples		37	37	36	24*	21	36	21
Mean			93.6	307	39.3	11.3	3.5	7.6
Standard Deviation			61.9	170	2.6	4.9	0.7	1.8

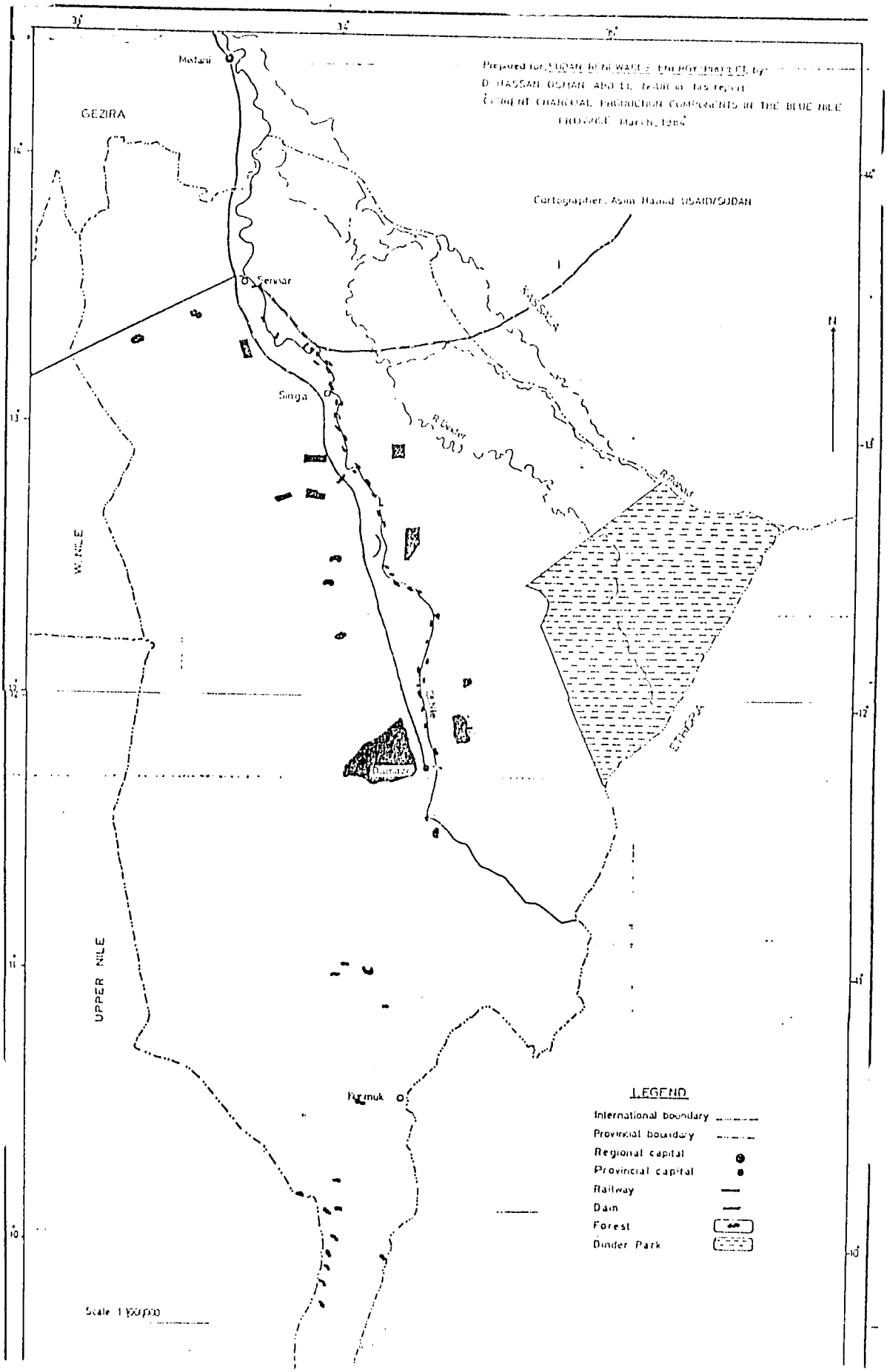
* 230 sacks at (each of 23 sites) plus 6 sacks at one site.

Appendix 3

BLUE NILE: PAST, PRESENT AND FUTURE CHARCOAL PRODUCTION SITES




Prepared for SUDAN RENEWABLE ENERGY PROJECT
by Dr HASSAN OSMAN ABU EL NOOR in his report
"URGENT CHARCOAL PROJECTS COMPONENTS IN
THE BLUE NILE PROVINCE - March 1994"
Drafted by A El Gali M (Damazin)
Cartographer: Asim Hamid/USAID/SUDAN
Scale 1:1000000
GEZIRA PROVINCE
KASSALA PROVINCE
WHITE NILE PROVINCE
UPPER NILE PROVINCE
ETHIOPIA
Medani
Sennar
Singa
Damazin
Kurmuk
R. Rahad
R. Dinder
N
LEGEND
International boundary
Provincial boundary
Regional capital
Provincial capital
Highway (existing)
Highway (under construction)
Railway
Dam
IRRIGATED SCHEMES
Area (ha) (1000)
1 Sennar
2 Gezira
4 Um Suoka
5 Wad Hashim
6 El Busata
7 Masara
8 Suki El Birair
9 Shashena
10 Bunzuga
11 Kenana Sugar
12 Abu Naama
13 Green Valley
30
D. RAINFED MECHANIZED SCHEMES
34 Dali-Mazmum 30
35 El Tahir A. Rahman 50
36 El Migirnat
37 Alaman
38 Karnal Gar El Nabi 30
39 Ali A. Rahim 10
40 Tozi
41 Dinder 250
42 Mazmum 140
43 Er Rihed 200
44 Agadi
45 Garabin 800
46 A El Karim Hussien
47 Goli
48 Rahama and Osman A.
49 Harbi 5
50 M. Khier Nori
51 Green Valley 89
52 Saudi Sudanese 628
53 10
54 Iz Eldin Khalifa and others 110
55 A. Mukhtar 74
56 Errigaba
57 A El Obied 50
58 Integration 550
59 Singa-Doll
60 Abu Muhar 124
61 TRIAD 1000
62 Ou Kenana
63 BNIAD 300
UNAUTHORIZED AGRI


Prepared for SUDAN NEW WASLE ENERGY PROJECT by
D. HASSAN OSMAN ABDEL RAHIM (as report
CURRENT CHARCOAL PRODUCTION COMPONENTS IN THE BLUE NILE
PROVINCE March 1984
Cartographer: Asim Hamid USAID/SUDAN
Medani
GEZIRA
Sennar
Singa
W. NILE
UPPER NILE
Blue Nile
Dindar
ETHIOPIA
Kurmuk
N
LEGEND
International boundary
Provincial boundary
Regional capital
Provincial capital
Railway
Dam
Forest
Dinder Park
Scale 1:500,000

List of People Contacted

Mr. Donald B. Peterson, Chief of Party, SREP.
Mr. Matthew S. Gamser, Project Economist, SREP.
Dr. Ahmed Hassan Hood, Assistant Coordinator, SREP.
MS. Carolyn Huskey, Dissemination Consultant, SREP.
Mr. J. B. Ball, Project Manager, FAO's Fuelwood Development for Energy in Sudan.
Dr. Osman Khalifa, Regional Minister of Agr. & Nat. Res., Central Region.
Dr. Abd El Monem Abd El Razig, Director General, Min of Agr & Nat. Res. W/Medani.
Syd. Yahia I. Bushara, Director of Nat. Res. Reg. Min. of Agr. Wad Medani
Syd. Abul Gasim Mohd Suliman, Chief Conservator of Forests BNP Sennar.
" Sheikh Idris Abul Gasim, Conservator of Forests BNP Sennar.
" Ibrahim Saeed Beraigie, Conservator of Forests Utilization, Sennar.
" Ahmed El Tayeb Ibrahim, C.F. Northern Fung Circle, Singa.
" Hassanein Mohd Nour, Forest Officer Abu Hugar.
" Mohammed Adam Abd El Hamid, F. O. Wad El Nail.
" Ahmed El Tom Bella, Forest Ranger, Wad El Nail.
" El Bagir Suliman, Mill Manager, Wad El Nail.
" Ahmed Dafalla, F. R. Haroun.
" Abd El Marouf Abd El Rahman, C. F. Damizine Circle.
" Ahmed El Naeem Idris ACF Damazine.
" Osman Hassan, F.R. Damazine.
" Saeed Ibrahim, F. R. Disa.
" Omran Balleila El Tahir ACF Roseires.
" Beshir El Siddig, F.R. Daiwa/Saolil.
" Ali Saeed El Zein, C. F. Suki Circle.
" Ali Mohd Osman F. O. Karkoj.
" Hag Geili Mohammed, F. R. Bunzuga.
" Izzel Din Saeed, C.F. Dinder Circle.
" Osman El Shiekh, F. O. Dinder.
" Mohammed Ali Abd Alla, F. O. Dinder.
" Idris Mohammed El Daw, F. O. Dinder./
" Mohammed El Hassan El Faki. F. O. Dinder.
" El Sir Awad El Karim, F. R. Kamrab.

List of People Contacted (Contd).

Syd. Ahmed Abd Alla, F. R. Dinder.
" Yousif Ahmed A/Rasoul , Forest Overseer, Kamrab.
" Ahmed Suliman Abd El Maqiid, Entrepreneur, Abu Hugar.
" Ahmed El Nour, Entrepreneur, Wad El Nail.
" Osman Abd Alla, Entrepreneur, Wad El Nail.
" Sharaf El Din El Beshir, Wad El Nail.
Prof. M. A. Toushan, Dept. of Forestry, Faculty of Agriculture, U. of K.
Dr. El Nour Abd Alla El Siddiq, " " " " " " ".
Dr. Omer Saeed Musa, " " " " " " " " ".
Syd. Zein El Abdin Abbas, Producer, Damazine.
Syd. Mohamed Abdel Rahim, Producer, Dinder.
Syd. Abdel Atti Mahgoub, Producer, Dinder.
Syd Izzel Din Saeed, Conservator of Forests, Dinder.

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