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FINAL REPORT

# THE USE OF ALIEN WOODY BIOMASS FOR LOW COST SMALL-SCALE CHARCOAL PRODUCTION

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PREPARED FOR THE NATIONAL ENERGY COUNCIL

BY

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## EXECUTIVE SUMMARY

This report investigates the potential of using low-cost small-scale charcoal production technologies to manufacture charcoal from biomass generated by bush clearing. Bush clearing programs presently attempt to curb the spread of certain alien wood species in conservation and agricultural areas. These programs are expensive and waste a valuable energy resource. No financial return is generated from the clearing activities because of the disposal policy used in bush clearing i.e. where cleared bush is heaped and burned after felling. The result is that expensive bush clearing programs are restricted to sensitive areas where high costs of clearing can be warranted.

While large quantities of wood are destroyed in bush clearing, other areas dependent on wood as a domestic fuel source, face extreme shortages. This report also evaluates the possibility of exploiting the advantages that charcoal possesses over wood in transportation, to open up unwanted stands of alien wood species as ready-made woodlots to areas needing fuelwood. If successful, this project will introduce a new concept to bush clearing, reducing operational costs; with the use of simple technology, create job and business opportunities for unskilled labour; and produce a low-cost fuel that can be transported to areas reliant on fuelwood.

The commercial value of biomass as firewood is often too low for exploitation in areas suffering infestation problems. Coupled with this, is the problem that high transport costs associated with firewood, prevent marketing in other areas. To improve the commercial value of biomass energy, the wood has to be upgraded to meet the needs of another market. One avenue for fuelwood improvement is through conversion to charcoal. Large-scale industries in South Africa already produce charcoal from one particular alien wood specie, <u>Acacia</u>

mearnsii. Plantations of this specie meet the needs of several other timber processing industries and wood residues produced by these industries make available large quantities of cheap uniformly sized timber, ideally suited to large scale charcoal production. The same large-scale industry would not be economically viable using biomass generated by bush clearing because the high cost of harvesting non-plantation wood and transport costs of timber to one central facility would have to be borne by the charcoal producer.

Low-cost small-scale charcoal production technologies provide charcoal to large well established markets in developing countries throughout the world. This same scale of technology could be used to carbonise bush clearing biomass, but the feasibility will depend on the economics of small-scale production. Very little information on the economics of simple charcoal producing technologies is available to evaluate the potential of charcoal to bush clearing. It was thus necessary to conduct an experimental program to determine charcoal production costs for these technologies.

Charcoal is produced from wood through, what is often called, dry distillation. The process involves heating the wood to temperatures in excess of 190$^{o}$C, in the absence of oxygen, beyond which temperature, thermal breakdown, or pyrolysis of the wood takes place, forming charcoal. The heat required to raise the temperature of the wood is either from an external source or is generated through combustion of a portion of the wood charge. Equipment used to accommodate the wood during pyrolysis falls generally into two categories, retorts and kilns. The retort generally uses external heating and the kiln, combustion of a portion of the charge. Retorts generally have higher charcoal to wood yields than kilns but are usually associated with more complex and expensive designs. As a result the simple technology usually employs kiln type operation. Four small-scale technologies were selected for evaluation. Selection was based on transportability, simplicity in construction and operation, low cost, and charcoal production yield. Three kilns and one retort design were selected: the Tropical Development and Research Institute (TDRI) kiln, the Tongan drum kiln, the Charcoal from Useless Scrub and Brush (CUSAB) kiln, and the Vita retort. An action research program was set up to evaluate the different techniques, involving people already making a living by cutting firewood from alien wood thickets.

The experimental work initially set out to establish wood production rates and costs. Three wood species were available for experimentation, Acacia saligna, Acacia cyclops and Hakea sericea. After a period of drying, the wood was used in trials with each of the four techniques and charcoal production rates and yields measured.

Wood production costs

Cost estimates and production rates of wood from alien specie thickets was obtained from the informal firewood industry operating in the vicinity of Cape Town. Monitoring production rates of the small team of firewood cutters provided additional information, which allowed costs of larger size wood pieces for charcoal production, to be estimated. Manual cutting and chainsaw operation were both evaluated, the latter being found to reduce wood production costs but only significantly where assistance with machine maintenance was available.

Alien wood harvesting was found to be an arduous, labour-intensive task. Generally labour involved in cutting of firewood was found to have minimal schooling and almost no alternative but to cut wood. Firewood prices dictated the cutter's earnings through his own production rate. The contract price for firewood, paid to the cutters, was found to be R30-R37/ton. Manual cutting rates earned R5/day, while chainsaw cutting rates R10/day for the wood cutter. Comparing labour input required to produce firewood with that required to produce wood for charcoal, enabled wood production costs for charcoal production to be calculated. Manual production costs for 1,8 and 0,5 meter lengths were R17-R24/ton, respectively, at the R5/day wage level. Chainsaw operation reduced the costs to R13-R21/ton. If minimum wages of R20/day were used for chainsaw operation, charcoal wood production costs for 1,8 and 0,5 meter lengths were calculated to be R24 - R30/ton, respectively

The pit kiln

No experiments were conducted with pit kilns as the sandy soils in the Cape would not support construction of the pit. It was however possible to evaluate an operation being conducted near Port Elizabeth. The kiln was being operated in a primitive fashion and therefore only achieving low yields. The wood specie Acacia mearnsii, was being cut down to reclaim infested farmland and converted to charcoal to offset clearing costs and provide a safe means for disposal of the wood produced.

Charcoal was estimated to be produced at R334/ton, excluding kiln and wood transportation costs, thereby recovering 45% of the clearing costs. If the operation were to be improved by using low-cost modifications, charcoal production could be increased almost fourfold using the same quantities of wood which would change the economics of the operation significantly Resiting of the kiln would alleviate transport costs and in conjunction with improved operation, reduce production costs to convert it into a profitable operation, capable of recovering 150% of clearing costs. This technique was however, not considered ideally suited to alien bush clearing programs as it was dependent on certain soil conditions, not often available.

## The TDRI metal drum kiln

The TDRI kiln was selected from the literature, for evaluation, on account of its simplicity of operation and construction, its mobility and good conversion yields. The kiln was made up of two cylindrical sections and conical lid, fitting together to make up a steel container with diameter of 2,3m and 7,5m$^3$ capacity. Metal working requirements, ruling out any do-it-yourself construction, and the kiln cost, were seen as distinct disadvantages. Construction, including materials, was found to cost R3100 (including tax) per kiln.

A limited number of experiments were conducted with this kiln design because of the large quantities of wood required for each run. Initial wood size recommended was found to be too small and a vertically on-end stacking arrangement in the kiln allowed less expensive pole length timber to be used. Carbonisation times required varied between 18 and 29 hours and cooling a further 24 hours, allowing a 2-3 day turnaround. Production ranged between 250 and 400 kg per run with yields of 17-31% on an oven-dry wood basis.

Results of the TDRI experiments were inconsistent. The exact reasoning for this was not well understood but threw uncertainty as to the effect of wood specie on charcoal yields. Experience in kiln operation played an important part in the results illustrating this technique of charcoal production not to be best suited to unskilled labour. Charcoal quality, especially where operation is to be incorporated into bush clearing, is not expected to meet industrial standards but is ideal for domestic braai charcoal. Operation of this kiln cannot be considered within residential areas as large quantities of smoke are produced.

Charcoal production costs at a given labour rate depend on the charcoal yield achieved by the operator. It was assumed that better operation would be accomplished as earnings improved. Manual cutting of the timber would allow charcoal production at costs ranging between R150 and R320 per ton for labour costs of between R5 and R10 per day. Chainsaw operation in the cutting operation would allow production costs ranging between R130 and R400 per ton, the latter being considered to be the worst case at a minimum wage level of R20 per day.

## The Tongan drum kiln

The Tongan drum kiln was selected for evaluation primarily on account of its low cost. Based on the '44 gallon drum', it is also extremely versatile, mobile and ideal for independent small-scale operators. The only drawbacks are the limits to the size of wood it can use and the short life of the kiln. The simple construction which required a slit, 20cm wide to be chiseled down the length of a drum was easily demonstrated and later accomplished by firewood cutters in the field. Operation was found to be extremely simple but yields could be improved through operator control. One operator was found to be capable of running 14 kilns at a time. A carbonisation cycle was typically 6 hours and cooling over night. 8 to 30 kg of charcoal were produced per drum with charcoal yields of 9-35% being achieved.

High operating temperatures were found to fracture the charcoal, resulting in a large production of fines. Minimising air inlet to the drum was found to reduce fines production and improve charcoal yields. Wood cutters operated the kilns extremely well, highlighting the suitability of this design for small-scale entrepreneurs.

Charcoal production costs were found to range between R190 and R480 per ton for manual cutting at labour rates between R5 and R10 per day. Charcoal production costs where chainsaws were used in the wood cutting operation, were found to range between R150 and R380 per ton at labour rates of R5 to R20 per day.

## The Vita retort

An attempt was made to produce charcoal from a simple retort design. The design called for simple welding, easily accomplished by farmers and do-it-yourself enthusiasts. The reason for selection of this design as part of this project was primarily because the technique could conceivably use both brush and timber from bush clearing. In addition construction costs were low and charcoal production yields reported to be high for the design.

The equipment design offered an attractive option for external combustion of brush to heat up and pyrolise timber inside a vessel constructed of oil drums, thereby using both the brush and wood constructively. External combustion of flammable pyrolitic gases, piped into the firebox, assisted the heating of the vessel. Major problems were experienced in maintaining sufficiently high temperatures in the vessel to sustain carbonisation. Insulation by burying the vessel in sand made brush combustion difficult and loading and unloading of the vessel contents a problem. Problems experienced with sealing of the vessel and buckling of metal walls after only two runs indicated a very short lifespan for this design. Low-cost retort technology was therefore considered inappropriate for carbonisation of bush clearing residues and no further work attempted.

## The CUSAB kiln

A large fraction, 45%, of the biomass produced during bush clearing was found to consist of brush. Carbonisation of this material was found to be possible through use of a kiln design very similar to the TDRI kiln. Simple modifications to the TDRI allowed it to double as both a TDRI and CUSAB kiln. Modifications consisted of a number of air inlet ports in the kiln walls and a large opening in the lid for brush. Construction difficulties and cost would then be similar to the TDRI kiln.

High temperatures generated through part combustion in the kiln, carbonised the brush very quickly and formed a pile on the floor. Opening and closing of air inlet ports allowed charcoal to accumulate on the floor and control temperature in the kiln, affecting both charcoal quality and yield. Operating temperatures between 470°C and 900°C were achieved with yields varying between 5% and 44%. Unfortunately the charcoal is produced in a fine form not easily used without briquetting, unfortunately an expensive operation. Contamination with soil using the design in its present form would also make it unsuitable for industrial consumption, making its product generally unsuitable without further upgrading. Use of this technique would therefore rely on the existence of a local briquetting industry to make the charcoal fines into a useful form.

The cost of fine charcoal production was found to be R30-R35 per ton at the R5 per day labour rate and R85-R135 per ton at the R20 per day labour rate.

Charcoal as a fuel for underdeveloped areas

Charcoal has an advantage over wood in that it is less expensive to transport in energy terms. If the energy content of alien wood is to be exploited and transport is involved, there is a distance, called the breakeven distance, beyond which, charcoal is a more cost-effective energy form to use then wood itself. If alien wood thickets are to be used as fuel sources for underdeveloped areas, transport of fuel to these areas is going to be necessary and breakeven distances will therefore apply. The breakeven distance is a function of costs of wood and charcoal production, the calorific value and the energy conversion efficiency of each fuel and the price of transport. As labour costs affect wood and charcoal production costs, they will influence breakeven distances. In practice prevailing labour rates and realistic charcoal production costs associated with alien wood utilisation, will involve breakeven distances of 20 - 60 km, implying that charcoal in many cases will be more cost-effective to use than the wood itself.

Whether charcoal will be used in underdeveloped areas or not, will depend on the final delivered cost of the fuel in relation to other alternatives. Comparison of costs of coal in several areas of South Africa show that charcoal will generally be unable to compete unless produced from wood wastes, obtained at zero cost. As a result charcoal cannot be expected to provide a solution to the fuel shortages of the underdeveloped areas.

Integration of charcoal production into bush clearing

Two alternatives for use of charcoal production are open to the landowners requiring extensive clearing operations. The owner (or administrator) may invite small business concerns to produce charcoal from the alien wood specie, or he may integrate a charcoal producing unit to an existing bush clearing operation. The former can be accomplished without any capital outlay but is reliant on an educational program to generate interested entrepreneurs. The latter requires capital outlay for the equipment and needs to be organised and controlled by the landowner himself.

The small entrepreneur would consist of a team of 18 men, cutting wood manually and 14 Tongan drum kilns. The Tongan drum is best suited to small businesses because it allows entry into the market with very little capital outlay, e.g. in this case R140. The team would produce 6 tons of charcoal per month, clearing 0,5-1,2 ha of densely infested land per month. Sales of charcoal through a middleman/wholesaler would allow earnings between R10 - R20 per day, twice that received from cutting firewood.

Integration of charcoal production into existing bush clearing is better suited to the TDRI/CUSAB combination kiln. The capital required would depend on the clearing rate. A clearing rate of 0,5 ha/month of densely infested bush would require an investment of R6200 in kiln costs. A further R6200 would be required if the brush was to be carbonised as well. Manpower requirements to prepare and carbonise wood, would increase 10 times that simply required to fell and burn equivalent areas, but charcoal produced would cover the wages at a R20/day level. A typical operation would consist of a team of 7 men, using chainsaws and 4 TDRI/CUSAB kilns. The team would produce 6 tons of lump charcoal and 11 tons of charcoal fines per month, clearing 0,5 ha of densely infested land per month.

An estimate of the costs for felling and burning a typical stand in Cape Town was found to be R825 per hectare. These costs at worst could be reduced to R440 per hectare and at best converted to a profit of R1130 per hectare of densely infested land.

Bush clearing needs follow-up procedures to be effective in stopping regeneration of the unwanted species. These procedures apart from requiring manual labour and chemical treatment, often require a hot fire to assist the chemical treatment or kill young seedlings. Burning of the felled biomass does therefore serve a purpose and it may therefore be necessary to leave the brush material behind for later burning. Integration of charcoal into existing clearing programs will definitely be better suited from an ecological point of view because follow-up procedures can be implemented correctly. The small business concept will have to be monitored and follow-up procedures implemented by the landowner himself if control of the alien species is to be effected. There is also a danger of perpetuating alien specie presence using small business operations, rather than destroying it if the landowner prefers to make a living from the species.

In conclusion, the alien wood species can be used successfully to produce domestic grade charcoal with small-scale low-cost charcoal production technology. Charcoal production will allow reduction and even elimination of bush clearing costs but charcoal produced will not be cheap enough for use in underdeveloped areas.

CONTENTS

# CHAPTER 1

## INTRODUCTION

Certain invasive alien wood species have created an extensive problem for nature conservationists and landowners alike throughout South Africa and Namibia. The bush clearing programs, set up to curb the spread of these species in areas supporting indigenous vegetation and agricultural activity are extremely wasteful in both monetary terms, because of the high costs involved, and in energy terms, because of the disposal policy used in bush clearing. Cleared bush is usually burned, destroying the biomass with no attempt being made to recover the energy in a useful form. The result is that the expensive bush clearing programs can therefore only be restricted to sensitive areas where high costs of clearing are warranted. For effective control of invasive vegetation, bush clearing programs will have to be expanded beyond these sensitive regions. This expansion is inconceivable at current bush clearing costs unless some commercial use for the biomass can be created to offset the large costs involved.

The bush clearing project costs are of concern to the organisations implementing the control programs but energy wastage is usually ignored. Ironically, it is the energy resource currently being discarded that holds the key to reduction and possibly even elimination of the large costs involved. Presently, the reasons for ignoring the energy value of biomass generated by bush clearing programs, is that the commercial value of the energy as wood, is low in an area suffering wood infestation problems. To aggravate this problem, the low energy density of wood makes it one of the least transportable fuels and therefore transport costs are high, which prohibits the movement of this energy resource to surrounding areas.

To enable marketing of the biomass energy, the wood has to be upgraded to meet the needs of another market. One avenue for fuelwood improvement is through conversion to charcoal. The product not only has a higher market value but also a higher energy density which reduces transport costs and in doing so, opens up a much wider market around the energy source. Charcoal can more than likely be produced from most of the alien wood species creating problems in South Africa but the viability of production will ultimately depend on economics associated with utilisation of this raw material. Large-scale commercial production of charcoal in South Africa is presently based on an invasive alien wood specie, Acacia mearnsii, commonly known as Black Wattle. Plantations of Black Wattle, cultivated for tannin production from its bark, produce large quantities of byproduct timber which provide a cheap and large source of raw material for charcoal production. The large-scale production is capital-intensive and depends on large and easily available supplies of cheap timber offered by plantations.

The use of timber generated by bush clearing in a large-scale charcoal production facility would not be suitable because the present scale of clearing activities would not provide sufficient timber for a large scale operation; clearing activities are spread over a wide area where transport to a central facility would make the timber costs too high; and the irregular shape and size of the timber would generally reduce efficiency of production. Instead it is proposed that numerous low-cost small-scale units along the lines of technologies used in other developing countries throughout the world, be used. The small scale would allow the operation on the 'forest floor' as an integral part of bush clearing, following the receding bush and thereby eliminating costly timber haulage. In addition, if carbonisation is based on simple technology, unskilled labour could be given the opportunity of becoming involved in the production process.

Very little information on the economics of simple charcoal producing technologies is available to assess the potential of charcoal to bush clearing. It was thus necessary to set up a project to evaluate charcoal production costs for these technologies along with the costs of generating raw materials from the alien wood species. The objectives set out for the project were:

- to identify low-cost small-scale charcoal production techniques suitable for carbonisation of alien wood species by unskilled labour operating in the field; and
- to evaluate the charcoal production costs of a selection of small-scale production techniques using alien wood species.

Charcoal production would inevitably depend on the market demand and as, potentially, the biggest consumer of fuelwood in South Africa is the underdeveloped sector (defined as those areas not provided with electricity), it was important:

- to assess whether charcoal production would enable utilisation of the alien wood energy resource as a domestic fuel in the underdeveloped areas of South Africa.

At the outset it was clear that laboratory evaluation would not provide appropriate information for these rudimentary techniques. As a result, it was decided to adopt a research approach that would evaluate the suitability of charcoal production in the field in as real a context as possible. After conducting an extensive literature review of simple charcoal producing techniques to identify the most appropriate for evaluation, an action research program was set up to determine their suitability. A small community already involved in cutting of firewood, was employed to clear bush and produce charcoal. As the project was to be conducted over one or two years, it was necessary to install two small wooden houses as accommodation and develop a small charcoal producing unit. Wood cutting and carbonising equipment were supplied and a small market for the charcoal product established. This type of approach enabled real production rate data to be measured.

The report that follows includes a review of the extent of alien vegetation in South Africa, identifying the species most problematic in each area; bush clearing programs and related costs; and low-cost small-scale technologies used in other developing countries. Results of measurements taken during the experimental program are reported, detailing raw material and charcoal production costs associated with the use of three alien wood species. Charcoal production costs are estimated for different labour rates and three different production techniques. The feasibility of using charcoal as a domestic fuel in the underdeveloped areas is evaluated. Final conclusions evaluate the potential benefits of charcoal in an integrated control strategy for alien vegetation.

# CHAPTER 2

## ALIEN INVASIVE WOOD RESOURCE

Comprehensive surveys of the extent of invasion by alien, as opposed to indigenous, wood species have been conducted for a large percentage of South Africa and Namibia under the directive of the Council for Scientific and Industrial Research. The South African National Scientific Programmes (Macdonald and Jarman, 1984, Macdonald and Jarman, 1985, and Brown, Macdonald and Brown, 1985) cover alien wood specie invasion for 'the Fynbos Biome', Natal and Namibia respectively. A similar survey for the Transvaal has been published by Henderson and Musil (1984). All areas surveyed show extensive invasion problems but each dominated by different species.

Certain indigenous wood species are also considered to pose infestation problems but the extent of the problem has not been well documented. Concern is usually expressed by farmers where indigenous bush encroachment reduces agricultural arable and grazing land usage. Indigenous species have been reported to create problems in the Eastern Cape region (Viljoen, 1980) and in Namibia (Margesson, 1985).

### 2.1 ALIEN INVASIVE WOOD SPECIES

#### 2.1.1 The fynbos biome

The fynbos biome occupies an area along the southern coastline of South Africa supporting a unique indigenous vegetation cover locally termed 'fynbos'. This clearly differentiated biogeographical area extending through the southern and eastern Cape Province and parts of Transkei and Natal, contains an extraordinarily high concentration of different plant species, some 8550. With 1585 species rated as rare, vulnerable or threatened and 36 species considered to have become extinct quite recently. the area has been called a 'conservation crisis zone'. Recent analyses have indicated that it is not only urban and agricultural transformations which pose a severe threat to the fynbos but also the impact of several invasive alien species (Macdonald et al., 1984a).

A case study of woody plant introductions to the Cape Town area, by Shaugnessy (1986), identified original motivations for introduction of several alien woody species. Shaugnessy reports lack of indigenous trees, botanical garden collections, experimentation, sand stabilization, economic gain and climatic amelioration to be important factors attributing to the early introduction of selected alien species. Early records show that most of the problematic alien species in the fynbos biome considered in this document were introduced between 1835 - 1865. Findings by Shaugnessy also show that the government forestry authority played a major role in the introduction of alien wood species. Alien plantations, since abandoned, were conspicuously created to replace the natural habitat.

An historical account of the introduction of two alien species to the Cape Flats (within the fynbos biome) described by Roux (1961) provides a good example of the origins of alien vegetation in this area. The purpose for the introduction of two Australian Acacia species, as early as 1845, by John Montagu, was as sand binders in the low lying sandy area, a purpose which the alien wood species achieved complete success. The two species introduced were Acacia Cyclops and Acacia Saligna, the critical period in their establishment being the decade 1876-1886, where the use of municipal refuse as fertilizer assisted in the plantation of some 1023 acres.

During the 1880's and 1890's farmers on the Cape Flats were encouraged to establish trees on their properties by a system of prizes awarded for the best plantations (Shaugnessy, 1986). Forestry officials, supplying enormous quantities of seed to private individuals, were motivated by the aim to cover the drifting sands and to produce tan bark.

The extent of alien wood specie invasion of the fynbos biome has been assessed by Macdonald et al. (1984a) and the ten most important species have been identified according to their current infestation. These species are listed below in order of priority:

Table 1: Species Currently Infesting the Fynbos Biome

(1) Acacia Saligna*
(2) Acacia Cyclops*
(3) Acacia Longifolia*
(4) Albizia Lophantha*
(5) Hakea Sericea*
(6) Acacia Mearnsii
(7) Leptospermum Laevigatum*
(8) Pinus Pinaster*
(9) Acacia Melanoxylon*
(10) Sesbania Punicea

Distribution of each species according to quarter-degree grid square infestation are included in Appendices 1 & 2.

Macdonald et al. (1984a) also rate the species according to the threat they pose to the fynbos biome in terms of five criteria, namely: current area infested, relative ease of control, extent of potential habitat, potential rate of spread and impact on the ecosystem. The first three acacias in the above table are also considered to be the three species posing most serious threat to the fynbos biome. The species marked by * above fall within the top ten category in terms of their potential threat to the fynbos biome.

It is interesting to note that two of the three acacias presenting the greatest threat to the fynbos, were the first alien species introduced to the Cape Flats more than a hundred years ago.

### 2.1.2 Natal

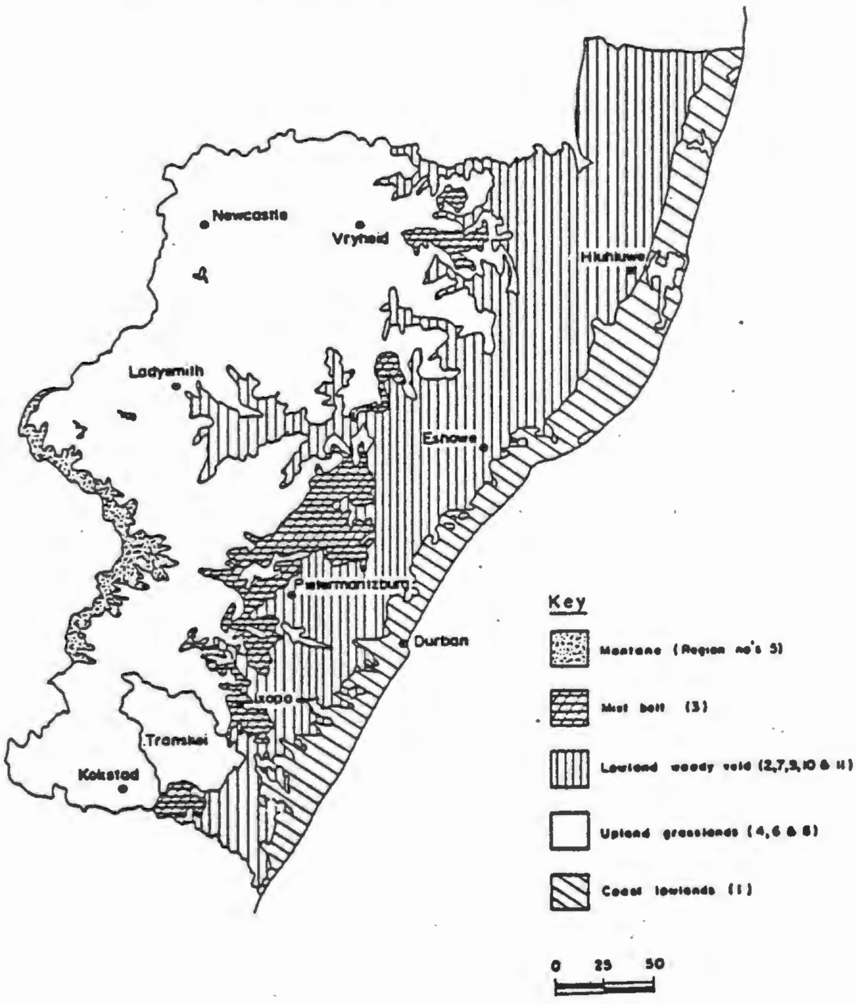
The Natal Province, extending along the eastern seaboard of South Africa, is characterised by a rapidly increasing altitude up to the Drakensberg escarpment, its western boundary. Valleys created by eleven major rivers dissect the landscape. Only in the north is there any flat terrain where rivers spread out into lakes and pans. The combination of this varying topography and associated climate as well as a diverse variety of soils has resulted in a large number of indigenous plants species, some 4506. Subsequently the area now also supports a wide variety of alien species totalling 312. (Macdonald et al., 1985)

The varying bioclimatic diversity of Natal complicated the assessment of alien invasion. Whereas the assessment of the fynbos biome was conducted as a whole, assessment of Natal is broken up into numerous bioclimatic regions and then again according to the land use of the area.

Shown below is a map of Natal identifying the bioclimatic regions used by Macdonald et al. (1985) in their analysis of the alien infestation of this province.

Figure 1: The bioclimatic regions of Natal

Source: Macdonald et al., 1985, p2




The assessment of Natal according to these bioclimatic regions ranked the habitats as follows with regard to their perceived alien invasion severity:

Table 2: Alien plant invasions of Natal's regions

(1) riverine habitat (lowland woody veld)
(2) forest gaps and ecotones (lowland woody veld)
(3) coastal forest (coastal lowland)
(4) riverine habitat (mist belt)
(5) plains - grassland (coastal lowland)
(6) woodland (lowland woody veld)
(7) grassland (upland grassland)
(8) dunes (coastal lowland)
(9) scarps and screes (lowland woody veld)

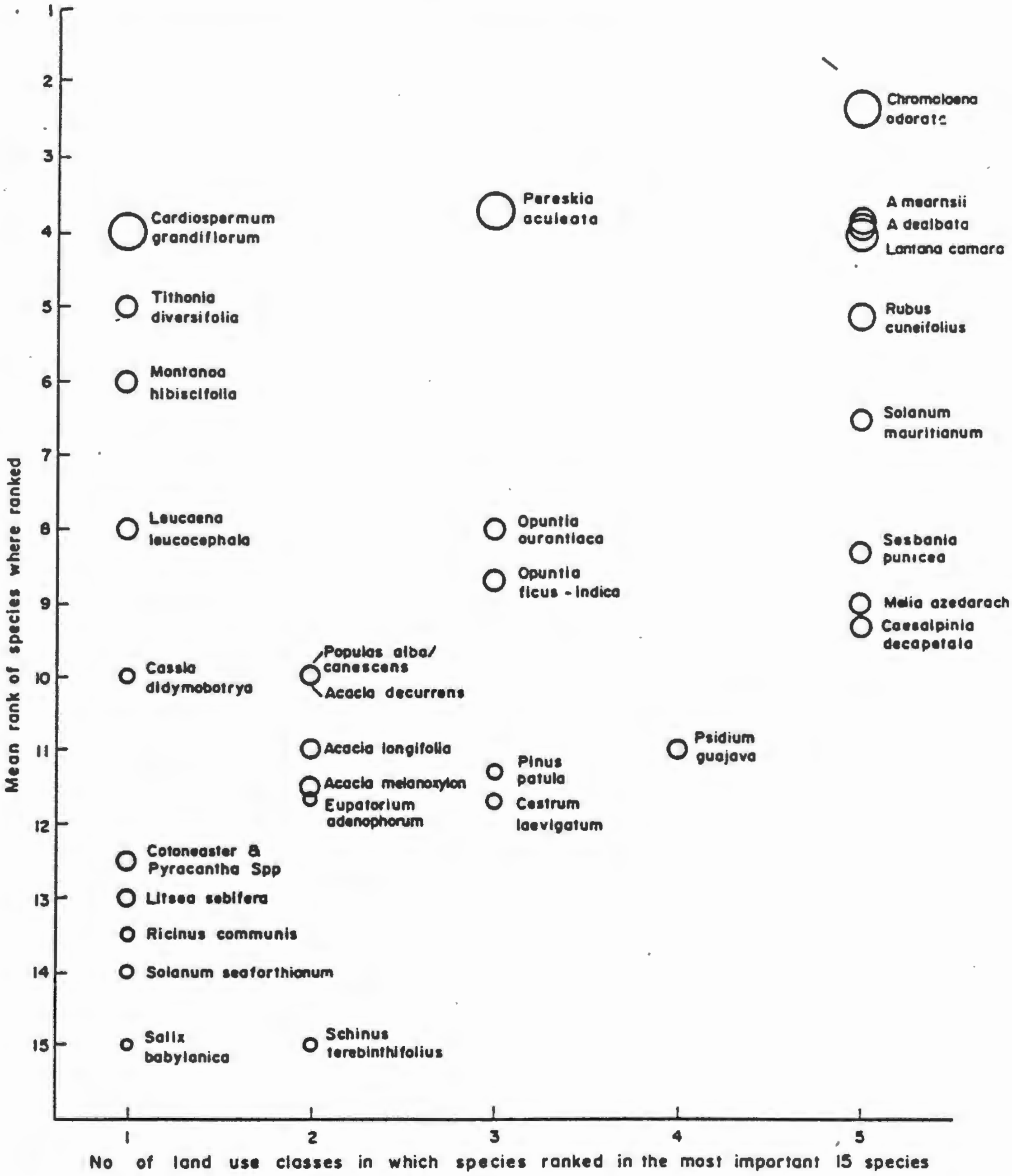
(10) forest gaps and ecotone (mist belt)
(11) grassland (mist belt)
(12) riverine habitat (upland grassland)
(13) forest gaps and ecotones (lowland woody veld)
(14) riverine habitat (montane region)
(15) grassland (montane region)
(16) forest gaps and ecotones (upland grassland) and forest gaps ecotones (montane region)
(17) swamp forest (coastal lowland)

Although there is some overlap in the type of alien species invading the fynbos biome and Natal, the species identified to be causing the greatest concern in Natal differ to those in the Cape. Assessment of the problematic alien species in Natal have been identified but their results have been categorised by land usage. The format adopted provides detailed information of species infestation of five land use areas, namely: agricultural grazing lands, nature conservation estate, utility areas (e.g. road verges), sylvicultural estate and urban open space. The alien species affecting each area do not necessarily coincide but an overall assessment of different species for the Natal Province has identified their order of importance according to a number of land use area specific criteria. (The reader is referred to the original text (Macdonald et al., 1985) for details of criteria used.)

The final ranking of the ten most important species is shown in the diagram below. The particular land use area where the problem manifests itself is also included in the diagram below.

Figure 2: The relative importance of the main invasive alien plant species in Natal.

Source: Macdonald et al. (1985), p34



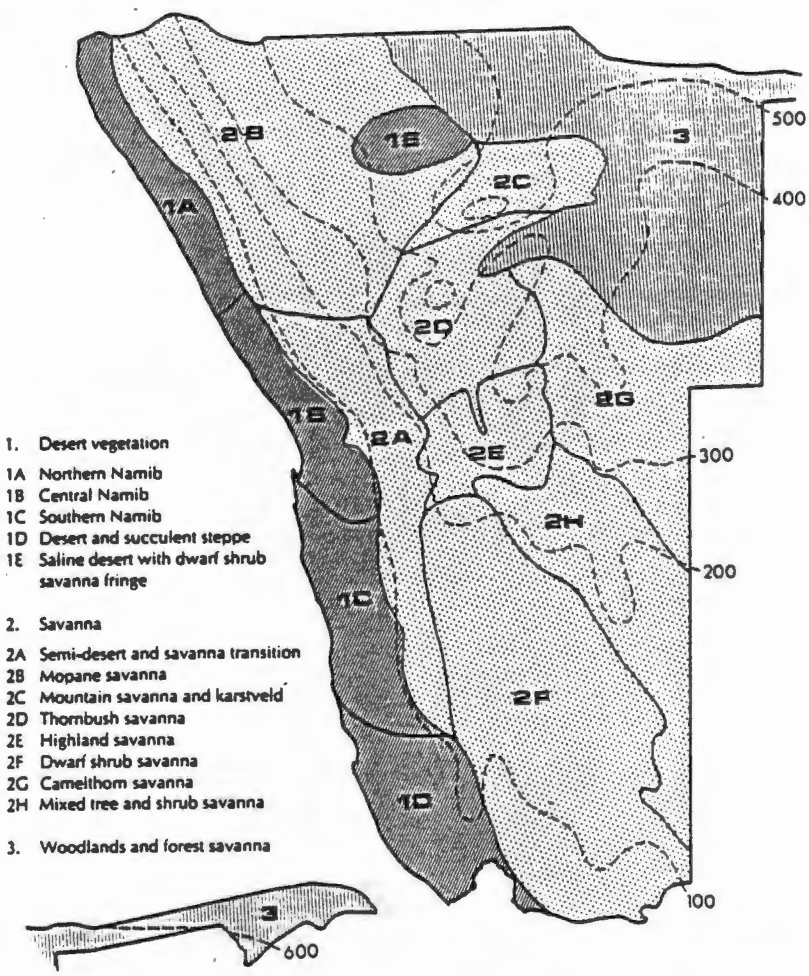

Of the ten most important alien species in Natal, only two are woody species, Acacia mearnsii and Acacia dealbata. Other woody species also known to present problems to a lesser extent are Sesbania punicea and Melia azedarach. Appendices 3, 4 and 5 demarcate zones where control of selected alien species is important to invasion management.

## 2.1.3 Namibia

Namibia's position on the western seaboard of Southern Africa produces a climate generally considered to be arid. Rainfall does however increase from west to east and south to north affecting the distribution of vegetation types as shown map below.

Figure 3: Vegetation zones and the mean annual rainfall isohyets in Namibia

Source: Brown et al. (1985), p48



The Namibia flora is known to contain some 3125 indigenous species (Macdonald et al., 1985) spread over a relatively large area. Approximately 40 invasive alien plant species (Brown et al., 1985) have been identified and although large parts of Namibia are reasonably free of invasion by alien species other parts are already seriously infested. A list of the ten most important invasive species identified in Namibia are listed below.

Table 3: The ten most important invasive alien species in Namibia

(1) Salvinia molesta
(2) Prosopis spp
(3) Nicotiana glauca
(4) Datura innoxia
(5) Opuntia ficus-indica
(6) Melia azedarach
(7) Lantana camara
(8) Ricinus communis
(9) Argemone ochroleuca
(10) Dodonea viscosa

Only the Prosopis spp, Melia azedarach and Lantana camara are woody species and therefore of interest to this project. Distribution maps for the three species have been included in Appendices 6 and 7.

### 2.1.4 Transvaal

The greater part of the landlocked province consists of the Highveld which rises up to the Drakensberg in the east before descending into the Lowveld. The highest rainfall generally falls on the Drakensberg escarpment but elsewhere generally increases from west to east. As a result of the bioclimatic conditions indigenous vegetation patterns are as shown below.

Figure 4: The four broad veld type categories in the Transvaal

Source: Henderson et al. (1984), p299

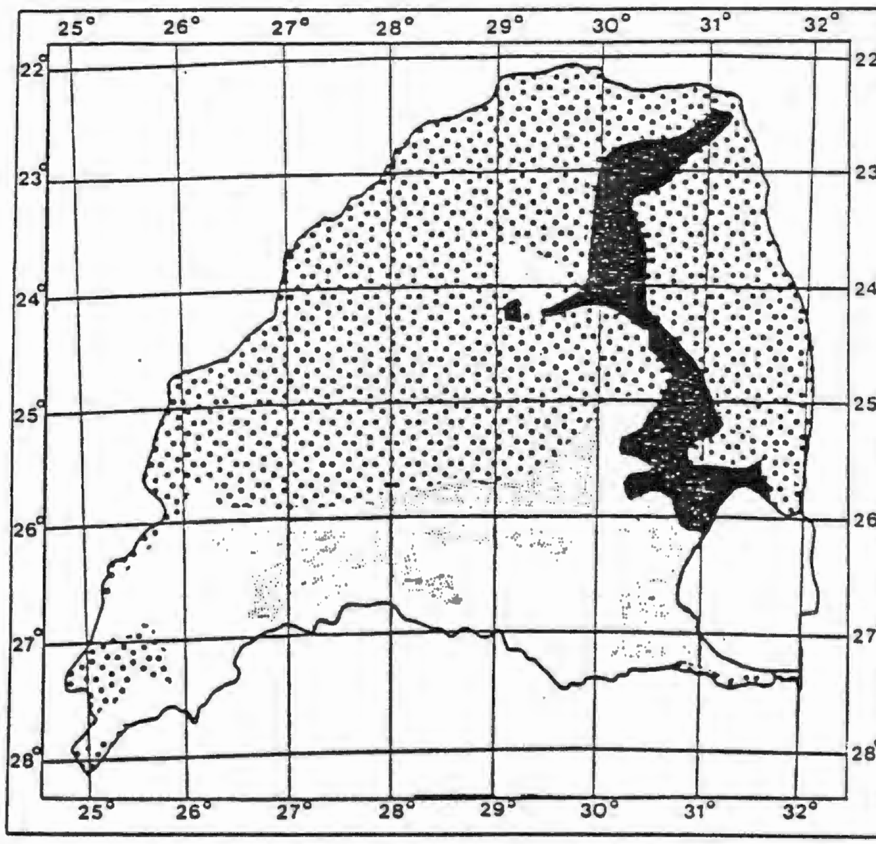



FIG. 2. THE FOUR BROAD VELD TYPE CATEGORIES IN THE TRANSVAAL.

Inland tropical forest types

Tropical bush and savanna types

False grassveld types

Pure grassveld types

Henderson et al. (1984) have assessed the extent of alien wood specie invasion in each of the veld categories. Their results are reported for two areas within each veld type, along streambanks, and roadside and veld areas. Sixty-one invader species were recorded of which the most important and aggressive were:

Table 4: The most important and aggressive alien wood species in the Transvaal

(1) Acacia dealbata
(2) Populus spp.
(3) Melia azedarach
(4) Opuntia ficus-indica (cactus)
(5) Salix bagylonica
(6) Acacia mearnsii

With the exception of Opuntia ficus-indica the problematic wood species in the Transvaal could provide raw material for charcoal production. Distribution maps of quarter degree squares supporting high abundances of each of the above-mentioned species are included in Appendices 8, 9 & 10.

## 2.2 INDIGENOUS INVASIVE WOOD SPECIES

The extent of indigenous wood specie infestation is not as well documented as the alien species. Problems do however exist where farmers have to bear the cost of keeping arable and grazing land area productive. Viljoen (1980) reports Eastern Cape farmers to be plagued by a thorn tree, Acacia karoo, estimated to occupy an area of 2 million ha in that region alone. Margesson (1985) reports encroachment of Eastern Cape farms by Acacia karoo and another indigenous bush specie Diospyros lyciodes.

In Namibia 8 million ha are reported to be infested to the extent that 30% - 50% of its grazing potential is lost. The wood species creating the problem are indigenous thorn trees, Acacia mellifera and Dichrostachys cinerea (Becker, 1985). Acacia erioloba is also already a source used to make commercial charcoal.

## 2.3 THE SIZE OF THE INVASIVE RESOURCE

The maps of the different parts of Southern Africa show that the invasive wood specie problems are encountered virtually countrywide, especially the alien species. This says little about the actual biomass associated with these species. Comprehensive estimates of the alien specie biomass have not been completed, probably because of the enormous task this type of study would involve. As a result it is not possible to make a quantitative estimate of the total area plagued by alien specie infestation but a figure can be put to known areas, where measurements have been taken.

In the fynbos biome Macdonald et al. (1985) have recorded degrees of infestation in several specific areas. The survey is split up into two alien plant groups, Pinus and Hakea; and Acacia and other thicket forming species. The two tables below show areas of infestation, of scattered plants, and of medium and dense infestation.

<u>Table 5</u>: Rough areas of different infestation in the fynbos biome ($km^2$)

<u>Source</u>: Macdonald et al., 1985

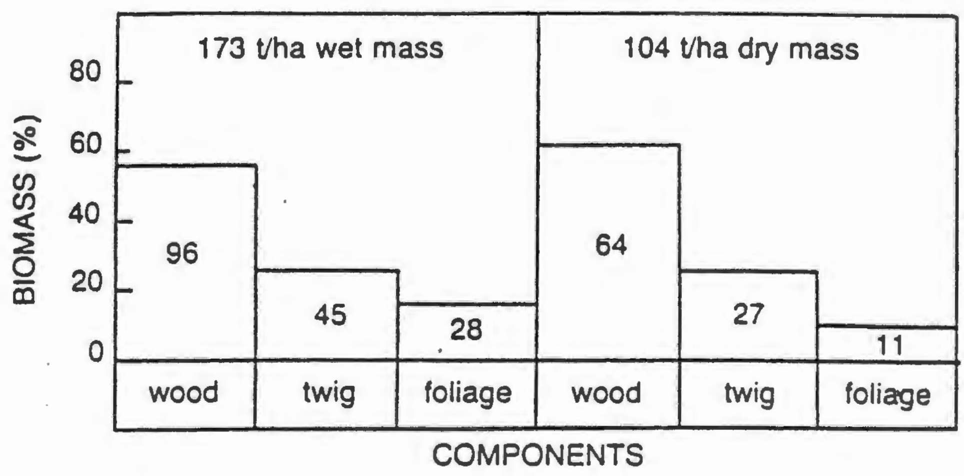
| Alien plant group by infestation and control status | 3118 Calvinia | 3218 Clan-william | 3318 Cape Town | 3319 Wor-cester | 3320 Ladi-smith | 3420 Rivers-dale | 3322 Oudts-hoorn | 3324 Port Elizabeth | 3326 Grahams-town | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| <u>Pinus</u> and <u>Hakea</u> | | | | | | | | | | |
| Uninfested natural vegetation | 4234 | 7983 | 1987 | 5959 | 6988 | 9382 | 7366 | 5360 | 300 | 49560 |
| Scattered plants | 2 | 29 | 231 | 1177 | 161 | | 102 | 697 | | 2400 |
| Medium dense infestations | | 3 | 125 | 307 | 55 | 2 | 122 | 9 | 4 | 627 |
| Dense | | 6 | 62 | 519 | 90 | 8 | 217 | 420 | | 1322 |
| <u>Acacia</u> and other thicket forming species | | | | | | | | | | |
| Uninfested natural vegetation | 4122 | 7630 | 1709 | 6217 | 7597 | 7551 | 9122 | 3970 | 274 | 48190 |
| Scattered plants | 114 | 425 | 161 | 1100 | 77 | 1295 | 86 | 2248 | | 5506 |
| Medium dense infestations | 8 | 164 | 532 | 224 | 27 | 202 | 490 | 156 | 10 | 1814 |
| Dense | | 58 | 881 | 2032 | 83 | 509 | | 671 | 21 | 4256 |

Estimates for Natal and Transvaal are not quite as current nor as detailed as the fynbos biome. Thickets of <u>Acacia mearnsii</u> jungle estimated in South Africa in 1980 totalled 12350 ha, 4344 ha in Natal and 6990 ha in the Transvaal (Bennie, 1982). The size of these thickets were reported to be increasing, measurements of these increases, over the period 1971-1980, being 83% for the whole of South Africa, 50% for Natal and 125% for the Transvaal.

Ignoring increases in wattle areas since 1980 and including areas measured in Natal, Transvaal and the Cape (fynbos biome) the known total area suffering infestation by alien species is 813 000 ha.

To make an estimate of the biomass contained in these infested areas it would be necessary to sample above ground biomass densities in all the areas cited and for all the different species. This immense task has not been done and probably never will be, so an approximation will have to be made. Biomass figures for plantations of <u>Acacia mearnsii</u> (NAS, 1980) are readily available but not for the wild growing thickets. A comprehensive investigation of the above ground biomass associated with mature stands of <u>Acacia saligna</u> and <u>Acacia cyclops</u> found an average of 173 tons per hectare (wet) for 15 different locations around Cape Town (Milton, 1981). The biomass was further broken down into the following categories:

<u>Figure 5</u>: Above-ground biomass for two Australian Acacias
<u>Source</u>: Milton, 1981, p710




If one extends this biomass density over the whole area suffering infestation, although the acacia density will not be representative of all invasive species, it provides an order of magnitude with which the total tonnage of wood, in known areas, can be estimated. Biomass from known areas suffering alien wood infestation can then be roughly approximated to total 140 million tons, 78 million tons of wood and 62 tons of brush (wet). Because of the lower biomass densities of many other invasive species, a more realistic figure is probably half this.

To put this tonnage into perspective, Sorfa (1983), put the estimated consumption of wood for charcoal production in the whole of South Africa, at 880 000 tons for 1985, less than one percent of the biomass available from areas known to be infested by alien wood species. More importantly, Sorfa predicted the surplus of wood residues, upon which the large-scale charcoal producing industry is based, to be absorbed by pulp mills, particle board plants and the charcoal industry by 1985. It may be necessary for the charcoal producing industry to turn to an alternative source of wood in the future, the unwanted alien wood species, but they may need to make use of entirely different technology for this to be economically viable.

Eberhard (1986) estimated the consumption of air-dried wood, as a domestic fuel, to be 12,88 million tons in the underdeveloped areas of South Africa for 1984. Many areas are reported to be facing rapidly diminishing supplies of this natural energy source and considering implementing afforestation programmes to meet the shortfalls. This may not be necessary, as their entire yearly fuelwood requirement is already contained in less than 20% of the known biomass in infested areas, ironically earmarked for disposal. Rather than going to the trouble and expense of large-scale afforestation, it is worthwhile to consider using the stands of alien species as ready made woodlots. Distances between wood supplies and areas facing shortages that presently make utilisation of the available resource uneconomic, may be overcome through charcoal production.

# CHAPTER 3

## BUSH CLEARING / FIREWOOD COSTS

Macdonald et al. (1984b) have produced a detailed document synthesizing the current knowledge on alien invader control within the fynbos biome. It is pointed out that perception of the problem associated with alien specie invasion of the natural landscapes is relatively new. Before the 1950's only a few botanists expressed concern over the threat posed by the alien invasion. It was only in 1958 that the first voluntary hack group (Mountain Club of South Africa) was convened. Acceptance of the problem posed by alien vegetation was only accepted by nature conservation policy makers in 1970.

### 3.1 ALIEN CONTROL TECHNIQUES

Alien control techniques fall into three categories: mechanical, chemical and biological. Descriptions and notes on a range of control techniques are reported by Macdonald et al. (1984b). Control strategies often employ a combination of techniques simultaneously to improve chances of successful alien control. Mechanical control of alien species, i.e. cutting down of alien plants, is often insufficient for alien control. The aim of mechanical control is to kill the offending plant but many species have coppicing capabilities, regrowing from the stump left behind. Enormous seed banks accumulated in the soil through the years, also make the task of mechanical control alone insufficient, as germination very quickly replaces the biomass removed. Chemical control techniques usually attack regrowth and are employed on freshly cut stumps and young plants. Combined with mechanical control, effective and relatively fast control can be achieved but the programs are expensive.

Biological control aims at reducing the reproductive potential of the offending specie by reducing their copious seed production. Effective pathogens and predators for many of alien species have been demonstrated but results are only noticeable in the long term. Where particular species have commercial value as timber or tannin producers a conflict of interests can prevent their use. The long term nature of the biological control strategy does not free biomass for utilization and is thus not as important as mechanical control.

## 3.2 MECHANICAL CONTROL COSTS

The document produced by Macdonald et al. (1984b) includes accounts by several official bodies on their alien plant control programs. Known distributions of the most important alien species are presented and tabular summaries of local experience gained in their control included.

A mechanical/chemical control strategy, used by the Department of Environment Affairs (Forestry Branch) (9) in their mountain catchment areas, is reported as follows:

(1) Alien invader plants are felled between months of September and March using chainsaws, bush cutters and machetes.

(2) A year later the area is control-burned.

(3) Follow-up weeding operations at regular intervals.

(4) Arbocides (foliar spray) are sometimes used on Acacia seedlings within five weeks of the control burn.

The cost of each operation is however not reported probably because of the large variation from one area to another. Cost data for a number of other alien plant control programs have been presented but generally the costs are not related to areas cleared or biomass generated. This does not allow clear assessment of costs involved of removing alien vegetation.

Description of one alien control operation conducted on the Cape of Good Hope Nature Reserve (Macdonald et al., 1984b) provides some insight into the costs of initial clearing of densely infested landscape. A 14-man team managed to clear and administer a herbicide treatment (to the remaining stumps) in 3-5 days per hectare at a cost of R250/day excluding some overheads. This works out to roughly R1000/ha. It is not clear whether this includes the cost of burning the felled bush or not but certainly does not include follow up operation costs. Further information in the form of an estimate for the clearing of the Driftsands Nature Reserve (Macdonald et al., 1984b) is included. An estimation of R200 000 is projected for an area of 592 ha representing a cost of R337/ha.

A request to the Conservation Forestry, Western Cape Region, generated more detailed information on clearing costs presumed to be typical of the Cape Peninsula Area.

Average felling costs were reported for <u>Acacia cyclops</u>/<u>saligna</u>/<u>longifolia</u> (80% cover, stem diameters 3-15 cms) to be:

| | Rand |
|---|---|
| Labour: 11 mandays/ha | 220 |
| Chainsaw running costs | 45 |
| Supervision: 1 manday/ha | 30 |
| Transport | 32 |
| Overheads | 98 |
| Total | 425 |

Average burning of felled material per hectare:

| | Rand |
|---|---|
| Labour: 10 mandays/ha | 226 |
| Supervision | 30 |
| Transport | 32 |
| Expendable stores (diesel, etc.) | 20 |
| Overheads | 92 |
| Total | 400 |

## 3.3 THE USE OF FIRE

Fire is used in conjunction with most control strategies for a number of reasons. Its use as a control strategy on its own is seldom recommended because many of the alien species are fire adapted thereby enhancing regeneration after the fire; burnt remnants hamper access for follow-up work on the regenerating seedlings; and successful alien control by fire may also eliminate the recovery of the natural vegetation.

One principle use for fire is to destroy the biomass generated in mechanical control programs thereby eliminating the fire hazard associated with piles of dead wood. The timber is felled, stacked in piles before setting it alight. The action of fire if used in the correct sequence can be beneficial in the control of several species. The heat from the fire can be used to burn regenerating seedlings and in assisting seed store reduction accumulated in the soil. Burning felled biomass to kill regenerated seedlings can be achieved on the following species (Macdonald et al., 1984b):

(1) <u>Hakea spp</u>
(2) <u>Pinus spp</u>

These two species do not accumulate seed in the soil and only produce seed after felling (or fire). Stacking of felled timber constrains the released seed to the area below the stacked biomass. Controlled burning of the stack 9-12 months later kills the seedlings that germinate under the stacked wood.

Burning of felled timber can be used to reduce the seed store accumulated in the soil. This technique is reported to be highly successful for the following species:

(1) Acacia cyclops
(2) Acacia longifolia
(3) Acacia mearnsii
(4) Acacia melanoxylon
(5) Leptospermum laevigatum

Germination of seed stored in the soil is triggered by the heat during burning of felled timber. Follow-up on dense regrowth of young seedlings increases the effectiveness of chemical herbicides administered soon after, resulting in a significant reduction in the seed store.

If biomass utilization is to be considered, the use of fire to kill seedlings or to create even germination will be reduced or even eliminated, thereby affecting current control strategies. It may be possible to utilize the biomass as it is harvested and thereby prevent seed release in the case of Hakea and Pinus. Alternatively exclusive use of the thicker timber would free the branches and leaves as a fuel for later burning.

## 3.4 FIELD EXPERIMENTS

The information collected from the literature on bush clearing rates invariably involved the use of chainsaws. Purchase and operating cost of these machines will in many instances be beyond the means of the rural operator who would then have to rely on manual implements. The action research program set up to measure real wood and charcoal production rates, provided an opportunity to measure the clearing rates based on manual implements as well as subsequent cutting up into firewood pieces and different sizes for charcoal production. The results of these experiments are presented below.

### 3.4.1 Bush clearing costs

Clearing of alien bush for control purposes is conducted extensively but a wide variation in associated costs are reported. The reason for the variation is probably due to large variations in above ground biomass from one area to another and reporting of marginal costs involved, rather than real costs. Two operations in mechanical control are involved: the felling and stacking of the timber and the subsequent burning of biomass piles. Information from the Department of Environment Affairs (Forestry Branch) listed in Section 3.2, would appear to be the most accurate cost data for bush clearing. Although no allowance for aboveground biomass is included, the information indicates that a felling rate of 900 $m^2$/manday can be achieved on 80% cover comprising 3-15 cm stems with chainsaw assistance incurring a cost of R425/ha. A further burning rate 1000 $m^2$/manday can be achieved on the piled timber, resulting in a total clearing cost of R825/ha.

During the practical experiments conducted with various kilns in this project, the clearing rates achieved by experienced wood cutters were measured for mixed stands of Port Jackson (Acacia Saligna) and Rooikranz (Acacia cyclops). Clearing rates of between 115-125 $m^2$/manday were achieved where biomass cover was approximately 100-120 tons/ha (wet), comprising 5-20 cm diameter trees. Assuming a daily labour rate earned by woodcutters in the firewood industry R4-5/day, manual clearing costs would be similar to those incurred by the Department of Environment Affairs (Forestry Branch), i.e. R400/ha. In areas supporting young aliens, less than 3m, biomass totalling roughly 60 tons/ha was cleared manually at a rate of 130-200 $m^2$/manday at a cost of R250/ha.

### 3.4.2 Fuelwood production

The assessment of firewood production costs has been approached from two angles, the manual woodcutter cutting for his own business and the hired woodcutter producing wood for a semi-commercial operation. The firewood cutters earning a living from roadside sales seem to be driven into the business through lack of any other alternative. As a result woodcutters tend to be poorly skilled with virtually no schooling. Wood-cutting is a menial and arduous task and with low motivation results in low production rates. More organised operators manage far better production rates usually through use of a chainsaw. Alien species are currently being used as a source for firewood in several areas of the Cape. Analysis of the time and labour involved in this informal fuelwood supply was conducted to determine the production costs.

### 3.4.3 Manual harvesting

The felling of the timber is taken on by local woodcutters who sell the wood either at the roadside or via a wholesaler, to earn a living. To assess the firewood production rate, a small team of these woodcutters were commissioned to produce firewood pieces from an area supporting Port Jackson (*Acacia saligna*). This particular wood species is not a popular firewood (N.A.S., 1980) but, it being an invasive alien Acacia, could be considered representative of invasive type species requiring control. If the energy value of the alien wood species is to be tapped in firewood form, size reduction to the 'stick' is necessary. One advantage of charcoal production is the wood need not be reduced to such a small size. Gaylard (1985) reports his retort to use timber lengths of 2,4 meters. The Armco Robson kiln is also reported to use the same timber dimension which significantly reduces the fuelwood supply costs. However not all the carbonization processes have this advantage but can usually operate well on 0,5 meter lengths. For this reason time related costs for 0,5 and 2,4 meter lengths are included in the fuelwood cost data. The experiment was based on the use of bowsaws and 'slasher' machetes. The results are presented below in manhours required per ton of wet wood.

Table 6: Manual fuelwood production costs

| | Poles | 0,5 m Length | Firewood |
|---|---|---|---|
| Labour (mandays/ton) | 3,3 | 4,6 | 6,9 |
| Production cost (Rand/ton) | 17 | 24 | 37 |
| Equipment cost (Rand/ton) | 2 | 3 | 5 |
| Earnings (Rands/day) | 4,64 | 4,64 | 4,64 |

Being self-employed means that the production costs are really only those of the equipment used. Real labour earnings need to be calculated from the selling price of the wood. Sale of firewood from the roadside was reported by the woodcutters to be erratic making it difficult to assess the earnings generated by the firewood preparation. This difficulty was overcome by consulting a firewood wholesaler buying wood directly from a dedicated woodcutting team. The contract price paid for wood is R 11.00 per 1000 sticks. Although the 'stick' specification was very loosely defined they were found to average roughly 0,3 kg each. The wood was purchased weekly allowing no time for drying out. Analysis of Rooikranz showed moisture content of freshly cut timber to be 100% on an oven dry basis. The contract price was thus equivalent to R37/ton (wet) and R74/ton (oven dry). From this data, costs of wood production at each stage could be estimated. The results are shown above. The woodcutter was expected to provide his own woodcutting equipment, estimates of which are also included in the table above. From this, nett earnings for the production of firewood were calculated. Assuming the same earnings per day, costs of 0,5m and 2m lengths could also be estimated and are included in the table above.

It is important to note at this stage, that even though the firewood produced by these woodcutters is for the braai market and prices paid, therefore, high, the earnings of the woodcutters are extremely low. If alien bush is to be considered as a basic cooking fuel for underdeveloped areas, wood prices would need to be lower and therefore earnings would be even lower. Lower earnings than those presented above are seen as a major obstacle to the viability of this wood energy supply to underdeveloped areas.

### 3.4.4 Mechanically assisted harvesting

Assessment of mechanical assistance in alien tree felling was conducted through discussions with woodcutters using chainsaws. Generally the woodcutters used one chainsaw between two or three operators because of the difficulties in felling this bushy species. One man would clear the way through the light branches at ground level and fell the tree with a light axe or machete. The felled timber would be trimmed to poles and carried to a central production site.

The chainsaw operator would then cut up the wood into short pieces. Those pieces too thick would then be split by hand. The results of mechanical assistance in alien fuelwood harvesting are presented below in the same format as the manual production figures.

Table 7: Mechanically assisted fuelwood production costs

| | Poles | 0,5 m Length | Firewood |
|---|---|---|---|
| Labour (mandays/ton) | 1,5 | 2,1 | 4,4 |
| Production cost (Rand/ton) | 13 | 18 | 37 |
| Equipment cost (Rand/ton) | 5 | 7 | 15 |
| Earnings (Rands/day) | 5,00 | 5,00 | 5,00 |

The fuelwood is still bought at the same contract price of R11 per 1000 sticks, but the production rate is faster so, gross earnings are higher. However the woodcutter is in many cases, expected to finance the cost of the chainsaw, costs for which are shown in the same table. The chainsaw costs are based on three year life using 2 chains a month. More skilled operation will no doubt produce better production rates but most woodcutters can little afford a course on chainsaw handling.

The influence of mechanical assistance does not improve the wages of the operator at this level significantly but does allow a higher production rate and a less arduous task. In view of the capital outlay, difficulties of field maintenance, the uncertainties of unskilled operator performance and the marginal economic advantage associated with chainsaw usage, manual harvesting of the alien species is recommended to the rural woodcutter.

### 3.4.5 Semi-commercial harvesting

Assessment of another operation near Ysterfontein showed different results. Here a farmer requiring removal of Port Jackson, supplied and maintained chainsaws for his labour, charging a hiring fee of R5/week per chainsaw. The woodcutters earned their pay through sale of wood to the farmer at R9/1000 sticks who then marketed the fuel to the coloured community in Saldanha Bay. Cutting a more abundant wood specie and better motivation (probably a result of support from the farmer) generated better production results, improving the earnings of these woodcutters. Earnings were still however low at roughly R10/day. These earnings fall in line with those quoted by Johansson (1986) and Gaylard (1985) for rural labour involved in wood processing industries. Salaries paid to Council labour involved in bush clearing in Cape Town indicate a minimum wage of R20/day (R400/month) (Bijl, 1988). If semi-commercial operations were to require more skilled labour, this wage level is probably more appropriate. Production rates would also rise correspondingly resulting in wood production costs as shown below:

Table 8: Semi-commercial wood costs

| | Poles | 0,5 m Length | Firewood |
|---|---|---|---|
| Labour (mandays/ton) | 0,95 | 1,2 | 1,7 |
| Production cost (Rand/ton) | 17 | 21 | 30 |
| Equipment cost (Rand/ton) | 5 | 6 | 12 |
| Earnings (Rands/day) | 10,58 | 10,58 | 10,58 |

If a minimum wage of R20/day is paid for labour, production costs will have to include equipment costs. The resulting wood costs would be:

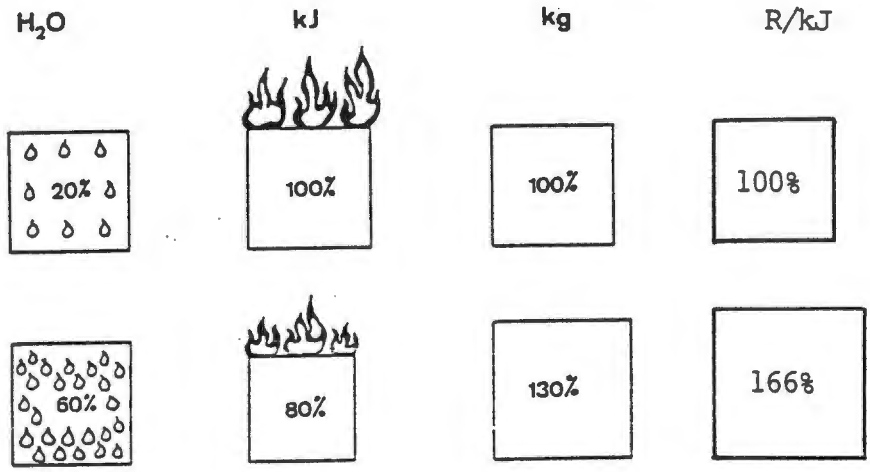
Table 9: Minimum wages of R20/day

| | Poles | 0,5 m Length | Firewood |
|---|---|---|---|
| Labour (mandays/ton) | 0,95 | 1,2 | 1,7 |
| Equipment cost (Rand/ton) | 5 | 6 | 12 |
| Labour costs (Rands/day) | 20 | 20 | 20 |
| Wood cost (Rands/ton) | 24 | 30 | 46 |

### 3.4.6 Wood moisture

Firewood in Cape Town is generally traded wet. Analysis of several informal firewood suppliers in and around Cape Town has shown that trading of firewood is conducted piecemeal, either on a daily or weekly basis. Payment is on a contract basis to maintain motivation and ensure production rate. Stock security and the 'stick' system of sales also force the operators to trade stocks shortly after felling. As a result wood is generally traded without any drying. As supplies of the popular firewood, Rooikranz, have receded some distance from Cape Town, transport of this wet wood represents gross inefficiency in energy terms. Although never done, allowing the wood to dry could reduce transport costs, borne by the wholesaler, by 60% in energy terms as shown below.

Figure 6: The effect of wood-drying on transport




Moisture content plays a much more important role in charcoal production economics. Wood moisture is driven off during charcoal production and raw material costs should therefore be measured on a moisture free basis. Green wood moisture content varies from one species to another and as a result the economics of production of oven-dry wood will vary as well. Some green wood moisture data is available from the literature but wood production rates as a function of different wood species are not.

If one assumes that the wood production rates for alien wood species can be approximated by the rates measured for Port Jackson and Rooikranz then green wood moisture content will have a marked effect on oven-dry wood production rates. In the absence of any other data, estimation of dry wood production costs can be used to project charcoal production costs based on other wood species. As this project has focused on the use of Port Jackson and Rooikranz, wood production costs will be reported in relation to these two species. The table below lists the invasive wood species of interest to this project, the dry wood production costs in relation to Port Jackson and whether manual harvesting can be considered. Where timber species generally produce stems thicker than 20cm chainsaws are recommended.

Table 10: Invasive wood species for charcoal production

| | Specie | Green Moisture | Manual/ Chainsaw | Relative dry wood costs |
|---|---|---|---|---|
| (1) | Acacia Saligna | 73 | m | 1,00 |
| (2) | Acacia Cyclops | 100 | m | 1,16 |
| (3) | Acacia Longifolia | | m | |
| (4) | Albizia Lophantha | | | |
| (5) | Hakea Sericea | | m | |
| (6) | Acacia Mearnsii | 64 | c | 0,94 |
| (7) | Leptospermum Laevigatum | | m | |
| (8) | Pinus Pinaster | 85 | c | 1,07 |
| (9) | Acacia Melanoxylon | 68 | c | 0,97 |
| (10) | Sesbania Punicea | | | |
| (11) | Prosopis spp. | | c | |
| (12) | Melia azedarach | 67 | c | 0,97 |
| (13) | Acacia dealbata | | | |
| (14) | Populus spp. | 110 | c | 1,21 |
| (15) | Salix babylonica | 76 | c | 1,02 |
| (16) | Acacia Karoo | 65 | m | 0,95 |
| (17) | Diospyros lyciodes. | | m | |
| (18) | Acacia erioloba | 45 | c | 0,83 |

# CHAPTER 4

## CHARCOAL VERSUS WOOD

Charcoal production from alien wood species already forms part of the timber processing industry in South Africa. Production of 76 100 tons was produced in 1982 and expected to increase by 47% by 1985 (Bennie, 1982). Production is primarily based on wood from plantations of *Acacia mearnsii* (Black wattle) and *Eucalyptus grandis* (Gum). The charcoal industry is concentrated mainly in Natal and South-eastern Transvaal. In Natal, charcoal is produced mainly from plantation wastes, generated by the pulpwood, mining timber and wood chip industries. The easy access and uniform size and density of the wood waste make it an ideal source for large-scale capital-intensive production. Charcoal production from invasive wattle jungle, primarily in the Transvaal, is reported to involve expensive harvesting costs and as a result restricts production to smaller scale operations, generally conducted by farmers as a sideline business. The charcoal produced by both the smaller and large scale operations, is supplied to the domestic and industrial markets with the industrial consumption taking 57% of the market in 1980 (Cohen, 1982). Charcoal has several uses in industry, as a source of carbon, being included. In the domestic market in South Africa, charcoal is used virtually exclusively as a fuel for braaiing and therefore a luxury product commanding good prices.

Charcoal is also one of the major domestic fuels used in the developing world, whose production provides a source of livelihood for large numbers of people who produce it, distribute and sell it. The use of charcoal in the developing world is primarily as a cooking fuel in urban areas. Foley

(1986) indicates that the consumption patterns of charcoal in the developing countries display wide variations without any easily identifiable reason. In certain areas its use is firmly established while in others firewood is the preferred fuel in apparently similar circumstances. These variations are evident in Africa, Asia as well as Latin America.

Energy consumption patterns in the underdeveloped areas of South Africa have been investigated by Eberhard (1986). Charcoal does not appear in any of the areas surveyed indicating the fuel to be foreign in this part of Africa. Fuelwood and dung are the two indigenous fuel sources used.

Use of charcoal for domestic cooking elsewhere is related to social and economic factors. Foley (1986) suggests that people (in those countries using charcoal) tend to change from one fuel to another as their income rises. In this progression charcoal usually fits between wood and conventional fuels. Many of the underdeveloped areas in South Africa make use of a range of fuels from dung to wood to conventional fuel types. It seems likely then that a cultural influence must play some part in the use of charcoal as the absence of charcoal usage in South Africa is probably a function of unfamiliarity with the fuel.

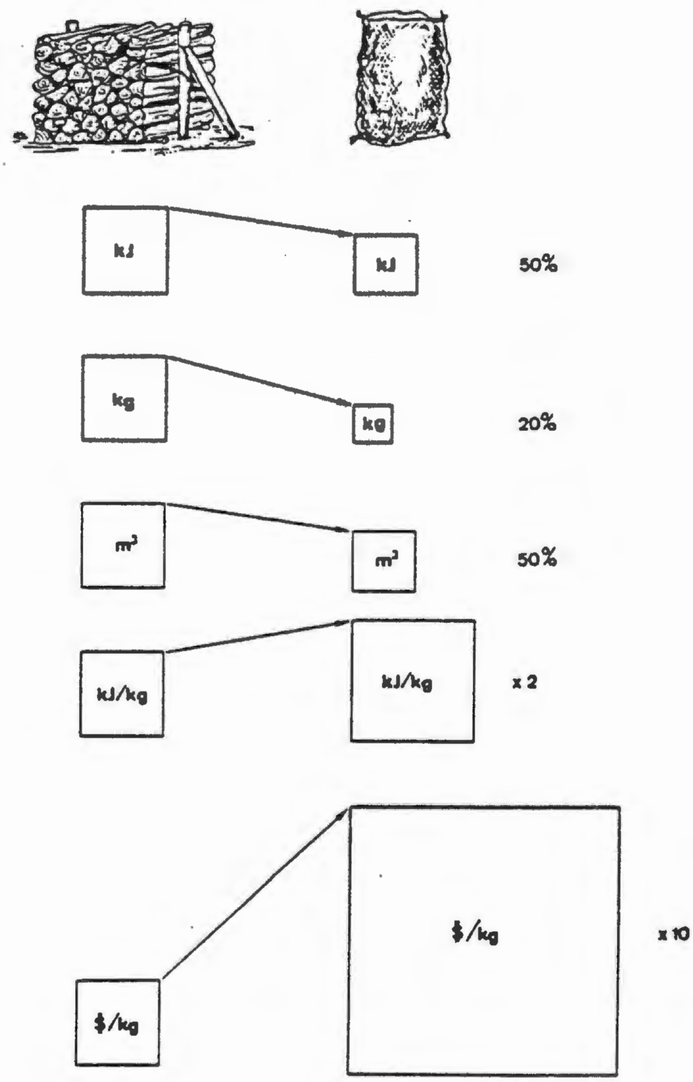
Domestic charcoal consumption figures vary widely from surveys reported by Foley (1986) without any reason for the variation given. The nature of rural and peri-urban fuel consumption surveys are probably responsible for the wide spread in data. Foley (1986) however reports an annual consumption range of 100 - 150 kg per head to be realistic. This is equivalent to 3-4.5 GJ/person-year.

## 4.1 CHARCOAL CHARACTERISTICS

An International Labour Office publication (1985) provides a simple illustration of the differences between wood and charcoal.

Figure 7: Differences between wood and charcoal

Source: ILO (1985), p49

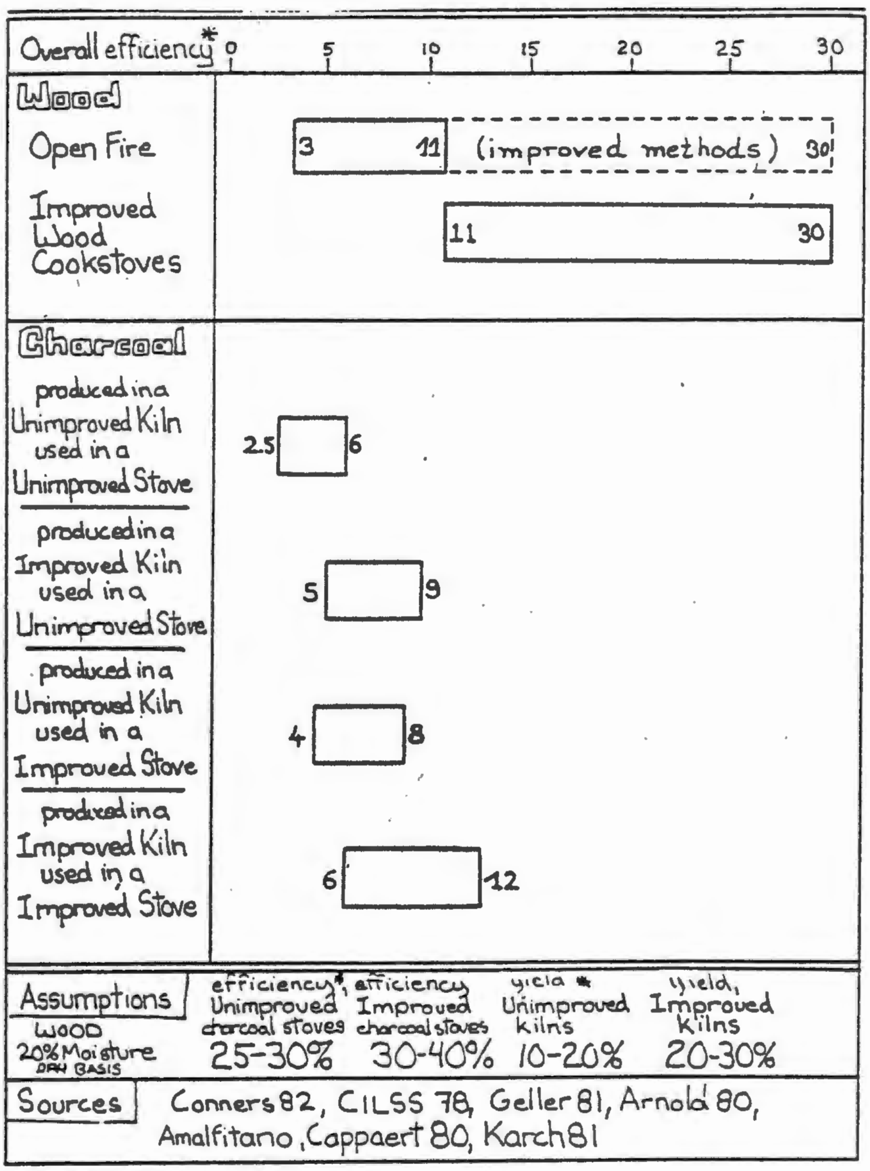



In addition, when compared to wood in the context of an urban fuel source, charcoal is easier to store, requires no breaking up before utilization and burns smokelessly. Charcoal can also be used in small, efficient and inexpensive stoves and it doesn't deteriorate in storage.

The overall efficiency of wood and charcoal utilization in useful energy terms is clearly illustrated by the following diagram.

Figure 8: Comparing the overall efficiencies of wood and charcoal

Source: Boutette (1984), p6




Several aspects of charcoal can be identified from the rough comparisons shown in the two preceding figures.

(1) Charcoal is not the most efficient means of using biomass for domestic cooking.

(2) If emphasis is placed on fuel resource economy, improved wood cooking stoves would have far greater impact on energy savings.

(3) Virtually the same overall efficiency in energy terms can be achieved in an open fire as that achieved by improved charcoal production and utilization technology.

(4) Energy costs to the consumer can increase fivefold using charcoal.

(5) Earnings can be increased twofold through the manufacture and sale of charcoal instead of wood.

(6) Twofold increase in energy density of charcoal halves the costs of energy distribution.

## 4.2 CHARCOAL TRANSPORT ADVANTAGE

It is in transportation that charcoal has the most marked advantage over wood due to the twofold increase in energy density. As charcoal consumption is primarily in the urban areas and production in the rural areas, transportation will affect the final energy cost. Charcoal is reported to be transported up to 400 km to the market in Nairobi (Foley, 1986). Simple calculations will however show that charcoal cannot be transported economically over this distance (round trip of 800km). The only explanation would seem to be that the charcoal is used to reduce the return trip costs of another commodity taken out to the rural areas. If wood and charcoal are the only two commodities produced in the rural areas, charcoal would most certainly generate the best return for both the charcoal suppliers and the truck owner as both would be constrained by the carrying capacity of the truck.

Smith (1985) and Boutette (1984) show that the higher energy density of charcoal, favours production of charcoal over wood in certain instances, when distances between the source and market involve expensive haulage. The argument shows that, taking into account the higher cost of producing charcoal than fuelwood and the lower cost of transporting it per unit of energy, a point distance from the production area will be reached where costs of producing and transporting charcoal and wood are equal in terms of usable energy content. Beyond the breakeven point or distance, it is more cost-effective to convert the wood to charcoal. Smith (1985) correctly points out that the evaluation of breakeven distances will not affect entrepreneurial decision-making. The entrepreneur will be influenced by financial returns of wood or charcoal. There will be, nevertheless, a breakeven distance based on financial considerations where the more favourable transportation costs will allow charcoal to be more profitable than wood. However breakeven distances calculated for the two cases need not show the same preference for wood or charcoal. In both energy and financial terms, there is a limit to which the breakeven argument can be taken before the transport costs inflate the fuel price beyond that of an alternative energy source.

When evaluating breakeven distances, it is therefore important to differentiate between energy users, who wish to create the most economic energy supply, and energy producers, who wish to supply energy most profitably.

## 4.3 COST OF ENERGY SUPPLY

The breakeven distance beyond which charcoal production provides a cheaper energy source than firewood can be calculated from the following formula (Smith, 1985, p37):

$$y = \frac{Pc - Pw.H}{Pt\ (H - 1)}$$

where y = distance in km; Pc = charcoal cost per ton at source; Pw = firewood cost per ton at source; Pt = transport cost per ton/kilometer, and H is the ratio of usable energy in charcoal to that in wood taking into account net calorific value of the materials and the relative efficiencies for each fuel.

$$H = \frac{Ec - Cc}{Ew.Cw}$$

Cc = calorific value of charcoal; Cw = calorific value of wood; Ec = efficiency of charcoal equipment (e.g. stove); and Ew = efficiency of wood-fired equipment.

The breakeven distance based on energy terms will enable organisations and governments intent on providing financial assistance for energy supply to identify the most cost-effective means of utilizing wood fuel to supply the energy needs in a region some distance from the source. This analysis will also be important to energy users organising their own fuel supply. An example would be a group of women traditionally collecting wood by hand, now hiring a vehicle to fetch wood supplies from the closest source. If they have to collect wood beyond the breakeven point it would pay them to convert the wood to charcoal before fetching it in the hired vehicle. The breakeven distance is also applicable to concerns using fuelwood as a fuel source in plant operations e.g. to run a boiler or gasification plant on biomass.

## 4.4 ENERGY VALUE TO THE ENTREPRENEUR

The entrepreneur who wishes to make a living from fuelwood reserves as an energy resource needs to evaluate the market prices of firewood and charcoal and the economics of charcoal production. A similar breakeven distance for firewood and charcoal viability can be calculated using the following equation:

$$y = \frac{(Mw-Pw) - (Mc-Pc)\,\frac{Eff.100}{Wm + 100}}{Pt\,\left(1 - \frac{Eff.100}{Mc + 100}\right)}$$

where Mw = market price of wood per ton; Mc = market price of charcoal per ton; Eff = conversion efficiency of wood to charcoal. The moisture content of the wood (Wm) plays an important role in this equation as the yield of charcoal is affected moisture content.

## 4.5 CHARCOAL PRODUCTION TECHNIQUES

The term 'charcoal' covers a wide range of materials from virtually pure carbon to a mixture containing carbon and a combination of tars, oil, water and organic acids (Foley, 1986). The production of charcoal from biomass is effected by heating the raw material, which after drying the wood out, instigates a reaction known as pyrolysis or carbonisation. To produce charcoal, heating has to be done with limited, or preferably no, oxygen. Oxygen present allows combustion to occur rather than pyrolysis, producing heat, gases and ash, not charcoal. The pyrolysis of wood involves a series of complex reactions where changes in heating conditions, wood composition and preparation, may not only affect the rate but also the course of these reactions (Kansa et al., 1977). Different carbonising techniques, wood types and wood preparation will therefore produce a range of charcoal quality and conversion rates.

While the process of pyrolysis can be analysed in complex mathematical models, the mechanisms of charcoal production can also be viewed in much simpler terms. The carbonistion process is often viewed as a distillation process, referred to as dry distillation of wood. Although not strictly correct this approach is simpler to understand and correlate with simple charcoal production techniques. Emrich (1985) describes the distillation process according to temperature:

100-170°C - all loosely bound water is evaporated and driven off

170-270°C - gases develop containing carbon monoxide, carbon dioxide and condensable vapours

270-280°C - an exothermic reaction starts, detected by a rise in temperature, CO and $CO_2$ cease and quantity of vapours increase.

Emrich indicates that once the exothermic reaction starts no additional external heating is required. The temperature will increase to 400-450 °C, assuming of course that the insulation is effective. To achieve higher temperatures the process must be supported with extra heat from outside.

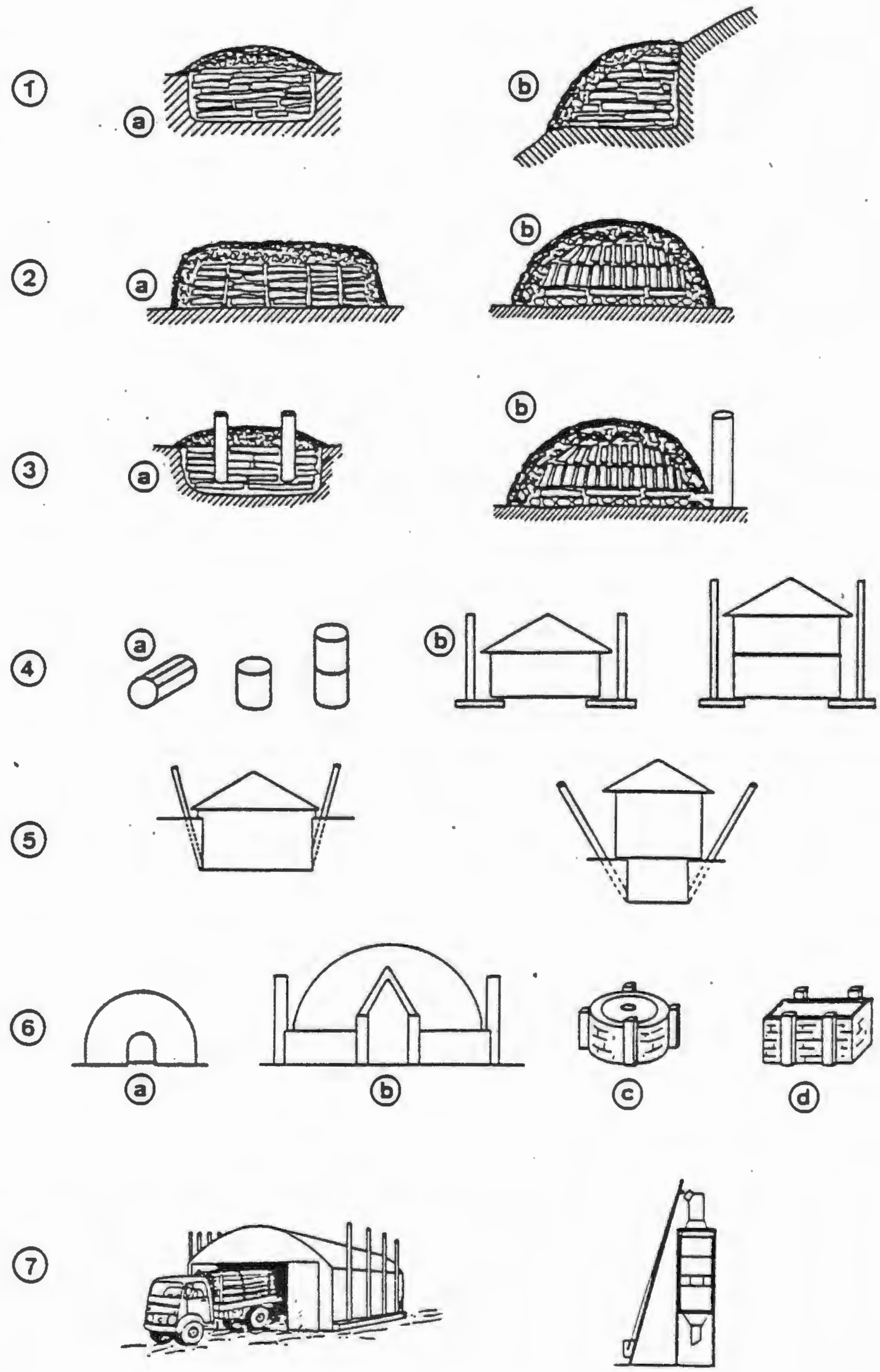
The exothermic nature of the pyrolysis of wood is not generally considered true. There is enough evidence to show that the principle decomposition reactions are actually endothermic (Gore, 1982). Nevertheless the amount of energy required once pyrolysis has begun is considerably less than the heating phase prior to it.

Heat for carbonisation can be generated in a number of ways but is usually derived through wood combustion. Kilns develop the heat required by combustion of a part of the charge packed into the equipment for carbonisation. As combustion is required, some oxygen has to admitted to the reaction zone. Direct heat transfer of the hot combustion gases to the rest of the wood charge should provide an ideal heat transfer for carbonisation but this technique does not produce the best yields. The best yields appear to be achieved using an external heat source while maintaining an oxygen free environment in the pyrolysis zone. Developments in this field have produced a more efficient carbonising concept known as a retort. The retort differs from the kiln in the manner in which the heat for carbonisation is generated, i.e. through combustion of wood gas produced during the destructive distillation of wood. This technique usually burns wood initially until the wood gas generated is dry enough to burn. Thereafter heat is supplied by the gas combustion.

The cost of producing charcoal depends to a large extent on the technology employed. Generally the greater the capital investment and more complex the technology the cheaper the charcoal produced. The larger scale operations would lean toward the industrial and export markets whereas the small-scale operators using cheap portable technologies could have stronger links with local demand especially where demand is scattered over a large unurbanised area. Small-scale operations rather than larger expensive production plants allow integration of the rural population into the charcoal producing business thereby generating income in that sector.

The use of charcoal elsewhere in the developing world has lead to the development of a number of small-scale charcoal production techniques. The traditional techniques for making charcoal typically have low production yields thereby requiring more wood for a given amount of charcoal. In areas where fuelwood shortages exist, attempts have been made to increase yields resulting in improvements of small-scale kiln designs. In industrialised countries large-scale charcoal production designs have emerged some with sophisticated technology recovering waste heat, volatile products as well as charcoal. Diagrammatically the range of techniques used in charcoal production has been categorised as shown below:

Figure 9: Charcoal kiln types
Source: ILO, 1985



The choice of charcoal making technologies should not be made on yield alone (Foley, 1986) which has been the principal criterion for assessment in the past. Factors affecting charcoal yield apart from equipment selection are reported to include:

(1) selection and preparation of wood,
(2) choice of site, and
(3) care and skill in operation.

More importantly concentration solely on yield can divert attention from the most important factor, the final cost of production of charcoal. Investment capital, wood preparation costs and kiln management all affect the cost of production. An additional consideration is the prohibitive influence of capital requirements. Expensive, even though the most cost-effective, technology may be inappropriate because of the difficulty in raising the capital requirements.

# CHAPTER 5

# PIT KILNS

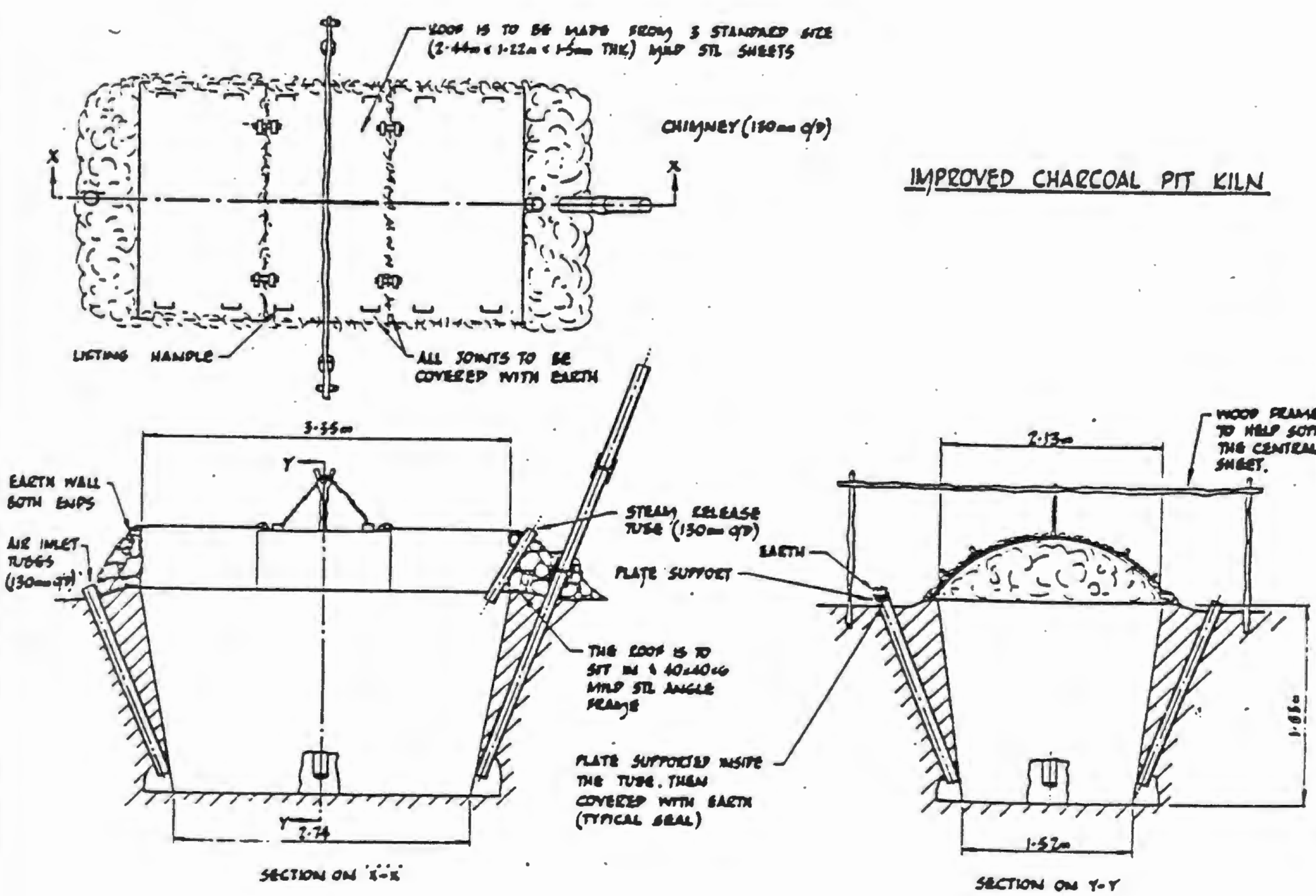
## 5.1 TRADITIONAL PIT AND EARTH MOUND KILNS

Descriptions and production capacities for the range of equipment have been reported by a number of authors (Boutette et al., 1984; Bennie, 1982; Emrich, 1985; Foley, 1986; ILO, 1985). The traditional earthmound and pit kilns described, all report that the traditional kilns suffer both low production rates and poor yields and require experience in both construction and operation. Although the kilns can be sited close to the timber supply they are technically not transportable as complete reconstruction has to be implemented to follow the receding timber supply. The experience required to construct and operate these type of kilns are seen as an additional drawback, particularly in a country where no skilled personnel exist and are therefore considered unsuitable for the requirements of this project.

## 5.2 ITDG IMPROVED PIT KILN

An extremely simple, clear technical booklet has been published describing the construction and operation of the improved pit kiln developed by the Intermediate Technology Development Group in Liberia. The kiln has a capacity of around $8m^3$ of stacked wood, the majority of which is contained in a pit dug in the ground to a depth of about 1,8m. The top of the pit is surrounded by a collapsible angle-iron frame clipped together to form a rectangle. Three stock-sized mild steel sheets are sprung into this framework with their edges overlapping to form the curved cover for the pit. Three steel air inlet tubes and one smoke outlet tube are recessed in the pit walls. Turnaround of 5-6 days per kiln is reported to produce up to one ton of charcoal (Paddon, 1984). In addition, availability of a wood supply sufficient for two months is recommended to warrant the effort of digging the pit. Trials conducted by Paddon demonstrated dry mass conversion efficiencies of between 25 and 30 per cent producing 775-900 kg per kiln. The combination of increased conversion efficiency, reduced supervision requirements, simplicity of construction and relatively low capital investment makes this type of kiln an attractive proposition for developing areas. A diagram of the improved pit kiln is shown below.

Figure 10: Improved charcoal pit kiln
Source: Paddon, 1984, p7



Apart from requiring moderate capital the major disadvantage of this kiln is that construction is restricted to regions of firm soil. Soft sandy soils supporting alien vegetation in many parts of the Cape would not suit this kiln design as can be seen from the diagrams of the kiln above.

## 5.3 ASSESSMENT OF A PRIMITIVE PIT KILN

Although there was not much considered going for the pit kiln, especially an unimproved type, the opportunity of evaluating a primitive pit kiln, offered by an ongoing concern based on a simple pit, was taken up. Charcoal is being produced on a farm in the Tsitsikama area as a means of generating income to offset bush clearing costs in a land reclamation program. Mr H. Burnett of Port Elizabeth, owner of the farm, has been selling the charcoal produced in two primitive pit kilns to supplement the costs associated with the removal of alien black wattle. The production of charcoal by the farm manager, Ben, has been conducted over the last 16 years with charcoal being sold to the local market.

Two options were originally available for the removal of the alien timber. He could either tackle the job with his own labour or attract an interested woodcutter to do the work for him. The latter option was tried initially, inviting firewood producers in to fell and remove the wood. The interested parties were only willing to work the area if the wood was supplied free of charge. In addition the woodcutters were also very selective and left unwanted branches and stumps behind. Mr Burnett then opted to use his own labour but, apart from the costs involved, disposal of the felled timber was also difficult. Employment of charcoal production partly solved both these difficulties. The sale of charcoal contributed to the costs of clearing and the use of a pit kiln enabled safe disposal of the bulk of the wood produced.

The charcoal production figures for the last year amount to 18 tons representing an earning of R2700 for the year. The sale of charcoal was conducted via a local retail outlet who purchased the entire production at a price of 15c/kg. Both the bags and transport costs to Port Elizabeth were borne by the retailer.

No detailed production cost figures were available so estimates have been made based on information made available by Mr Burnett.

<u>Wood production costs</u> (ignoring transport costs):

| | |
|---|---|
| Charcoal production rate | 1,5 tons/month |
| Number of runs required @ 400kg/run | 3,8 |
| Volume of wood required 3.8 * 25 = | $94 m^3$ |
| | |
| Wages | R 400 |
| Chainsaw costs (@ R875 each) | R 54 |
| Chain costs (life 2 weeks) | R 26 |
| Petrol (7 litres/day) | R 22 |
| | |
| Wet wood weight (500 $kg/m^3$) | 47 t |
| Wood moisture content | 64 % |
| | |
| Wood cost | R 11/t |
| | |
| Yield (dry basis) | 5.2 % |
| Charcoal production costs | R 334/t |

<u>Economic yield</u>:

| | |
|---|---|
| Monthly costs | R 502 |
| 1,5 tons charcoal @ R150/t | R 225 |
| | |
| Shortfall | R 277 |
| | |
| % recovery of costs | 45% |

Although the charcoal production does not recover all the costs incurred, it does allow the farmer to tackle reclamation of a farm that was overrun with black wattle. It would be possible to improve the very low yield, initially by allowing the wood to dry before charring and improving the kiln design along the lines of the ITDG improved pit kiln. If one assumes the costs of the modifications necessary to be R2000 (basically the metal lid) and this to last roughly three years, capital costs will be R50/month. A zero discount rate is assumed as inflation rates currently match interest rates on capital. If usability is improved to 20% monthly, figures would become:

| | |
|---|---|
| <u>Capital</u> | R 50/month - 1/3 TDRI |
| <u>Charcoal production costs</u> | R 330/month |
| Wood moisture content | 20 % |
| Yield (dry basis) | 20 % |
| <u>Economic yield</u> | |
| Normal monthly costs | R 380 |
| Additional capital costs | R 50 |
| 5,8 tons charcoal @ R150/t | R 870 |
| Profit | R 490 |
| <u>% recovery of costs</u> | 230 % |

Resiting of the kiln would also do away with transport costs. If one assumes a biomass density of 173 tons/ha (Milton, 1981), the bush clearing rate of this operation would be 0,5 hectare per month.

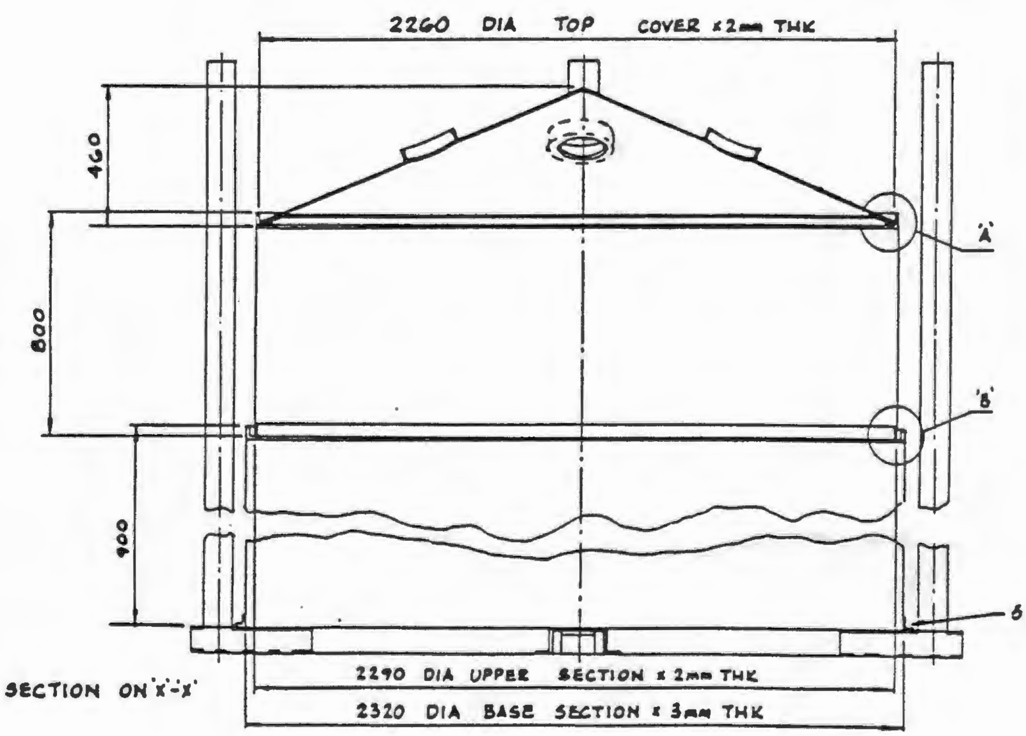
This technique could be suitable in areas that have firm soil conditions and allow a pit to be dug. However in many areas rocky or sandy soils would not permit this technique to be used. Greater interest in this project has therefore been placed on techniques that are less specific about operating conditions.

# CHAPTER 6

## TDRI METAL DRUM KILN

A metal kiln developed by the Tropical Development and Research Institute (TDRI) is one of many portable metal drum kilns that have emerged over the last two centuries. The kiln, known as the TDRI metal drum kiln, was designed specifically as an improvement to the traditional kilns used in the developing countries. The kiln is essentially an improved version of the Uganda Mark V, a kiln developed in Uganda in the late 1960's (Foley, 1986), and, as a result, is often referred to as the Mark V. The kiln is made up of two cylindrical sections and conical lid, which fit together to make up a container with diameter of 2,3m and 7,5m$^3$ capacity. The design has paid particular attention to the practical aspects of operation in the developing countries. Extremely clear technical booklets have been produced which demonstrate the manufacture of these kilns. A diagram of the kiln is shown below.

Figure 11: TDRI metal drum kiln
Source: Paddon, 1980



The operation of the kiln is detailed in the same simple format as in the construction booklet, once again, paying attention to the practical aspects of operation by unskilled labour. A turnaround of 2-3 days per kiln is reported to produce 2-3 tons of charcoal a week if two kilns are operated with two operators. Wood has to be cut into sections not bigger than 0,6 meters long and 0,2 meters in diameter and allowed to dry for three weeks before use. Two methods of operation are possible with one being recommended when wood is wet. The operations differ simply by the position of the initial lighting of the kiln, the one at the base of the kiln and the other, for wet wood, at the top of the kiln. For further details, the reader is referred to information taken from the construction and operation booklets included in the Appendix.

Rigorous trials by Paddon et al. (1979) demonstrated conversion efficiencies on oven dry basis of between 20-24%, producing 350-450 kg per run. The effect of wet wood was demonstrated to increase carbonisation from 21 hrs to 34 hrs but reduce yield only from 22 to 21 %. The quantities of undersized charcoal fines were not reported nor the quantity of incompletely carbonised wood, namely brands. Temperature profiles are reported over the duration of the test runs. These show large fluctuations and temperature gradients in the kiln with core temperatures generally being the highest. Lighting from the top showed higher average temperatures than lighting from the bottom but no explanations are given. Presumably the higher temperatures are what prompted the recommendation for wet wood operation i.e. lighting from the top.

The major drawback of this design is reported to be the capital cost involved. The informal charcoal producer would have to access to bank loans to consider use of this technology. It would however be ideally suited to small businessmen, farmers and government organisations needing to utilise or produce useful energy from biomass.

## 6.1 CONSTRUCTION

Although the TDRI kiln is considered expensive, it is still cheap in carbonization equipment terms. Nevertheless, this kiln design is still beyond the means of any rural entrepreneur. Farmers with relatively little capital could conceivably find this design ideal but construction may present a problem. Although extremely clear documentation is available on the construction of these kilns, do-it-yourself construction can almost certainly be ruled out.

The kiln is recommended to be made of a corrosion resistant steel to increase life expectancy. The corrosion resistant metals can be difficult to cut and weld which forces the entrepreneur to have the equipment constructed by experienced metal working concerns. The kiln design also calls for rolling of sheet steel and angle iron which cannot be contemplated without the appropriate metal working equipment. These requirements are rarely available on the farm or in the backyard forcing an entrepreneur to have the kiln built in a metal workshop. Although construction requires experienced metal working knowledge the technology has been established in a number of developing countries including: Dominica, Equador, Fiji, Guyana, Jamaica, Liberia and Sudan (Paddon, 1980).

The TDRI kiln is designed to be manhandled by two men. Its transportability over longer distances requires at least a one ton truck to fit the cylindrical sections. Damage to the kiln during transportation and manhandling is reported to be a significant disadvantage to this design because of the difficulty of repair in the field.

## 6.2 EXPERIMENTATION

Experimentation with alien specie timber was conducted for this project using a full-scale metal kiln. Labour was only used to prepare and load wood into the kiln, not to control the operation. The kiln was constructed by a local firm, Continental Fan. Middelburg Steel provided the material for the experiment, a local corrosion resistant product known as 3CR12, which cannot be cut using conventional oxy-acetylene. Material costs were estimated and added to construction costs totalling R3105 (including tax) per kiln. Modifications to the kiln were completed to allow temperature measurements to be taken during the course of a test run. The modifications involved addition of nine thermocouple wells following the example of Paddon et al. (1979) in their evaluation of the TDRI kiln.

The first trials conducted with the TDRI kiln provided an introduction to carbonisation of wood. Experiments had to be conducted away from the residential areas because of the large quantities of smoke produced, especially in the drying out phase in the first hour of operation. The site chosen was Redhill, situated on the Cape Peninsula in the vicinity of Simon's Town. Charcoal production being somewhat of an art, which was not altogether acquired during the duration of the TDRI experiments, hampered experimentation.

The wood specie used initially was Hakea sericea. The supply was produced from a housing development construction site in Noordhoek where the trees had been bulldozed into heaps possibly nine months earlier and as a result the wood was well seasoned. Informal woodcutters from that area were commissioned to cut up the wood up into 0,5 metre lengths for a price which worked out to be roughly R50/ton. Transportation of this wood to the operation site proved to be too cumbersome and expensive, resulting in the implementation of the action research program, where a number of tasks could be achieved simultaneously. Thereafter the experimental equipment was moved to a closer site, Silvermine Nature Reserve, where bush clearing and charcoal production were continued in a more realistic environment. Fresh wood was cut and separated into two species and allowed to dry. The two species present were Acacia saligna and Acacia cyclops, the former being more prolific.

Charcoal production rates are a function of wood species, wood dimensions, wood moisture and operating conditions within the kiln which meant completing a considerable number of experiments to determine the effect of each variable. The cumbersome nature of the experiments and the large quantities of pre-dried wood required for each experiment restricted the scale of the experimental program. It was therefore realised that the experiments could only be used to demonstrate the suitability of the technique for carbonisation of several alien wood species and possibly identify any inherent difficulties of the wood types, rather than to provide exact experimental data on particular wood species. The experiments also provided hands on experience with the equipment and labour providing valuable insight into how appropriate the technique would be for carbonisation of alien timber.

Once familiarisation trials with Hakea were completed, the two other species were tested. The precut and dried wood was weighed on a beam balance and loaded manually into the kiln. Kindling was placed at the base of the wood charge as demonstrated in the instruction manual. Firing was initiated from the base of the kiln for five out of the six experiments and monitoring of the carbonisation process done by observation of smoke produced and temperature measurement of the charge. Carbonisation took between 18-29 hours and as visual observation of the smoke was required, control was lost during the night. Control was effected by interchanging chimneys stacks and air supply as a function of smoke colour. As a rule the operation during experimentation was conducted according to instructions from the booklet.

None of the test runs conducted were considered entirely successful in view of the quantities of brands left after each test run. Problems were believed to be a function of inexperience and the large variation in wood diameter characteristic of alien timber. A final test was conducted in an attempt to improve the charcoal production costs of the kiln, rather than improve operation. Pole length timber, which requires less preparation, thereby reducing its production cost, was stacked vertically in the kiln. Vertical stacking was necessary to achieve a reasonable packing density in the cylindrical vessel. As drying rates of pole length timber was slower than the shorter 0,5m lengths, the timber was generally wetter. As a result the charge was ignited from the top rather than the base on recommendations from Paddon et al. (1980) for high wood moisture content.

## 6.3 RESULTS

In general, the results of the experiments with the TDRI metal drum kiln were not good, even though the trials were not controlled by the unskilled labour. Most of the test runs had significant quantities of uncarbonised wood left behind at the end of the run, generally a result of inexperience in operation. This is in itself relevant though, showing that operational experience will have to be gained before this technique can be used effectively.

Relatively low packing densities were achieved with the alien wood species tested in the experiments for this project. This problem was exaggerated for Acacia Cyclops because of the generally thinner branches characteristic of this species. As a rule generally thinner timber will therefore have lower production rates. The bulk density limitations reduce potential charcoal production to below reported figures of 0,5-0,75 tons per run but it is possible that these production figures may be on the high side because experimental results reported by the same author, Paddon et al. (1979), achieved results similar to those from this project, i.e. 0,3-0,5 tons per run.

Charcoal produced was separated into fines and usable char using a 10mm sieve. Incomplete carbonised pieces, known as brands, were manually separated from the char. The experimental results reported below show both total and usable char production for selected runs. Yields are based on an ovendry wood mass and corrected for incomplete carbonisation by subtracting the brand weight from the initial charge mass. The results of the field trials conducted with the TDRI kiln are shown below:

Table 11: TDRI metal drum carbonisation test results:

Hakea

| Run No: | | 1 | 2 | 3 |
|---|---|---|---|---|
| WOOD | kg | 2300 | 2500 | 2350 |
| MOISTURE | % | 23 | 23 | 23 |
| CHARCOAL | kg | 350 | 290 | 359 |
| BRANDS | kg | -- | 200 | 100 |
| FINES | kg | -- | -- | 52 |
| RUN TIME | hrs | 18 | 21 | 21 |
| TOTAL YIELD | % | -- | -- | 22,7 |
| USABLE YIELD | % | 18,6 | 15,8 | 19,8 |

Rooikranz : Port Jackson

| Run No: | | 4 | 5 | 6* |
|---|---|---|---|---|
| WOOD | kg | 1300 | 1950 | 1916 |
| MOISTURE | % | 18 | 27 | 32 |
| CHARCOAL | kg | 201 | 216 | 255 |
| BRANDS | kg | 293 | 200 | 0 |
| FINES | kg | 56 | 49 | -- |
| * RUN TIME | hrs | 29 | 21 | 21 |
| TOTAL YIELD | % | 31,8 | 19,8 | 17,6 |
| USABLE YIELD | % | 24,9 | 16,2 | -- |

* top-down burn, 1,8m pole length, stacked vertically

## 6.4 DISCUSSION

During experimentation, difficulties were encountered in wood moisture measurement and carbonisation control. Wood moisture was found to vary significantly with wood thickness. Each piece of wood also showed variation, moisture content being lower at the ends than that of the body, particularly for thicker wood. The difficulties experienced in wood moisture measurement affected the accuracy of calculated yield as this is based on ovendry wood mass. Variation in wood moisture also affected kiln operation by varying carbonisation times for individual pieces probably contributed to the large quantity of brands produced in some of the experiments. To improve operation, the variation in wood moisture can be overcome to a certain extent by using one particular wood size for each run. Unfortunately large quantities of wood were not available so selection was not possible.

Poor carbonisation control was also a result of the lack of experience in TDRI operation. The variation in yields achieved and wood moisture inaccuracies unfortunately throw uncertainty as to the effect of wood specie on yield. Yields are however in the range expected for the TDRI kiln but what is important to note is that the yields of 20-22% reported by Paddon et al. (1979) probably applied to total production including fines produced. For economic evaluations a lower, usable charcoal yield, which excludes fines produced, will have to be used.

The top-down burn using vertically stacked poles provided the best results. First it demonstrated that the more economical, pole length timber, could be used. Second the high moisture content of the wood was shown not to affect runtime as expected. Higher moisture content normally extends carbonisation runtime very significantly. The yield measured for the top-down burn was lower than the other runs but may have been a result of not shutting down the kiln soon enough. Quantities of ash and complete absence of brands found in the kiln at the end of the run, indicated that the run time had been too long.

The charcoal quality could not be considered homogeneous in most of the experimental batches produced because of the large amount of brands or incompletely carbonised wood left at the end of each run. As a result the charcoal quality could not be accurately determined. Proximate analysis was however conducted to gauge approximate values. The absence of brands in the top-down burn enabled more confidence to be attached to the analysis of the charcoal produced. Proximate analysis of the two different operating methods are shown below.

Table 12: Charcoal proximate analysis

| | | Hakea | | Port Jackson | |
|---|---|---|---|---|---|
| Run No: | | 3 | | 6* | |
| Moisture | % | 3,5 | 3,6 | 3,5 | 3,5 |
| Volatiles | % | 30,5 | 29,6 | 13,7 | 19,7 |
| Ash | % | 1,5 | 1,5 | 2,5 | 5,5 |
| Fixed Carbon | % | 64,5 | 65,3 | 80,3 | 71,3 |

* top-down burn

The results show that the charcoal composition is affected by the use of a top-down burn. The lower volatile and higher fixed carbon content is considered to be a superior charcoal quality. Ash content is inevitably higher but is consistent with the more severe distillation effected in the top-down burn. The variation in product quality displayed is a disadvantage as users often prefer a consistent product, particularly industrial users.

In conclusion, the use of pole length timber offers several advantages:

- cheaper production cost;
- shorter carbonisation times;
- capable of using wet wood; and
- better quality charcoal.

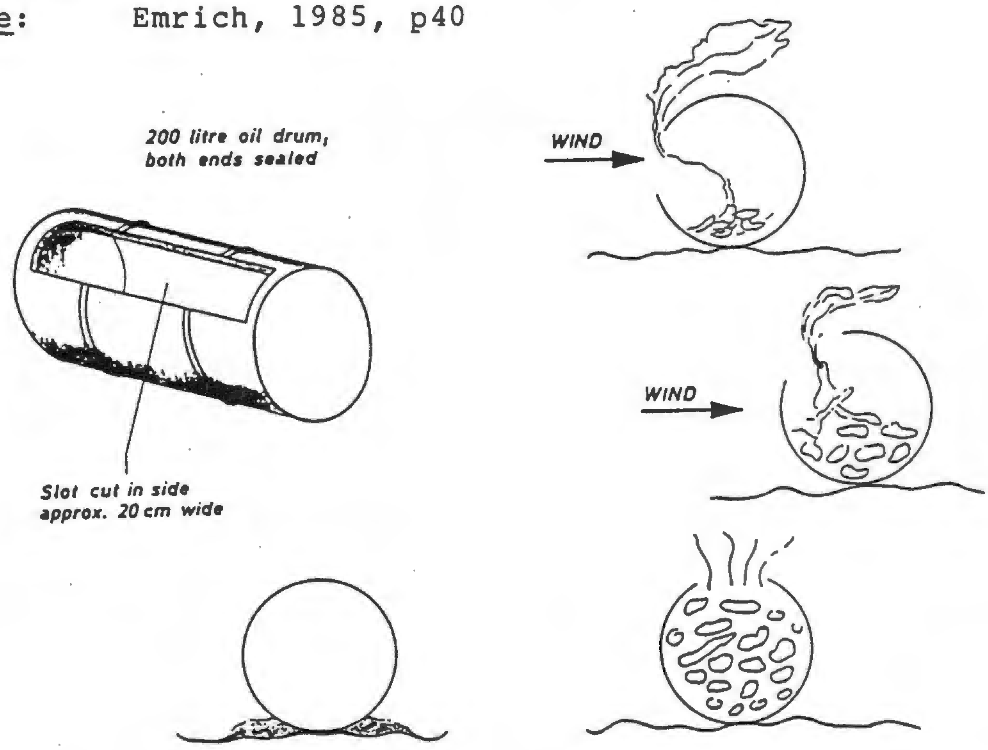
It is therefore recommended that pole length timber be used in the TDRI stacked vertically in the kiln. Lighting from the top should be used especially where wood moisture is high.

# CHAPTER 7

## OIL DRUM KILNS

There are a number of small-scale kiln designs that have emerged from the charcoal industry in South East Asia and the Pacific. They are based on the "44 gallon oil drum" making them extremely easy to handle and probably the cheapest portable kiln around as long as the oil drums are readily available. Of these, the Tongan oil drum kiln is a good example (Emrich, 1985, Foley, 1986). It is constructed by cutting a slit roughly 20 cms wide down the length of the drum. The drum is then laid on its side with the hole facing the prevailing wind. Wood is then introduced through the opening and set alight. The heat from the fire breaks up and carbonises the wood in the drum. With time, a level of charcoal builds up in the base of the drum and as the charcoal is produced, wood is consumed, allowing room for more wood to be added. Wood is continually added until the drum is filled with charcoal. The drum is then turned upside down and sealed with sand to cool down. Yields of 22.7% on ovendry basis are reported for the Tongan drum kiln (Foley, 1986, p151). A diagram of the Tongan drum kiln below shows how the kiln is used.

Figure 12: Tongan drum kiln
Source: Emrich, 1985, p40




The same oil drum is reported to be used in the vertical position (ILO, 1985; Foley, 1986; Emrich, 1985) known as the Philippines kiln. A special lid is constructed with the one end of the drum or with sheet steel, while the other has two more holes added making a total of four holes. Operation involves propping the kiln up on bricks holes facing downward and filling the open end with wood or coconut shells. Lighting is reported to be done from both the top or the bottom but the effect of each not documented. The kiln is continually recharged as the level drops during the carbonisation cycle. 12-15 kg of charcoal are produced per run taking between 4 and 8 hours depending on the operator skill. Ten kilns can be managed at one time by a skilled operator producing a total of 120-150 kg/day.

A variation of the Philippine kiln is the mini-CUSAB (a small version of the CUSAB kiln described later) developed for use in Western Samoa. The mini-CUSAB has a series of air inlets up the side of the kiln which are progressively closed as the level of charcoal increases from the bottom. Theoretical yields of 28.9% (taking into account the fines and brands) have been demonstrated producing a usable charcoal yield of 23.4%.

## 7.1 TONGAN DRUM KILN EXPERIMENTS

Of the oil drum kiln designs reported, the Tongan drum kiln stood out amongst the options, in its ease of construction and operation. An experimental program was thus initiated to establish whether it was suitable for carbonisation of alien biomass. The field tests conducted with the Tongan drum kilns were accomplished using the team of informal woodcutters previously commissioned to supply and cut up the fuelwood for the TDRI kiln experiments. The objectives of the action research type of experimentation were to increase the number of tests results, to evaluate how appropriate the kiln design was to labour already involved in alien wood utilization, to teach the skills of charcoal production and to evaluate real charcoal production and real bush clearing rates.

Construction of a number of kilns was undertaken in the field using a hammer and chisel to demonstrate the simplicity of its construction to the woodcutters. After a few demonstration runs three kilns were set up and operated daily by the wood cutters. Tests were carried out using Hakea sericea, Acacia cyclops and Acacia saligna with moisture content ranging between 17-34%. Wood consumed and charcoal produced were weighed on a beam balance. Brands produced were separated and weighed. To calculate yield efficiencies, the charcoal produced (assumed dry) was divided by the oven dry mass of wood used less the mass of brands produced. Charcoal production yield is reported as product larger than 10mm. Fines produced were measured in several experiments and reported. The results of the experiments conducted are shown below.

<u>Table 13</u>: Tongan drum carbonisation test results

| NO OF KILNS | WOOD MASS | MOISTURE | CHARCOAL | FINES | PRODUCTION | BRANDS | TIME | YIELD |
|---|---|---|---|---|---|---|---|---|
| | kg | % | kg | kg | kg/drum | kg | hr | % |
| HACKEA | | | | | | | | |
| 2.00 | 341.00 | 23.00 | 51.00 | | 25.50 | 7.00 | 6.00 | 18. |
| 1.00 | 100.00 | 23.00 | 16.50 | | 16.50 | | 5.00 | 20. |
| 3.00 | 300.00 | 23.00 | 32.00 | | 10.67 | | 4.00 | 13. |
| 3.00 | 300.00 | 23.00 | 44.00 | | 14.67 | | 3.00 | 18. |
| 3.00 | 300.00 | 23.00 | 25.00 | | 8.33 | | 4.00 | 10. |
| 3.00 | 400.00 | 23.00 | 42.00 | | 14.00 | | 5.00 | 12. |
| 3.00 | 300.00 | 23.00 | 22.00 | | 7.33 | | 3.00 | 9. |
| 3.00 | 300.00 | 23.00 | 24.00 | | 8.00 | | 3.00 | 9. |
| PORT JACKSON | | | | | | | | |
| 3.00 | 375.00 | 17.00 | 42.00 | | 14.00 | 7.00 | | 13. |
| 3.00 | 450.00 | 17.00 | 44.00 | | 14.67 | 25.00 | | 12. |
| 3.00 | 600.00 | 17.00 | 52.00 | | 17.33 | 11.00 | | 10. |
| 3.00 | 300.00 | 17.00 | 33.00 | | 11.00 | 25.00 | | 14. |
| 3.00 | 300.00 | 17.00 | 33.00 | | 11.00 | 25.00 | | 14. |
| 3.00 | 300.00 | 17.00 | 25.00 | | 8.33 | 20.00 | | 10. |
| 3.00 | 375.00 | 17.00 | 42.00 | | 14.00 | 7.00 | | 13. |
| 1.00 | 124.00 | 34.00 | 20.50 | 10.00 | 20.50 | 5.00 | 6.00 | 23. |
| 1.00 | 151.00 | 34.00 | 20.00 | 6.00 | 20.00 | 4.00 | 6.00 | 18. |
| 14.00 | | | 225.00 | | 16.07 | | 7.00 | |
| 7.00 | | | 118.00 | 50.00 | 16.86 | | 7.00 | |
| 1.00 | 120.00 | 19.00 | 19.50 | 6.50 | 19.50 | 1.00 | 4.50 | 19. |
| 1.00 | 125.00 | 61.00 | 11.50 | 6.50 | 11.50 | 14.50 | 4.50 | 18. |
| ROOIKRANZ | | | | | | | | |
| 1.00 | 150.00 | 45.00 | 14.40 | 7.60 | 14.40 | 3.00 | 5.00 | 14. |

Initially tests were carried out ensuring visible flame in the kiln. This technique seemed necessary to be sure that the carbonisation process was still ongoing. Maintaining visible flames meant operating the kiln half filled with wood which allowed free access of air to the wood charge. Free access of air did not appear to be a problem as the combustion primarily took place with volatiles in preference to char. The release of volatiles provided a natural blanket around the char preventing char combustion whilst in the reaction zone. With time, char would breakup and fall below the reaction zone, into the base of the drum away from the oxygen supply. As air could only enter from the top, it would have to pass through the reaction zone to get to the char in the base of the drum.

During passage through this zone the oxygen would be taken up in combustion of the volatiles thus preventing combustion of the char. Char was thus able to build up gradually in the base of the kiln. These earlier tests however showed both low and erratic charcoal yields and production, presumably also due to lack of operator experience.

The yields measured in the earlier tests ranged from 9% - 18%. These results seemed low as usable charcoal yields of 22.7% were reported in the literature (Foley, 1986, p151). Unfortunately the simple equipment offered little variation possibilities to improve yields. Trial and error experiments were conducted with the kiln finally increasing usable charcoal yields to a maximum of 23,4%. Improvements were achieved through choke feeding of the kiln rather than maintaining visible flame. A strong fire was allowed in the kiln during start-up by allowing good air supply initially to the burning charge. Once the charge was burning strongly the kiln was packed tightly with fresh wood. Wood was also packed up over the opening of the kiln concealing the flames for most of the carbonisation cycle. This had both the effect of predrying and heating of fresh wood before carbonisation and limiting the air supply into the kiln. The only disadvantage of this technique was the increase in smoke produced with the improved operation.

The Tongan drum kiln generally produced a small sized product, typically all less than 40mm and a high percentage of fines (30-50%). This high production of fines unfortunately limits the usable charcoal yield of the Tongan drum kiln. Fines produced were measured in some experiments showing that a total charcoal yield of 20-35% could be achieved. The reason for the high production rate of fines was believed to be related to the thermal shock experienced by the fresh feed.

The Tongan drum kiln was found to reach operating temperature of 500-600°C very quickly and maintain this temperature throughout the carbonisation cycle. The high temperature gradient experienced by the fresh wood added to the kiln increased char fracture and thereby production of unwanted fines.

Nevertheless the small size of the kiln allows versatile operation and affords easy transport of the kiln to the wood supply. The small size also improves the turnaround because the cooling cycle is very short with such a small charge. Given some experience, one operator was found to be capable of running 14 kilns a day producing an average of 16 kg a drum. Cooling is effected overnight. Charcoal quality was variable because of the dependence on operator control and by the nature of the operation. As wood is continually fed into the kiln, the final addition does not have time to carbonise. The presence of brands in the final product indicates a non-homogeneous charcoal composition as found in the TDRI kiln. Proximate analyses were conducted to gauge the composition:

Table 14: Charcoal proximate analysis

| | Hakea | |
|---|---|---|
| Moisture | 3,9 | 3,8 |
| Volatiles | 14,4 | 14,3 |
| Ash | 2,6 | 2,1 |
| Fixed carbon | 79,1 | 79,8 |

One major disadvantage of the Tongan drum is that the wood has to be reduced to half metre lengths to fit into the kiln increasing the costs of wood preparation. However, the operation and control is very rudimentary and found to suite the woodcutter ability very well. Carbonization control is considered an art and in the older pit kilns is quite difficult. The Tongan kiln, because of the continuous addition of fuelwood, allows the progress to be monitored visually, simplifying the control significantly. The low capital cost of this kiln design and its ability to produce reasonable quality charcoal make this technique a promising option for self-employment in the low-income group.

# CHAPTER 8

# OLD DRUM RETORTS

## 8.1 ENERGY FROM BUSH

Up to now the brush material, leaves and seed pods have been ignored as lump charcoal production is based on use of timber or wood at least 50 mm in diameter. Milton's investigations of *Acacia saligna* and *Acacia cyclops* show that on an oven dry basis an average 36% of the biomass in the Cape Town area is contained in brush (less than 20mm). The brush then represents roughly a third of the energy content in the biomass assuming that the brush and wood have equal calorific values. If combustion of the brush material is not to be used in bush clearing to assist seed bank reduction, it would have to be removed from the site to eliminate the fire hazard it poses.

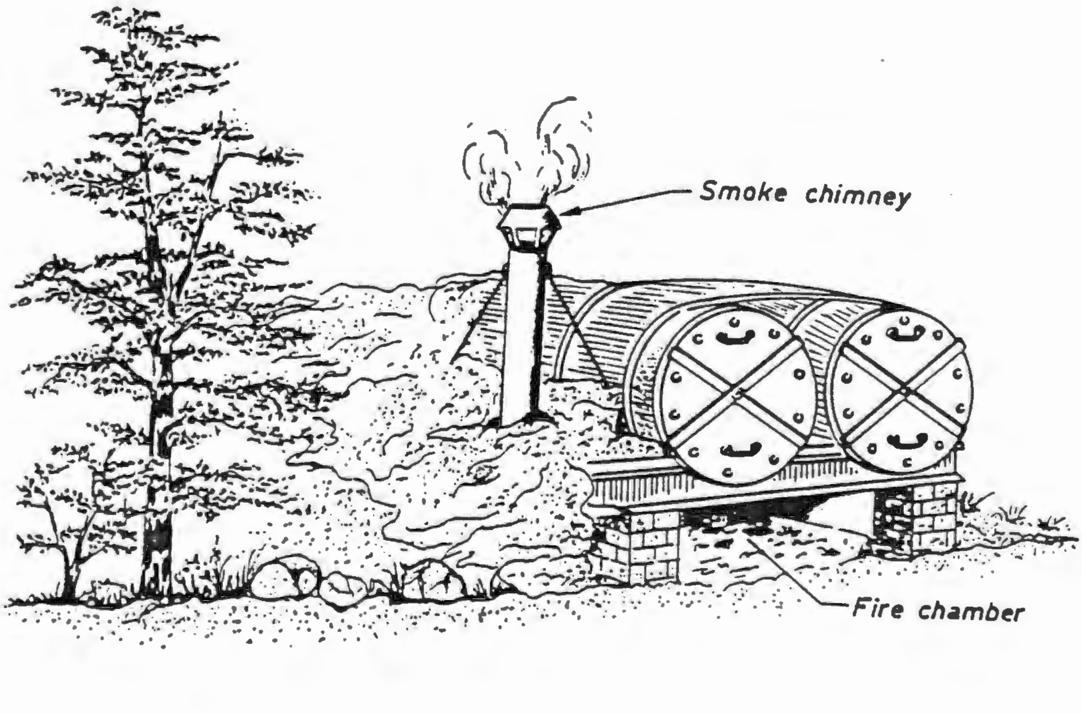
The retort concept for charcoal production relies on utilizing an external heat source to carbonize the wood charge contained within a sealed vessel. The applied heat is usually generated by combustion of cheap or waste wood underneath the vessel until such time that the wood charge has dried out and the pyrolysis reaction initiated. The woodgas generated during pyrolysis can then be used to supply the fuel for further heating of the wood charge for complete carbonisation by routing the gas to the fire box. Alternatively waste fuel is continually fed to the fire box beneath the vessel and the gas routed for use elsewhere.

The energy content of the brush material could be used to supply the external heat for retort operation. This concept would then appear to be ideally suited for bush clearing as it would be able to utilize both the timber and brush fractions efficiently. Retort technology is generally sophisticated and expensive with the exception of one design.

## 8.2 THE VITA RETORT

Retort technology is reported to produce the highest yields in charcoal production. Only one low-cost retort design is reported, a retort built out of '44 gallon drums'. Two cylinders are constructed, each by welding the ends of two to three drums together. The cylinders are each open at one end to allow packing of the wood charge. The open end is designed to be sealed by a tight fitting lid. The two cylinders are mounted alongside each other over a firebox, created either by a trench or a brick support as shown in the sketch below.

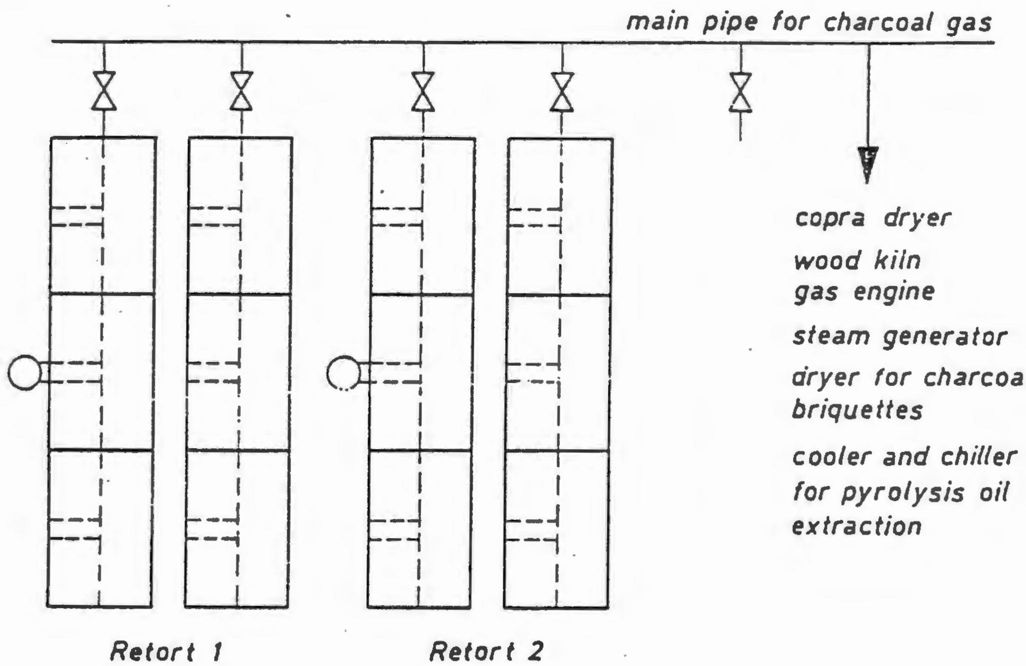
Figure 13: The VITA retort
Source: Emrich, 1985, p100



A pipe welded to the end of each cylinder allows hot gases generated to escape. Operation involves filling the two cylinders with wood and after sealing the end, lighting a fire with scrap or waste wood underneath. Initial heating dries out the wood after which woodgas generated escapes through the vents and burns in the firebox. High efficiencies are reported for these retorts but efficiencies are usually quoted without taking into account the amount of wood used to heat the kiln. Trials showed that charcoal yields of 33-34% can be achieved but that 160 kg of waste wood were required to produce 35 kg of charcoal (and tar). Rerouting of the woodgas back to the firebox reduced wood consumption for heating to 80kg, but this is still not very attractive in an overall balance. Assuming the waste wood to have 20% moisture the overall yield drops to 20% and 15% respectively for the retort carbonisation with and without woodgas utilisation respectively. This demonstrates that retort technology is only efficient as long as the energy for carbonisation can be supplied by an otherwise unusable wood source.

It is however reported that if a number of retorts are used excess woodgas can be routed to fire a freshly loaded cylinder through interconnecting piping as shown below. If sufficient woodgas is generated here, the system could be self-sustaining. This sort of facility would however, not be considered to be transportable.

Figure 14: Interconnecting pipework for VITA retorts
Source: Emrich, 1985, p100

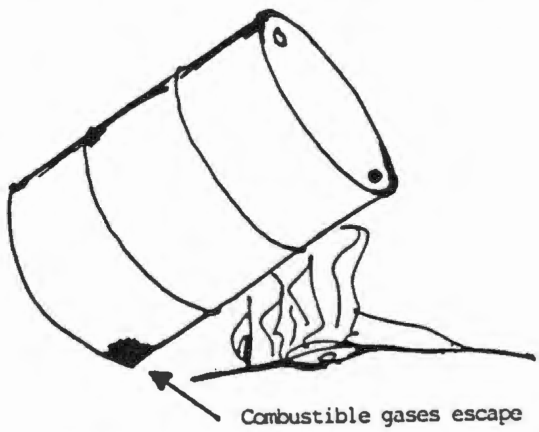



8.3 APPROPRIATE RETORT DESIGNS

Although the VITA retort technology is considered simple and inexpensive it does require welding equipment for its construction, seldom available to the rural operator. An attempt was thus made to produce an energy-efficient retort that could be constructed in the field without welding and oxy-acetylene requirements and furthermore was small enough to be truly transportable. The idea was borne from the simplicity of the Tongan drum kiln design both in its construction and operation. In principle the retort requires a sealed vessel that can be heated by an external source and allow hot gases generated to escape into the firebox for further combustion. The combustion of the woodgas generated would be allowed to continue until no more was produced, whereupon the drum would need to be sealed and allowed to cool. The attractions of such a design are the improved charcoal yields and opportunity of utilizing the brush material generated during bush clearing as the energy source.

The first concept tried was based on a steel drum similar to the conventional oil drum but with a detachable lid. A hole was cut at the base of the drum with a hammer and chisel, to allow release of steam and combustible gases into the fire box. The drum was charged with seasoned wood and propped up from one end with the hole positioned so that escaping gases would be forced into the fire box.

Figure 15: A simple low-cost retort prototype




Final sealing for the cooling phase was achieved by piling sand over the hole at the base of the drum. Partial carbonisation of the charge was achieved with several tests but the rate of woodgas generated appeared to be insufficient to maintain the required carbonisation temperatures. The experiment was aborted after some time when combustion of brush under one vessel proved to be inefficient, time-consuming, laborious and not worth the charcoal it could potentially produce.

The number of drums was increased to four, two charged with wood and two on either side to provide insulation. The drums were supported off the ground by two metal pipes to allow more brush material to be fed into the firebox at a time. In addition a steel sheet was laid over the top of the drums to reduce heat losses. It was envisaged that a second tier of drums could be positioned, instead of the steel sheet, at a later stage once the combustion of the woodgas had been initiated. Excess heat from the combustion of the woodgas could then be used to initiate the carbonisation of the second tier. Once again only partial carbonisation of the charge was achieved and handling of large quantities of brush did not justify the small production potential.

It is believed that due to lack of insulation, excessive heat losses prevented the retort prototypes operating successfully. Soil would provide an excellent insulating material but it would make the kiln a semi-permanent fixture. It was thus decided to evaluate the semi-permanent VITA retort.

## 8.4 VITA RETORT EVALUATION

The objectives of the experimentation with the VITA retort were to establish:

(a) whether brush material could be used as an energy source for carbonisation;

(b) whether insulation was necessary for the operation of the retort (without insulation the retort could be considered transportable); and

(c) what production costs could be achieved.

The construction of the VITA retort is simple when compared to the TDRI kiln and can be accomplished by do-it-yourself enthusiasts as no special welding, cutting or rolling is required. A simple document detailing the construction of this retort design has been published by VITA (1980). For the purposes of comparison the price of construction by a metal working concern was obtained. The price including materials was R550 for a 1,2m$^3$ unit (6 drums).

A retort comprising two cylinders was made up according to VITA diagrams allowing for combustion of the woodgas in the firebox. Instead of welding a pipe to the cylinder, pipe fittings were attached to the cylinder lid to screw fittings characteristic of steel drums. The pipe fittings allowed the woodgas to be directed back into the firebox. The two cylinders were laid alongside each other over a trench and covered with sheeting and sand to provide insulation. One economic advantage of the VITA retort over the small-scale prototypes was that pole-length timber could be used reducing the production cost of the raw material. The two cylinders were packed with seasoned pole-length timber, loading approximately 150 kg in each. Loading was found to be awkward and time-consuming. The loading trays made of thin (1mm) steel were found to be unsuitable for supporting a charge of wood and could therefore not assist in the packing of the retort.

A fire using timber was lit underneath the cylinders and maintained until a flame issued strongly from the pipe outlet into the firebox. The flame was allowed to burn until it petered out. The end of the woodgas return pipe was then sealed and the retort allowed to cool. The charcoal yield was unfortunately once again incomplete only being produced at the end closest to the woodgas return pipe where the localised heating was produced by a short flame issued from the return pipe.

Although the results of the first test were not successful and actual yields not measured it is assumed that the technique could be made to work. However the semi-permanent nature associated with insulation by sand, the difficulty of using brush in a buried retort and the difficulty involved with charging and removal of products led experimentation away from this technique using sand insulation. A metal support was constructed to lift the two cylinders off the ground and allow brush to be fed into the fire box. Minimal insulation was used in the form of metal sheeting over the top of the cylinders and down the length of one side. The cylinders were charged again with pole-length timber, moisture content roughly 22%; the total load weighing 272 kg between the two cylinders.

In this experiment a brush fire was used and the consumption of brush measured. The experiment was abandoned after 2,5 hours during which time 515 kg of brush had been consumed far in excess of that reported in the literature. The temperature inside the retort reached a maximum of 290°C; woodgas was being produced but insufficient quantities to sustain carbonisation temperatures. Buckling of the cylinders was noted after the second firing indicating possible short life expectancy. Generally the conclusions drawn from the limited experimentation was that the retort was not suited to this type of operation and no further work was conducted with retort type carbonisers.

# CHAPTER 9

# THE CUSAB KILN

## 9.1 CHARCOAL FROM BRUSH

Instead of using brush material to supply heat for carbonisation the brush can be carbonised to produce charcoal itself. The only technique identified in the literature to be suitable for this application was developed specifically for this purpose (Little, 1972). The kiln known as the CUSAB kiln (Charcoal from Useless Scrub And Brush) was developed in Kenya to improve the economics of brush clearing required to re-establish infested grazing areas. The kiln was developed from the TDRI metal drum kiln introduced initially to produce charcoal from the cleared brush. As a result the CUSAB kiln looks very similar to the TDRI kiln but is operated differently. A diagram showing the kiln design is included below.

The CUSAB kiln operates with a continual feed of light branches and leaves through an opening in the lid. Air supply is admitted through rows of holes in the walls of the kiln.

The charcoal produced, breaks up and falls to the floor of the kiln, out of the reaction zone. As the charcoal layer builds up on the floor of the kiln the air inlets are progressively closed to prevent complete combustion of the charcoal produced. Operating temperatures of 800-1000$^{o}$C are reported to be typical inside the kiln, resulting in rapid carbonisation of the material. The major drawback of the system is that the charcoal produced comprised mainly fines unsuitable for domestic use in such a fine form. Experimental work reported by Little (1972) demonstrated production rates of 24-33 kg of charcoal per manhour with teams of 4-5 men, producing a total of 700 kg per day. In another set of tests measurement of biomass fed into the kiln and charcoal produced allowed conversion yields to be calculated. Yield achieved in one test was reported to be 32.5%, but the result does not state whether this is on an ovendry basis or not, nor what operating conditions or production rate this was measured at.

<u>Figure 16</u>: The CUSAB kiln

<u>Source</u>: Little, 1972

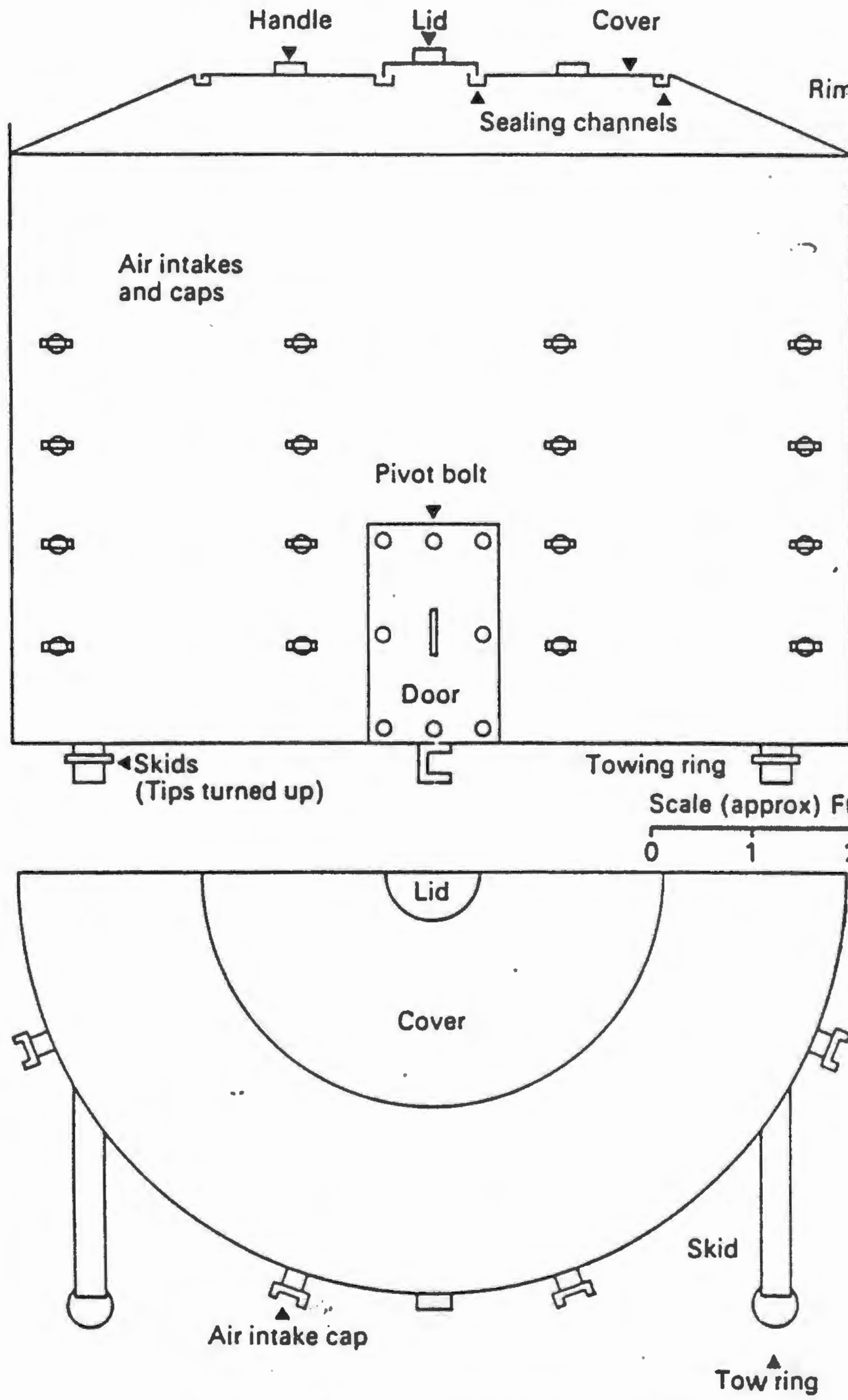



FIG. 1. The CUSAB kiln. In elevation (above); plan (below).

## 9.2 CUSAB EXPERIMENTATION

The CUSAB experiments were conducted using brush generated by the earlier charcoal experiments. The kiln was constructed by modifying the TDRI kiln by addition of air inlet ports in the kiln walls and a hole in the lid. Initially, before the modifications, tests with the cylindrical section of the TDRI were conducted without a lid or air inlet ports. The cylindrical sections of the TDRI were placed directly on the ground and soil banked up at the base to prevent air leakage into the kiln. The large opening at the top allowed easy loading of large brush sections. A very hot environment (900°C) could be maintained in the reaction zone as air supply could be drawn into the kiln by natural draft over the sides of the kiln walls. Dry brush was used in most experiments but it was found that green brush could also be carbonised in the kiln. The only control afforded by this configuration was the feed rate of the biomass to the kiln. Measurement of brush weight and moisture content with any sort of accuracy was difficult to achieve. As a result, the initial test runs were conducted without measuring brush mass or moisture content. In all the tests runs it was attempted to keep the feed rate of fresh brush to the kiln to a maximum. Control of air supply could then be used to control the carbonisation temperature and rate. Before the lid was used, little control of the air supply could be achieved and temperatures were consistently between 800-900 °C similar to those reported by Little (1972). Later experiments with a lid fitted allowed better control of air supply and therefore the operating temperature. The results of the series of tests conducted with brush material as shown below.

Table 15: CUSAB kiln field results

| NO OF MEN | TIME | FEED RATE | TEMPERATURE | CHARCOAL | PRODUCTION | YIELD |
|---|---|---|---|---|---|---|
| | hr | kg/hr | C | kg | kg/manhour | % |
| 5.00 | - | - | 900 | 405.00 | ERR | - |
| 3.00 | 5.00 | - | 900 | 456.00 | 30.40 | - |
| 4.00 | 2.00 | (3000)* | 900 | 275.00 | 34.38 | 5.00 |
| 2.00 | 7 | 1125.00 | 900 | 224.00 | 16.00 | - |
| 2.00 | 2 | 1125.00 | 900 | 161.00 | 40.25 | 10.00 |
| 4.00 | 2 | 3000.00 | 900 | 254.00 | 31.75 | 6.00 |
| 2.00 | 3 | 1230.00 | 550 | 286.00 | 47.67 | 10.00 |
| 2.00 | 2.5 | 266.00 | 470 | 150.00 | 30.00 | 29.00 |
| 2.00 | 2.5 | 242.00 | 470 | 195.00 | 39.00 | 44.00 |

* estimate

The experiments with the CUSAB kiln demonstrated that there was substantial flexibility associated with the kiln operation. Operation of the kiln centred around temperature control through restriction of air supply to the kiln. Increasing air supply to the kiln increased temperatures and carbonisation rate. The higher carbonisation rate increased the biomass consumption rate but the associated high temperatures reduced char yield. Charcoal composition was also linked to operating temperature. Higher temperatures distilled off more of the volatile component originally inherent in the biomass. Char analysis as a function of temperature is shown below.

Table 16: CUSAB charcoal analysis

| | | Acacia saligna | | |
|---|---|---|---|---|
| | | 460 | 550 | 900 |
| Moisture | % | (5)* | (5)* | (5)* |
| Volatiles | % | 15,5 | -17,0 | 6,0 |
| Ash | % | 4,0 | 1,5 | 2,5 |
| Fixed Carbon | % | 75,5 | 76,5 | 86,5 |

* Estimate

One would expect ash levels to increase with operating temperature. The decrease in char yield with increasing operating temperature should concentrate the ash levels in the char. However, the results of the charcoal analysis do not show this trend. This may be due to experimental error or the result of ash loss during the higher temperature operation. If the char is to be used for industrial purposes, the ash content, volatile and fixed carbon content are important and could therefore fix the operating conditions of the kiln. For domestic grade charcoal operating conditions would be dictated purely by economics of production.

The ash content of charcoal produced by the CUSAB kiln is also subject to raw material properties. In the case of *Acacia saligna*, the specie used in most of the CUSAB experiments, analysis of the brush material showed the following results:

Table 17: Analysis of Acacia saligna brush

| DESCRIPTION | MASS FRACTION % | MOISTURE (airdry) % | ASH % |
|---|---|---|---|
| LEAVES | 12 | 20.3 | 2.94 |
| < 5mm | 15.2 | 21 | 1.63 |
| 5-10mm | 18.4 | 25.2 | 1.56 |
| 10-15mm | 15.2 | 30.3 | 0.61 |
| 15-20mm | 17 | 31.8 | 0.61 |
| 20-25mm | 22.2 | 33.8 | 0.89 |
| AVERAGE | | 27.8 | 1.11 |

The results show that the thinner the branch the higher the ash content markedly so for the leaves. This is probably due to the increase in bark per unit mass of wood for thinner branches. To keep ash levels down for industrial grade charcoal it may be necessary to exclude feed below a certain diameter. Control of the charcoal yield could also be used to vary the ash content but more work needs to be done to establish this effect.

# CHAPTER 10

# CHARCOAL PRODUCTION ECONOMICS

## 10.1 TDRI METAL DRUM KILN

The TDRI kiln, in view of the capital cost per kiln, is envisaged to be suitable for farmers, small businesses and town or regional councils but not for unskilled labour seeking self-employment opportunities. Timber costs from alien species are shown in Chapter Three as a function of labour costs. Charcoal production costs are directly related to wood costs and are thus indirectly a function of labour rates. In firewood production and bushclearing operations, wages range from R93 to R400 per month (R4.64 to R20/day).

The yield of charcoal will depend on operator skill but will range between 16-25% usable char, i.e. greater than 10 mm in diameter. Bennie (1982) reports yields (presumably usable) for metal drum kilns, used in South Africa to range between 12,5-25,0%, averaging 22,5%. The low figure, 12,5%, represents a charcoal yield for operation using green wood. An example of a cost estimation for charcoal production using the TDRI kiln with a 22,5% yield and wage level of R 200 per month are presented below.

Table 18: Charcoal production cost: TDRI

KILN SPECIFICATIONS

| | | | |
|---|---|---|---|
| WORKING VOLUME | m3 | 7.50 | |
| YIELD | % | 22.50 | |
| CAPITAL COST/KILN | R | 3100.00 | |
| LIFE | years | 3.90 | (Bennie, 1982) |

CHARCOAL PRODUCTION

| | | | |
|---|---|---|---|
| NO OF KILNS | | 2.00 | |
| NO OF OPERATORS | | 2.00 | |
| LABOUR RATE | R/day | 5.00 | |
| HEAT CAPACITY | Mj/kg | 31.00 | |
| CAPACITY | run/month | 10.00 | |
| WOOD MOISTURE | % | 20.00 | |
| PACK DENSITY §20%MOISTURE | | 0.25 | |

WOOD USED FOR CHARCOAL PRODUCTION
(0,5 meter lengths 73% Moisture)

| | | | |
|---|---|---|---|
| PROD RATE | Mandays/t | 4.60 | (manual production) |
| COST | R/ton | 24.00 | |
| PACK DENSITY | tons/m3 | 0.36 | |
| NO OF WOOD CUTTERS | | 12.42 | (theoretical) |

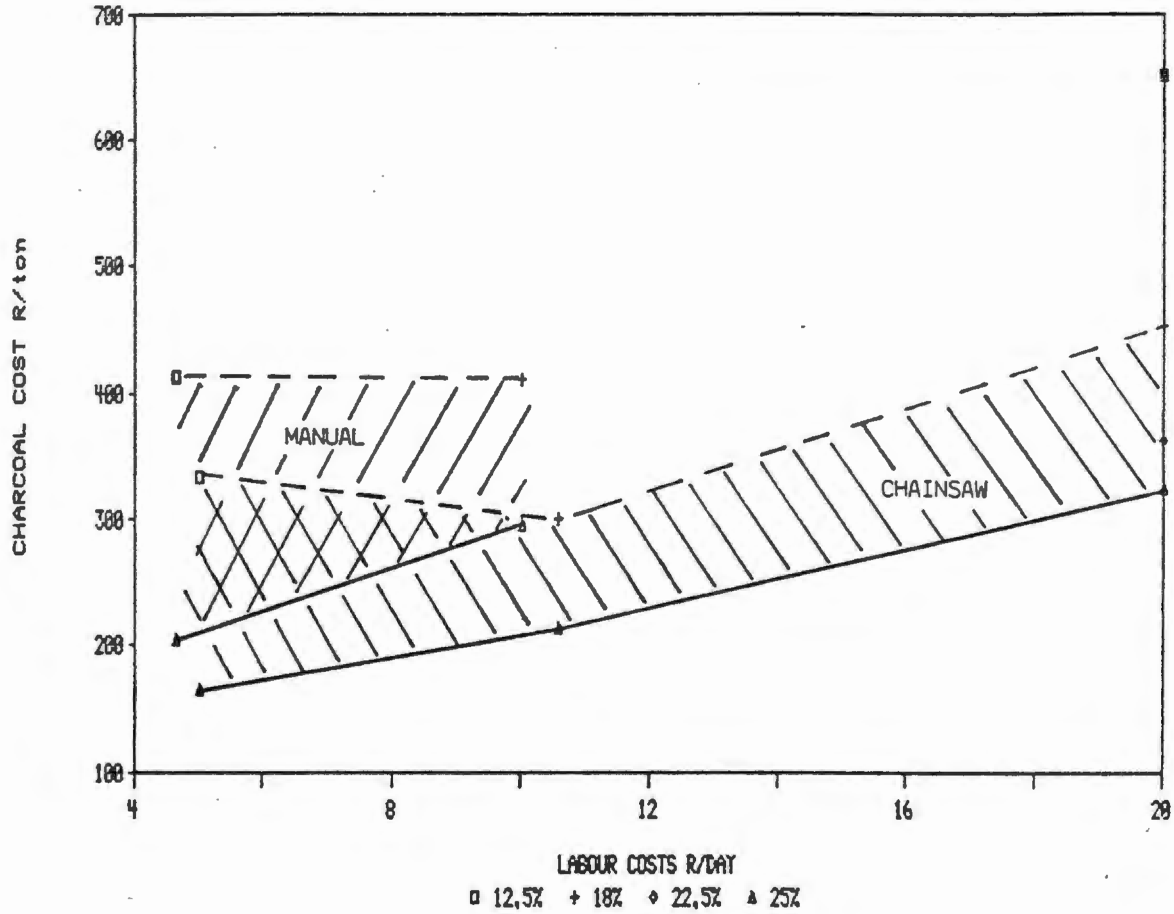
MONTHLY PRODUCTION AND COSTS

| | | |
|---|---|---|
| CAPITAL | | 132.48 |
| LABOUR | | 200.00 |
| WOOD | 54.00 tons | 1296.00 |
| CHARCOAL | 7.05 tons | 1628.48 |

PRODUCTION COST 231.09 R/ton

The effect of labour rate and charcoal yield on the charcoal production cost are shown below.

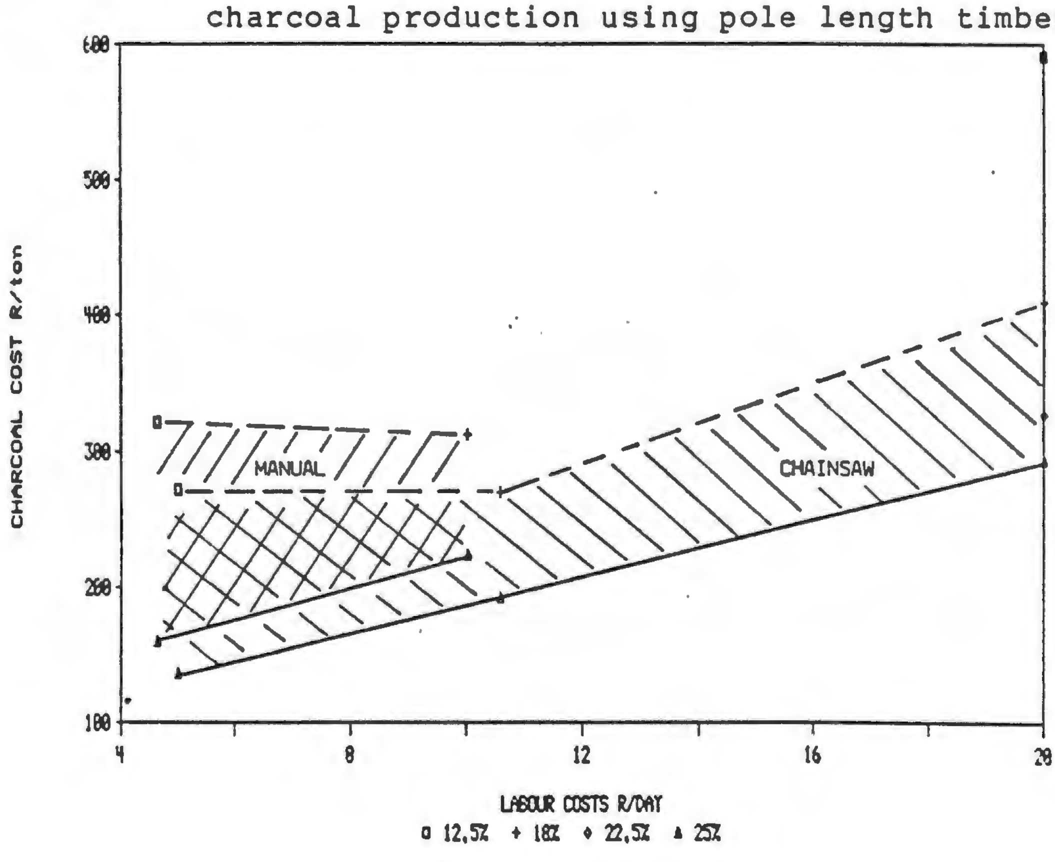
<u>Figure 16</u>: Effect of labour cost and charcoal yield on charcoal production using 0,5m length timber: TDRI




The results show that the most economical charcoal production can be achieved through use of a chainsaw in the preparation of the wood. This will not always be the case as shown by the overlap in the manual and chainsaw data. The solid lines represent the best case i.e. 25% charcoal production yield. The dashed line is an approximation of the worst but theoretically charcoal production can be infinite if operation produces only ash. In the calculation of these results, for the worst case, the charcoal yield is assumed to be 18% for wages in excess of R10/day. Below this wage, it is assumed for the worst case that unskilled labour will probably use wet wood and yields will drop to 12,5%. This explains the increase in the worst case charcoal production costs for low labour rates.

Generally charcoal production rate of the TDRI kiln is limited by the mass of wood that can be loaded into the kiln. Higher density wood is therefore more favourable than low density. In the experiments conducted Hakea siricea and Acacia cyclops have similar ovendry densities but the bulk densities varied almost twofold. This is a result of the wood specie shape and size. Acacia cyclops is a smaller bushy tree with many thinner branches whereas Hakea sericea produces less but thicker branches. The thicker timber produces higher packing densities which are more favourable for charcoal production. Bulk density of the timber is thus more important to charcoal production rate than the specific density. Generally thicker timber is thus better suited to charcoal production but wood size for the TDRI kiln is recommended to be limited to 60cm in length and 20cm diameter, thicker wood to be split. The experiments conducted for this project show the limitation in length of 60cm to be unnecessary if the charge is packed into the kiln with lengths standing on end. Length limitations are then defined by the height of the kiln, 1,8m. Charcoal production costs can then be calculated using pole length timber costs. The effect of using pole length timber reduces charcoal production costs to that shown below.

Figure 17: Effect of labour cost and charcoal yield on charcoal production using pole length timber: TDRI



## 10.2 TONGAN DRUM KILN

The low capital cost of the Tongan drum kiln makes this technique especially suitable for self-employment in the low income group. It may also suit the small business already involved in informal firewood industry allowing diversification using the same labour. Simplicity of construction and operation offer an attractive yet very simple method of making domestic grade charcoal. The experimental program conducted with alien wood species, Acacia saligna, Acacia cyclops and Hakea sericea demonstrated usable charcoal yields ranging between 9-24% at a production rate of 10-20 kg per drum. The small size of the kiln has the disadvantage of requiring wood pieces 0,5m in length and no more than 0,15m in diameter, requiring more wood preparation than the TDRI kiln thereby making the wood costs more expensive. As with the TDRI kiln, charcoal costs from the Tongan drum kiln are directly related to wood costs and should therefore have higher production costs. The nature of operation of the kiln and its small size, require continual attention and feeding of raw material. Charcoal quality and more importantly quantity or yield, are as a result, dependent on the operator. Charcoal production costs at a labour rate of R200 per month and yield of 20% are shown below.

Table 19: Charcoal production costs: Tongan drum kiln

KILN SPECIFICATIONS

| | | |
|---|---|---|
| WORKING VOLUME | m3 | 0.20 |
| YIELD | % | 20.00 |
| | kg/run | 20.00 |
| CAPITAL COST/KILN | R | 10.00 |
| LIFE | years | 0.50 |

CHARCOAL PRODUCTION

| | | |
|---|---|---|
| PRODUCTION | Tons | 6.00 |
| NO OF KILNS | | 15.00 |
| CAPACITY | run/month | 20.00 |
| WOOD MOISTURE | % | 20.00 |
| LABOUR RATE | R/day | 5.00 |
| NO OF OPERATORS | | 1.07 |
| HEAT CAPACITY | Mj/kg | 31.00 |

WOODCUTTING

WOOD USED FOR CHARCOAL PRODUCTION (WET)
(,5 meter lengths 73% moisture)

| | | |
|---|---|---|
| PROD RATE | Mandays/t | 4.60 |
| HEAT CAPACITY | Mj/kg | 10.34 |
| COST | R/ton | 24.00 |
| NO OF WOOD CUTTERS | | 11.94 |

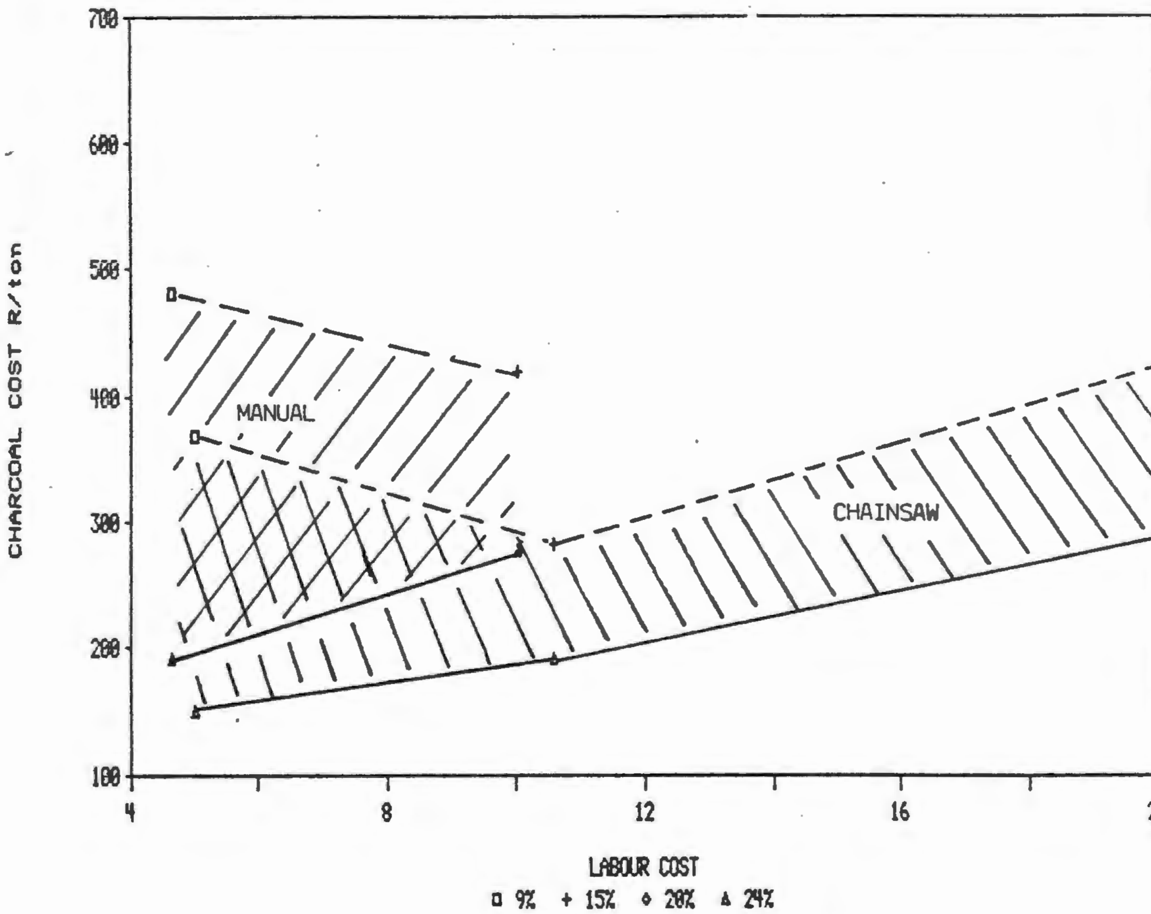
MONTHLY PRODUCTION AND COSTS

| | | |
|---|---|---|
| CAPITAL | | 25.00 |
| LABOUR | | 107.14 |
| WOOD | 51.90 tons | 1245.60 |
| CHARCOAL | 6.00 tons | 1377.74 |

PRODUCTION COST 229.62 R/ton

The effect of labour cost on the charcoal price over the range of charcoal yields is shown below.

Figure 18: Effect of labour cost and yield on charcoal production costs: Tongan drum kiln




The charcoal yields are expected to decrease with lower wages in a similar fashion to the TDRI kiln and therefore explain the worst case charcoal costs shown above.

## 10.3 CUSAB KILN

The CUSAB kiln is ideally suited to carbonisation of brush material normally generated by bush clearing. Capital costs are similar to the TDRI kiln and therefore tend to prohibit self-employment opportunities to the low-income group. The most suitable application would be in organisations already involved in large-scale clearing operations to dispose of piles of brush in an efficient, safe and non-polluting manner.

The kiln could also be used by small businessmen involved in the firewood industry to make use of brush material normally wasted by firewood cutters. The major disadvantage of the technique is that the charcoal produced is in a fine form not easily used in present charcoal stove designs. However, if produced in sufficient quantities, the fine material could be briquetted as is already done in the formal charcoal industry. Briquetting of the charcoal fines is well understood but involves a capital-intensive process. The process involves milling the charcoal down to less than 3mm, mixing in a binder and then compressing the mixture. The most commonly used binder is starch which has the added requirement of drying the product after compressing.

The operational flexibility of the CUSAB design introduces a range of operating conditions, choice of which has to be based on optimisation of charcoal production costs. The cost of raw material preparation for the CUSAB kiln could conceivably be negligible in the case of waste brush material from firewood/timber but handling costs will be incurred getting the biomass into the kiln. Measurements of manual brush feed rates were conducted allowing estimates of labour required to feed the kiln. Cost of this labour introduces a raw material cost whose effect on charcoal production cost are shown below.

Table 20: Charcoal production cost: CUSAB kiln

KILN SPECIFICATIONS

| | | | |
|---|---|---|---|
| WORKING VOLUME | m3 | 7.50 | |
| CAPITAL COST/KILN | R | 3100.00 | |
| LIFE | years | 3.90 | (Bennie, 1982) |

CHARCOAL PRODUCTION

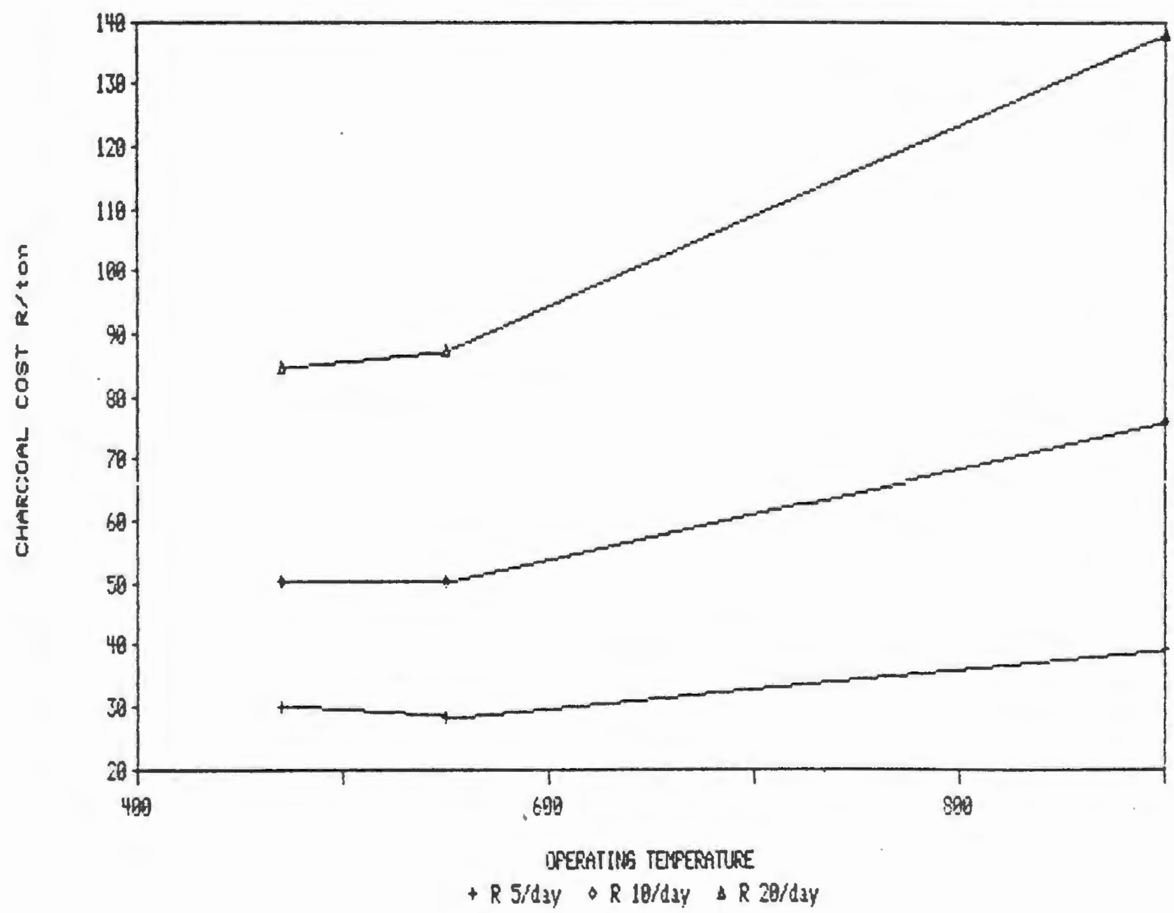
| | | |
|---|---|---|
| NO OF KILNS | | 2.00 |
| LABOUR RATE | R/day | 5.00 |
| HEAT CAPACITY | Mj/kg | 31.00 |
| CAPACITY | run/month | 10.00 |
| OPERATING TEMP | C | 900.00 |
| YIELD | % | 0.05 |
| PRODUCTION | tons/run | 1.06 |
| FEED RATE | Ton/Mday | 3.00 |
| COST | R/ton | 0.00 |
| NO OF OPERATORS | theory | 7.07 |
| | practical | 7.00 |

MONTHLY PRODUCTION AND COSTS

| | | |
|---|---|---|
| CAPITAL | | 132.48 |
| LABOUR | | 700.00 |
| WOOD | 424.00 tons | 0.00 |
| CHARCOAL | 21.20 tons | 832.48 |

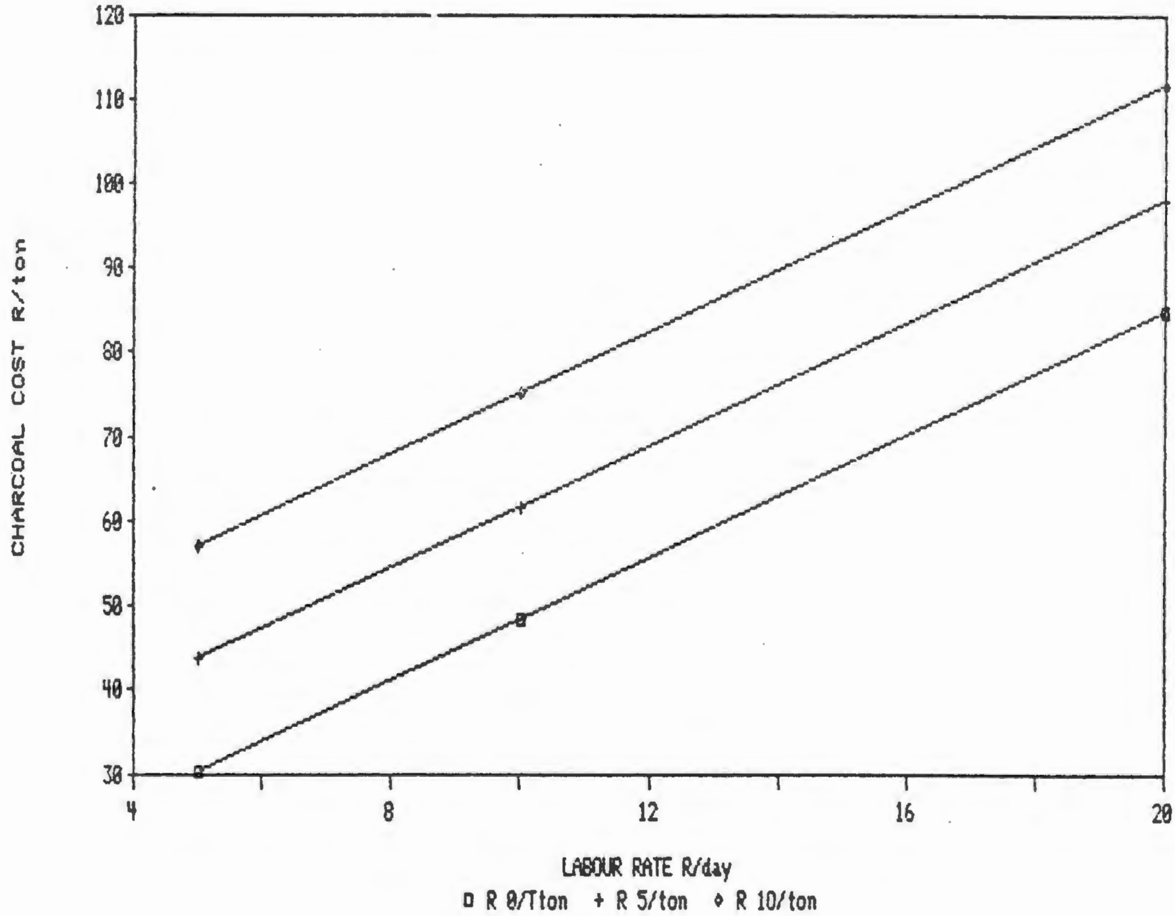
CHARCOAL PRODUCTION COST 39.27 R/ton

Figure 19: Charcoal production cost as function of operating temperature and labour cost: CUSAB



Should the wood costs not be negligible, the effect of raw material costs on the charcoal fine production price is shown below using the lowest operating temperature.

Figure 20: Charcoal production cost as function of labour rate and raw material cost




The improvements in charcoal yield with decrease in operating temperature dominate the production economics of charcoal fines in the CUSAB kiln. The increase in charcoal production rate with temperature does not reduce production costs even when raw material costs are negligible. This is a result of the increased raw material handling required with low charcoal yields. In conclusion therefore, the CUSAB should be operated at the lowest temperature possible. The operating point may however be determined by volatile or ash requirements which will effect the charcoal production costs.

## 10.4 WASTE WOOD UTILISATION

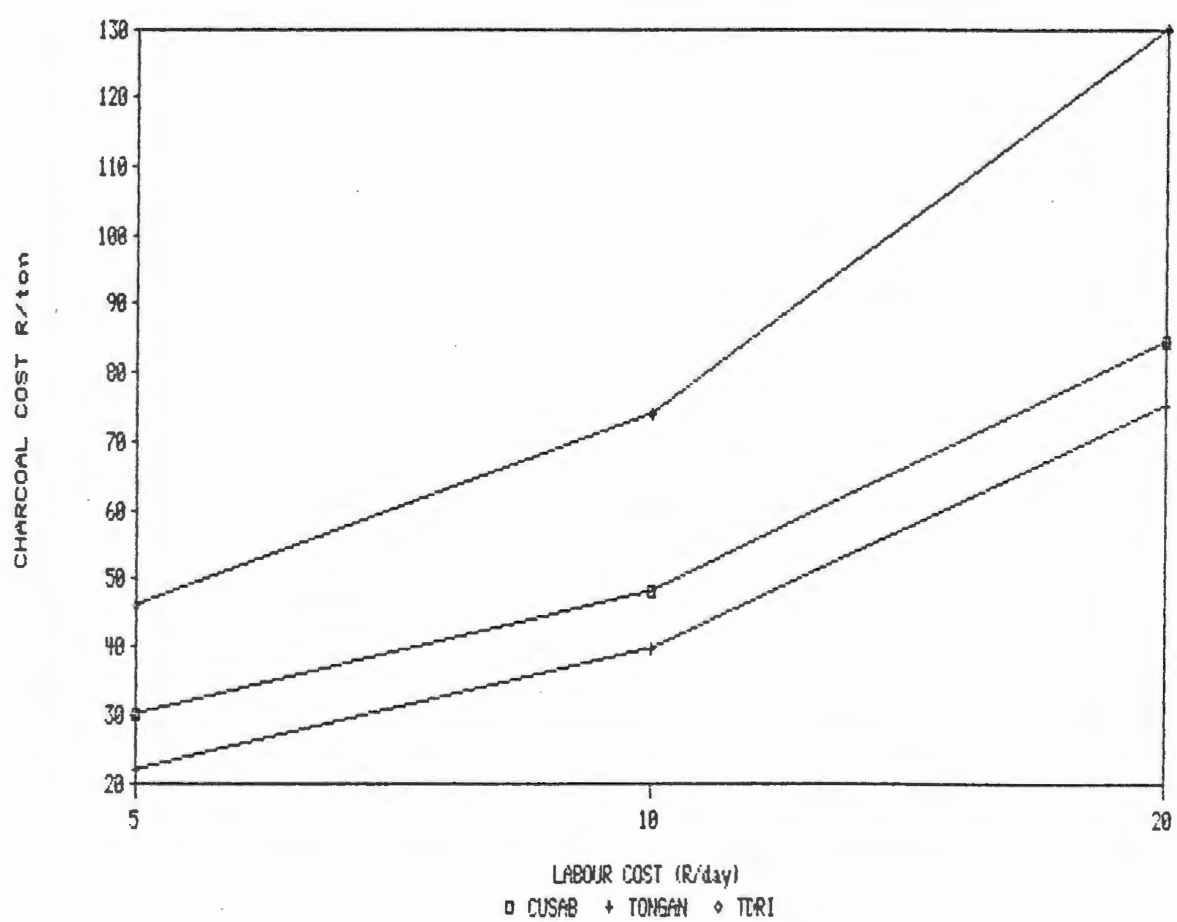
Wood processing industries generate waste material which in many cases has to be discarded as no economically viable use exists. This resource could provide a cheap raw material on which to base a small-scale low-cost charcoal production industry. Charcoal production based on negligible raw material costs is shown below as a function of labour costs. The physical size of the waste wood pieces will determine which technique to utilize:

- longer than 0,6m lengths : TDRI

- shorter than 0,6m : Tongan drum kiln

- very irregular to fine : CUSAB

<u>Figure 21</u>: Charcoal production costs using waste wood



# CHAPTER 11

# THE POTENTIAL ROLE OF CHARCOAL AS A FUEL IN UNDERDEVELOPED AREAS

## 11.1 CHARCOAL AS AN ENERGY SOURCE

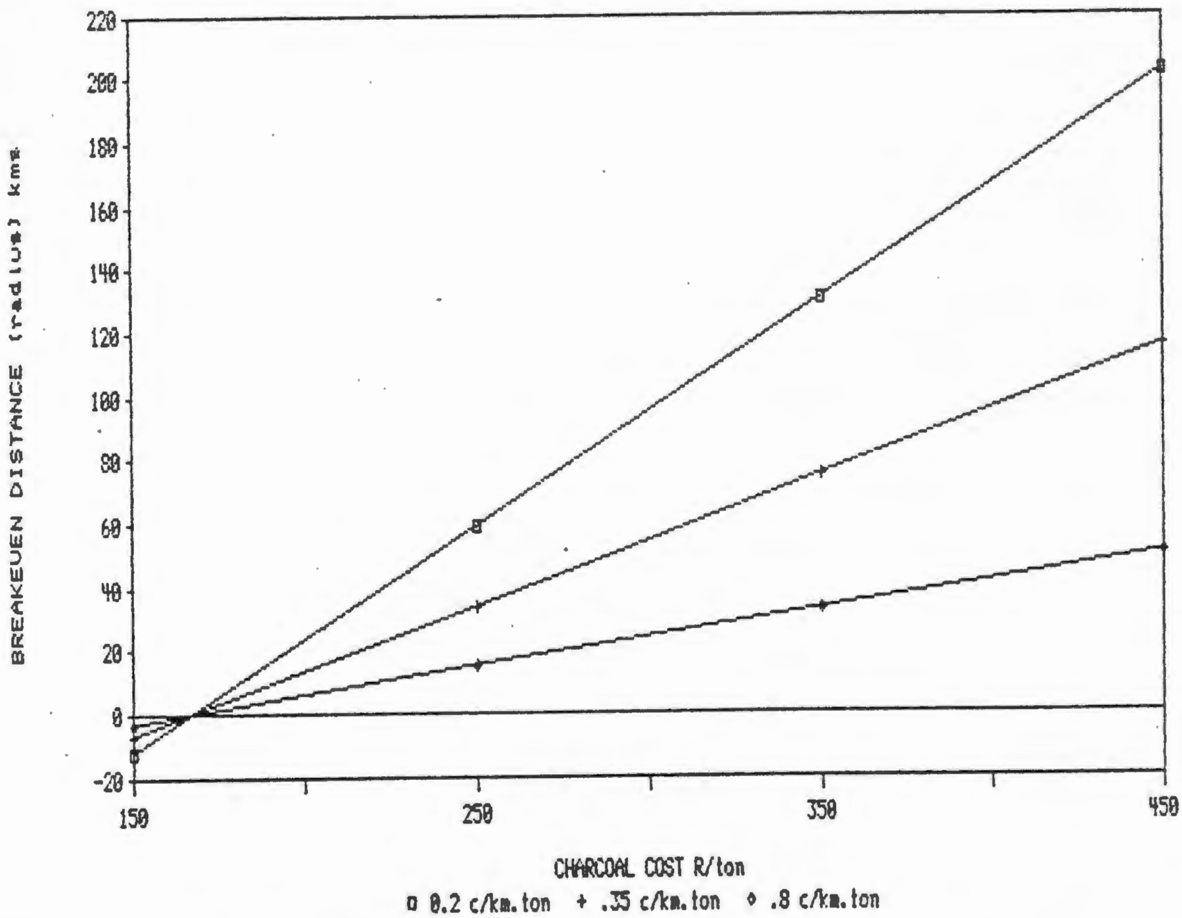
When fuelwood is to be considered as an energy source, there is a distance, often called the breakeven distance, beyond which charcoal is cheaper to use than wood itself. The higher energy density of charcoal improves the cost of transport, enabling the fuel to recoup costs of production during transportation. Thereafter the energy cost of charcoal is lower than that of wood. Evaluation of the breakeven distance is important to any fuelwood user who has to transport the wood some distance to the utilization point e.g. a remote woodgas powered generator. The validity of breakeven distance is usually limited by the cost of the alternative energy sources.

Of particular interest to this project has been the possibility of charcoal production from invasive alien species for underdeveloped rural areas. Ironically these tracts of alien species are considered 'noxious weeds' to be eradicated and programs to control their growth are being implemented at substantial expense. The biomass generated by these control programs could ideally provide a source of fuel for the underdeveloped areas if the cost of transportation could be reduced.

To investigate the feasibility of using alien biomass, the cost of energy supply from the infested areas must be compared with alternative energy costs. It is assumed that wood produced from alien species for use in underdeveloped areas would be similar in form to that marketed in Cape Town. The firewood production cost of 30-37 R/ton (wet), characteristic of the informal firewood industry in Cape Town, then provides a realistic minimum cost to work with. In view of the low wages earned by woodcutters producing the firewood, it is assumed that lower prices would not be realistic.

As already shown in the previous chapters the charcoal production price from alien wood species is primarily a function of labour costs. The breakeven distance is dependent on both the charcoal and wood production cost, the efficiency of each fuel type as well as a function of transport costs. Stove fuel efficiencies, as seen from 2.3.1, vary markedly. For this work, average wood (20%) and charcoal (30%) stove efficiencies have been used which results in charcoal stoves having 150% efficiency over wood stoves. The graphs below show the breakeven distances calculated for three transportation costs ranging between 0.2-0.8 R/km.ton, 0.2 being the most realistic and representing hired vehicle costs, and 0.8 that of a small newly purchased bakkie. Wood is assumed to be transported wet as is so often the case in Cape Town.

Figure 22: Breakeven distance




This shows that, from an energy point of view, use of alien vegetation to supply domestic fuel would be best converted to charcoal before distribution, where low labour costs allow cheap production of charcoal. Whether this new energy resource could be used or not, would depend on the energy cost in relation to alternative fuels, in particular, coal.

From a production point of view, the cheapest charcoal prices based on alien wood species range between 150-340 R/ton, the range being a function of labour costs. Taking into account the calorific value and average stove efficiency, the useful energy cost of charcoal would be 16-37 R/GJ. Coal production costs range from the pithead price of R23 to the price in Cape Town of R86 per ton. These costs translate into a useful cost of 3-11 R/GJ, assuming the coal stove to have the same average stove efficiency as charcoal (30%). From these figures it is evident that charcoal could only compete with coal in areas some distance from the coal sources. Transport costs of coal offered by the railways are low, allowing relatively cheap coal to be delivered anywhere along the railway network. However assessing the best and worst cases shows the following:

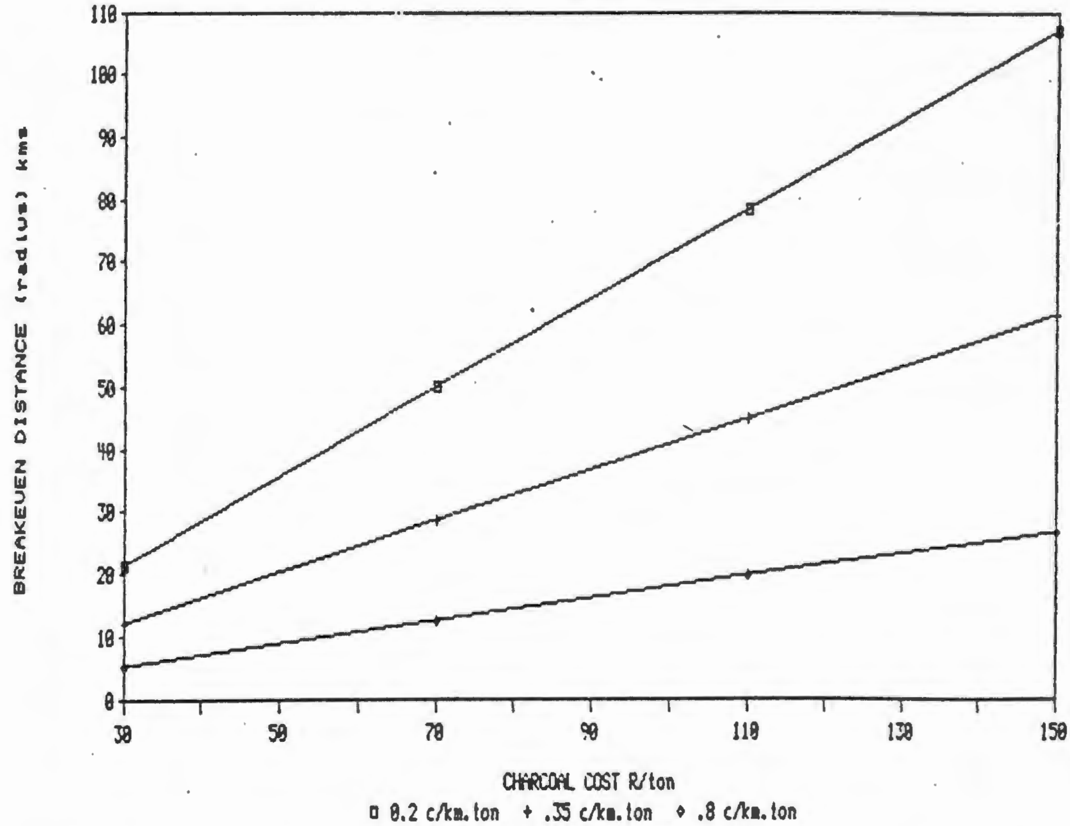
| | Best case | Worst case |
|---|---|---|
| Coal price (R/ton) | 86 | 23 |
| Charcoal price (R/ton) | 150 | 340 |
| Difference (R/ton) | 64 | 317 |
| Transport cost (R/km.ton) | 0.8 | 0.2 |
| Distance from coal depot (km) | 80 | 1585 |

As seen from the figures above, charcoal could conceivably compete with coal some distance between 80-1585 km from the railway network. The railway network in South Africa covers most of the country quite well, to a point where few areas greater than 80 km the railway network exist. As a result the chances of charcoal competing with coal are quite remote. Specific cases may however occur, probably only in the Cape and Northern Transvaal, i.e. far from the coalfields in Natal and Eastern Transvaal.

## 11.2 CHARCOAL FROM WOOD WASTE

Making use of wood wastes reduces the cheapest charcoal production cost with low cost technology, down to 20-130 R/ton, the range once again being a function of labour costs. The lower price of charcoal and the absence of wood costs produces breakeven distances tabled below:

Figure 23: Breakeven distances for wood wastes and charcoal




The results show that even though wood supply is at zero cost, very short breakeven distances exist, suggesting that use of wood wastes as a energy source for underdeveloped areas would benefit by charring the biomass before distribution. The lower production costs would allow greater opportunity for competition with coal. From a production point of view, the cheapest production cost of charcoal from wood wastes represents a useful energy cost of 2-14 R/GJ which overlaps with the production cost of coal (3-11 R/GJ), indicating that charcoal based on wood wastes could compete with coal in many if not all instances.

## 11.3 CHARCOAL AS A SOURCE OF REVENUE

Supply of a fuel source to the underdeveloped areas would more than likely be accomplished through a small business. Breakeven distances still exist but are based on profitability. If charcoal is to be used in the underdeveloped areas its similarity in appearance will inevitably force it to compete with coal. Eberhard's (1986) energy survey of eleven communities in both rural and peri-urban areas provides some insight into the cost of both wood and coal in the underdeveloped areas of South Africa. These figures have been inflated to 1987 at an inflation rate of 15% per year and presented in the table below.

Table 21: Rural and peri-urban fuel costs (R/ton)

| Town | Wood cost | Coal cost |
|---|---|---|
| **Rural** | | |
| Lugiko | 41 | - |
| Manzimahle | 51 | 357 |
| Clarkebury | 56 | 251 |
| Nkanga | 41 | - |
| Cottondale | 30 | 106 |
| Mokumuru | - | 225 |
| **Peri-urban** | | |
| Vulindlela | 66 | 159 |
| QwaQwa | 251 | 119 |
| Amateleng | 304 | 145 |
| New Bethesda | 105 | 132 |
| Crossroads | 119 | 172 |

From this data a small businessman would be able to decide whether to make charcoal or supply wood to the town depending on the breakeven distance. Having identified whether the natural or charred form of the fuelwood would be more profitable, it would then be necessary to evaluate whether the business could be run profitably. In general the charcoal production business will be better suited to remote areas where coal prices are significantly higher than wood prices. From the data above, the best charcoal production price can barely match the retail coal price in the peri-urban areas making wood the better option. Of the rural towns surveyed by Eberhard (1986) where sufficient data is available breakeven distances have been calculated, using cheap charcoal prices and transport costs of 0.2 R/km.ton. Results show that woodcutters supplying Manzimahle and Clarkebury would be better off producing charcoal if wood supplies are beyond the breakeven distances shown. Charcoal production cost shown is at the breakeven point.

Table 22: Charcoal/coal costs in rural areas

| Town | Wood cost | Coal cost | Distance | Charcoal |
|---|---|---|---|---|
| Lugiko | 41 | - | | |
| Manzimahle | 51 | 357 | 0 | 150 |
| Clarkebury | 56 | 251 | 13 | 155 |
| Nkanga | 41 | - | | |
| Cottondale | 30 | 106 | n/a | |
| Mokumuru | - | 225 | | |

Charcoal production costs from wood wastes has already been shown to match coal pithead prices. Similar production costs should allow charcoal from wood wastes to compete with coal, as a cheap domestic fuel, extensively but coal has the advantage of special cheap rail tariffs which will enable it to maintain low prices over a wider radius than charcoal. Small charcoal businesses will therefore only be able to compete with coal in the proximity of wood waste production centres.

Having shown that charcoal may or may not be able to compete with coal, as a cheap domestic fuel in the rural areas does not mean that wood resources would be converted to charcoal for that purpose. A large demand for luxury braai charcoal exists in South Africa and any small businessman producing charcoal will be drawn to this market naturally seeking the best price for his product. As a result only remote areas will be suited to domestic charcoal production where large distances to the bigger towns and cities, will prevent the small businessman attempting to supply the more lucrative market. The more lucrative market does have one advantage for those plagued by invasive wood species in that it provides a greater opportunity for wood utilisation.

# CHAPTER 12

## INTEGRATION OF CHARCOAL PRODUCTION AND BUSH CLEARING

Bush clearing is being conducted by numerous regional councils, conservation organisations and landowners at both small and large scale. All incur large expenses and generally seldom see any financial return. Charcoal production from the biomass generated by bush clearing could change this situation, allowing the same operations to operate profitably and if not, recoup most of their usual bush clearing expenses. Charcoal production could be introduced into the existing plant control strategy or through the creation of a new task force, operating as independent business concerns. If small business concerns are created through say for example, a technology transfer program, the simple low-cost technology identified in this project would allow job opportunity to the low-income group. Technology would also suit farmers involved in expensive bush clearing.

### 12.1 THE CHARCOAL MARKET

Although it has been shown that charcoal will not be marketable in the underdeveloped areas, charcoal produced from bush clearing biomass can be marketed through other existing, more lucrative channels, the domestic and industrial charcoal markets, but here the question of charcoal quality is raised.

The standards for domestic charcoal quality are specified in SABS 1399 (Gore, 1985). Both the TDRI and Tongan drum kiln have been demonstrated to be capable of meeting these specifications with the exception of the drop test specification which was not measured. However, meeting the SABS requirements would seem to be of little significance, as the sale of domestic charcoal in South Africa does not need the approval of this specification. In fact, enquiries made through the South African Bureau of Standards showed that not one domestic charcoal supplier in South Africa uses the SABS stamp of approval.

Gore (1985) reports the industrial charcoal market to be several fold larger than the domestic market but very few written specifications for physical and chemical properties to exist. Recommendations are given to the charcoal producer that he identify from industrial concern what particular properties are of importance. The proximate composition of four industrial charcoal grades are reported by Gore (1982):

| | Silica quartz reductant | Carbon disulphide manufacture | Safety fuse | Ferro-alloy |
|---|---|---|---|---|
| Fixed carbon % | > 78 | > 92 | > 84 | > 96 |
| Volatiles % | < 22 | < 5 | -- | < 2 |
| Ash % | < 3 | < 2 | -- | < 2 |
| Moisture % | -- | < 1 | < 6 | < 0,2 |

From these figures only the silicon and safety fuse industries could conceivably be supplied by low-cost technologies. However one major problem will be maintaining charcoal product uniformity, a feature not achieved during experimentation. Possibly with experience and better control of wood preparation, the uniformity may be improved, but this sort of control would not be easily accommodated in a bush clearing program and least of all in a poorly skilled business concern.

The CUSAB kiln operating at high temperature was demonstrated to produce the highest fixed carbon content achieved out of all the low-cost techniques tested. Unfortunately, the CUSAB process produces charcoal in fine form typically less than 10mm, generally unsuitable for use as is, with the exception of manufacturing of safety fuse carbon. The charcoal used in this industry is crushed into a fine powder anyway. An important requirement for safety fuse carbon is high reactivity which Gore (1985) reports can be achieved through carbonisation of twigs. Reactivity is uniformly high when small pieces are carbonised as volatiles escape easily and pores do not become blocked with condensates. With the low-cost technology CUSAB kiln, these high reactivities could probably be achieved, but contamination of the charcoal with grit, which is unavoidable, would make the charcoal product unacceptable.

As a rule therefore, it must be concluded that the charcoal produced by these low-cost technologies and poorly skilled labour cannot be considered for industrial charcoal markets, especially if the emphasis is on bush clearing. The charcoal produced is best suited to domestic use in the braai market.

## 12.2 INTEGRATION WITH EXISTING BUSH CLEARING OPERATIONS

### 12.2.1 Timber usage

The clearing operations being conducted by the regional councils and conservation organisations make use of chainsaws, brushcutters and organised teams of men. The cost of clearing depends heavily on the density of the vegetation but for the case of this exercise is assumed to be that reported in Section 3.2. The total cost of R825 per hectare including the cost of burning the felled biomass, is based on a labour rate of R20 per day, approximately the minimum wage for unskilled labour. If charcoal production is to be incorporated into existing clearing operations, then the same labour rate will apply in the charcoal production side of the operation. From Chapter 10 charcoal production costs at this labour rate would range between R250-R470 per ton, Tongan kilns having a small advantage over the TDRI kiln. The range in production cost is a result of the charcoal yield achieved, which will depend on operator skill. Enquiries put to the large retailing outlets in Cape Town, indicated a charcoal production price of less than R400 per ton would be necessary to compete in the market. This price allows for bagging and distribution costs to bring the final wholesale price to R600 per ton. This price would however be dependent on sales direct to the retailer.

Seeing that the two low-cost charcoal production techniques can produce charcoal for less than R400 per ton at the prevailing labour rate, it would seem obvious that organisations conducting bush clearing operations should include a charcoal producing operation to their team. The sale of their product through local marketing channels would allow them to recoup all their operational expenses even if their charcoal yields are not optimum. However the decision to include charcoal production in the bush clearing programs cannot be made on economics alone, as the disadvantages of administration of a much larger combined operation may not warrant the economic advantage.

Integrating charcoal production with bush clearing will increase the total number of people employed in the operation, several fold, as wood preparation and carbonising requires additional manpower over and above that required to simply fell and burn. The number of people involved will depend on the number of kilns being used. A minimum of two kilns is recommended for optimum usage of the equipment. The resulting minimum operating team size as follows:

| | |
|---|---|
| No. of kilns (TDRI) | 2 |
| No. of kiln operators | 2 |
| No. of wood cutters | 3 |
| Charcoal produced | 5-7 tons/month |
| Value @ R400/ton | 2000-2800 R/month |
| Clearing rate * | 0,5 Ha/month |

* based on 173 tons (wet mass) biomass per Ha (Milton, 1981)

For higher clearing rates multiples of this minimum size are recommended.

12.2.2 Brush usage

The charcoal/bush clearing unit as shown above will not consume all the biomass produced. The thin brush material and leaves are not used in the Tongan and TDRI processes. Two options for this material exist. In alien vegetation control as discussed in Section 3.3, burning of the biomass is considered an important part of the follow-up operation. The brush material left behind will provide material to continue the necessary burning practice. Alternatively the brush could be consumed in the CUSAB kiln to produce charcoal fines. Here the use of the TDRI kiln is particularly suited to bush clearing because with small modifications it can double as a CUSAB kiln for brush carbonisation.

Unfortunately the market for charcoal fines is not widespread as it relies on a briquetting facility close by to convert it into a saleable product. No working facilities exist in Cape Town but the domestic charcoal briquette (produced elsewhere) is consumed in far greater quantities than lump charcoal according to retail outlets consulted in Cape Town. As a result if a consistent supply of charcoal fines were to be established, a briquetting concern would no doubt follow soon after. Enquiries put to a small, presently non-operational, briquetting concern indicated a raw material value of R100 per ton for the charcoal fines.

The production cost of charcoal fines with the CUSAB kiln, is a function of labour rates but also a function of the degree of carbonisation required. High fixed carbon content is achieved through higher temperature operation but the associated lower yields result in a higher charcoal production cost. These high carbon contents are required for industrial applications generally not considered suitable to production with these low cost techniques. The production of domestic grade charcoal is produced at lower operating temperatures and higher yields allowing a cheaper production price. From Chapter 10 the production cost at the minimum wage rate of R20/day is R85 per ton. As the kiln can be constructed through small modifications to the TDRI kiln production of fines can be accomplished as a secondary process in conjunction with carbonisation of thicker timber.

Alternatively a dedicated unit can be organised to carbonise the brush in a separate operation. The minimum size recommended for this would be as follows:

| | |
|---|---|
| No. of kilns (TDRI) | 2 |
| No. of kiln operators | 2 |
| No. of wood cutters | 0 |
| Charcoal produced | 11 tons/month |
| Value @ R100/ton | 1100 R/month |
| Clearing rate * | 0,7 Ha/month |

* based on 173 tons (wet mass) biomass per Ha (Milton, 1981)

For higher clearing rates multiples of this minimum size are recommended.

12.2.3 Comparison with existing operations

The figures for both charcoal lumps and fines are based on above-ground biomass measured at 15 sites around Cape Town (Milton, 1981). As precise manpower requirements for felling and burning of the same biomass density are not available, the information from Conservation Forestry reported in Section 3.2, will be considered the best approximation for comparative purposes.

| | Alien plant control programs | with charcoal integration |
|---|---|---|
| <u>Initial clearing</u> | | |
| Labour (mandays/ha) | 11 | 200 |
| Cost (R/ha) | 425 | 4690 |
| Product value (R/ha) | 0 | 4000-5570 |
| <u>Burning</u> | | |
| Labour (mandays/ha) | 10 | 60 |
| Cost (R/ha) | 400 | 1430 |
| Product value (R/ha) | 0 | 1680 |
| <u>Total operation</u> | | |
| Labour (mandays/ha) | 21 | 260 |
| Cost (R/ha) | 825 | 5430-7000 |
| Net cost (R/ha) | 825 | 440-(-1130) |

Both timber and brush usage require a minimum of two kilns each if operated as separate concerns. The minimal additional capital outlay required to implement charcoal production would be:

| | | |
|---|---|---|
| Timber usage | R 6200 | (rate 0,5 ha/month) |
| Brush usage | R 6200 | (rate 0,7 ha/month) |

Faster clearing requirements will require proportionately more capital input.

These figures show that bush clearing can be converted into a self-sustaining operation but larger numbers of personnel will be required and additional capital input.

## 12.3 BUSH CLEARING THROUGH SMALL BUSINESS OPERATIONS

An alternative to integrating charcoal production into existing operations would be to open up the areas requiring clearing, to small informal charcoal producing enterprises. The technology for charcoal production is simple enough for this concept but as no experience in small-scale charcoal production exists in the country, the concept would rely on some sort of training program. Distribution and marketing of the product would also present a big hurdle as transportation is seldom available to small informal enterprises and sales from the roadside are unlikely to be successful. As production would primarily be rural and consumption in the towns and cities, transportation would involve a middleman, inevitably forcing production costs down, only possible through reduction of labourers' wages. This is precisely the plight of the informal woodcutter. Sales from the roadside command good prices but the market is small, while the alternative of working through a middleman who possesses a truck, means low prices for his wood but a good market.

To assess what a middleman would do to the earnings of an informal charcoal producer the example of an informal firewood business is investigated. A truck owner, acting as a middleman for a firewood wholesaler in Cape Town, trucks a six ton load to town daily, buying firewood at R37/ton and selling at R65/ton, makes a living as follows:

| | | |
|---|---|---|
| <u>Costs</u> | | |
| Wood | 6 tons x R 37/ton | R 222 |
| Transport | 60 km @ 0,2 R/km.ton | R 72 |
| <u>Sales</u> | | |
| Wood | 6 tons x R 65/ton | R 390 |
| <u>Leaving</u> | | R 96/day |

If this same individual were to transport charcoal on the same basis, the price he would be prepared to pay for charcoal would determine what labour rate the charcoal producers could earn. Using the same middleman earnings of R96/day the following would represent a small charcoal enterprise:

| | | |
|---|---|---|
| Sales | | |
| Charcoal | 6 tons @ R300/ton | R 1800 |
| | | |
| Costs | | |
| Middleman | | R 96 |
| Transport | 60 km @.R/km.ton | R 72 |
| | | |
| Production cost | | R 1632 |
| | | R 272/ton |

Taking the example of the firewood sales, the middleman would sell the charcoal to a wholesaler who would package and redistribute to retailing outlets. As a result the price he would get for his charcoal would be in the order of R300/ton and not R400/ton as in the previous case. The middleman would then be able to pay R272 per ton, for the charcoal which would allow potential earnings of R10/day and R20/day for manual and chainsaw wood production respectively. Although these earnings do not seem good, they represent double the earnings made cutting firewood.

If the production of charcoal can provide increased labour earnings, incentive for this type of business should exist. Landowners requiring clearing could theoretically then allow producers on their properties as a clearing mechanism, controlling access through permits or something similar. Using this concept would create a clearing mechanism without the capital costs and administration difficulties associated with integration into existing clearing operations.

It is acknowledged that this avenue (allowing firewood cutters to clear bush) has been tried with firewood cutters in the areas around Cape Town, with little success, but this does not mean that it would not work for charcoal. The failure was as a result of preference for Rooikranz, which resulted in only selective felling, leaving an area partially cleared. This should still have been to the landowners advantage, constituting some saving in labour, but the brush material left behind by the woodcutters mixed in the thickets of unwanted species posed a problem for later clearing operations by official clearing teams. Charcoal production would not suffer the same problems, as it is not species selective. All wood species would be felled and used. Brush would however be left behind by this operation and would therefore only suit areas where the brush is needed for later burning (see Section 3.3).

The optimum size of operation would be one where a number of wood cutters prepare wood for one kiln operator. The team would look as follows:

| | |
|---|---|
| No. of kilns (Tongan) | 14 |
| No of kiln operators | 1 |
| No. of wood cutters * | 6-17 |
| Charcoal produced | 6 tons/month |
| Value @ R272/ton | 1630 R/month |
| Clearing rate ** | 0,5-1.2 Ha/month |

* depending on charcoal yield (9-24%)

** based on 173 tons (wet mass) biomass per Ha (Milton, 1981)

Smaller teams could produce charcoal as well, though less efficiently as the kiln operator would be working below his optimum. The cost involved in converting firewood operations to charcoal production would be the cost of the kilns, i.e. 14 x R10 = R140 (clearing rate 0,5-1,2 ha/month). This assumes that the wood cutters already have wood cutting equipment.

## 12.4 CLEARING THROUGH LARGER SCALE OPERATIONS

To draw comparison between small-scale low cost technology and larger scale operations, the production cost for two more sophisticated processes are evaluated. The two processes are, the Gaylard retort and the Armco Robson Kiln. Gaylard (1986) shows that the Gaylard retort design is capable of producing charcoal cheaper than the Armco Robson kiln. Although for an equivalent production rate (42 tons/month) the Armco Robson kiln (R 10 000) costs less than 1/3 of the retort (R 35 800), the high charcoal production yield of the retort enables it to produce cheaper charcoal. Comparative costing indicates charcoal production costs of R 104/ton and R 142/ton for the retort and kiln respectively. These costs are based on charcoal production yields of 30% and 20% respectively, labour costs of R 150/month (R 7,50/day) and wood costs of R18/ton. A copy of Gaylard's calculations are included in the appendices. A similar cost estimation is completed using alien wood species.

If existing bush clearing programs were to process the biomass in one central facility, the production of timber and operational staff would command at least the minimum wage of R20/day. The wood costs and operating costs would then reflect this labour rate. The use of alien wood species would not permit high density packing in the kiln and as a result drop production rates. The packing density achieved with pole length timber was 0,23 ton/$m^3$, only 54% of the 0,42 ton/$m^3$ achieved using plantation timber. This reduces production rates to 23 tons/month. Taking these figures into account, the charcoal production cost will increase to R 350/ton and R400/ton for the retort and kiln respectively, without taking transportation into account. These figures certainly do not warrant going to the expense and risk of a large-scale operation.

## 12.5. SELECTION OF CLEARING TECHNIQUE

The choice of which option to choose also depends on the wood species to be cleared. Generally the larger the tree the more capital necessary to convert it to charcoal. Table 8 in Section 3.4.6 shows which species are considered to grow too thick for manual harvesting. The same trend will be evident in carbonising equipment selection. The TDRI kiln is capable of handling thicker timber than the Tongan kiln and as a result is better suited to the thicker growing species. Thicker growing timber will as a result require both chainsaws and the more expensive TDRI kiln, involving capital that would be beyond the reach of an informal business. Larger timber species will as a result be better tackled by integration of charcoal production into existing operations. The list below suggests which technique will be best suited to each of the problematic species.

Table 21: Invasive wood species for charcoal production

| | Specie | Manual/ Chainsaw | Technique | Operation |
|---|---|---|---|---|
| (1) | Acacia Saligna | m | Tongan | business |
| (2) | Acacia Cyclops | m | Tongan | business |
| (3) | Acacia Longifolia | m | Tongan | business |
| (4) | Albizia Lophantha | | | |
| (5) | Hakea Sericea | m | Tongan | business |
| (6) | Acacia Mearnsii | c | TDRI | integrated |
| (7) | Leptospermum Laevigatum | m | Tongan | business |
| (8) | Pinus Pinaster | c | TDRI | integrated |
| (9) | Acacia Melanoxylon | c | TDRI | integrated |
| (10) | Sesbania Punicea | | | |
| (11) | Prosopis spp. | c | TDRI | integrated |
| (12) | Melia azedarach | c | TDRI | integrated |
| (13) | Acacia dealbata | | | |
| (14) | Populus spp. | c | TDRI | integrated |
| (15) | Salix babylonica | c | TDRI | integrated |
| (16) | Acacia Karoo | m | Tongan | business |
| (17) | Diospyros lyciodes. | m | Tongan | business |
| (18) | Acacia erioloba | c | TDRI | integrated |

Of course where the species is still young, the Tongan drum kiln will be capable of carbonising the wood. Where complete removal of biomass is required, it is best tackled with TDRI/CUSAB operation integrated with existing bush clearing operations. The versatility of the TDRI/CUSAB kiln allows carbonisation of both wood and brush.

## 12.6 ECOLOGICAL EFFECTS

Elsewhere in the world there is concern about the production of charcoal from an ecological point of view. As roughly 50% of the fuelwood energy content is wasted through the production of charcoal (Section 4.1) consumption of wood reserves are faster than necessary, a serious problem where wood is in short supply. However we have the reverse situation here. We have large reserves of wood considered 'noxious weeds' that need to be eradicated for a number of reasons. The high consumption of wood through charcoal production is then considered an advantage.

However, other ecological effects need to be considered. Efforts to remove alien invasive species are plagued by the ability of many species to regenerate vigorously after initial clearing. Follow-up procedures have been devised through experience that assist in controlling the regrowth. If uncontrolled felling takes place without any follow-up, which would be the case for small informal operations, regrowth will re-infest areas cleared. It is therefore important for any operation to be backed by specialised follow-up operations. For that reason it is advisable to ensure that any charcoal production from alien wood species be coordinated by the landowner who could ensure follow-up procedures are carried out. Another danger associated with basing business on the alien Acacias is that, like the tannin industries, conflict of interests can result to an extent where the species are protected for their commercial value. Intuitively, charcoal production integrated with existing bush clearing operations would then appear to have the best chance of successful alien specie control.

# CHAPTER 13

## CONCLUSIONS

Bush clearing is required in many parts of South Africa and Namibia. Both indigenous and alien wood species have invaded large areas, through deliberate action by man and through inherent regeneration mechanisms, characteristic of these species. Clearing of sensitive areas is already underway but much larger scale operations will be needed if these problematic species are ever to be brought under control. Clearing is not only required for conservation reasons but also for land utilization, especially farming. Present clearing costs prohibit escalation of the control programs designs to curb the spread of the invasive species. This is not surprising when one considers the current practice, whereby trees are manually felled, with the aid of a chainsaw, heaped and burnt on site. This is both costly and wasteful, as the energy contained in the wood is a valuable renewable energy resource, virtually untapped at present.

Charcoal production from alien wood species can be achieved using small-scale low cost technologies, converting wood to a fuel form, used extensively in the domestic and industrial markets. The use of this technology has the potential of allowing the market value of charcoal produced from bush clearing residues to be used to recoup the costs of initial clearing. The irregular, generally thinner timber from alien species suit small-scale low-cost technologies rather than large-scale production. These simple technologies also benefit from being able to operate on the forest floor close to the wood source, thereby eliminating costly transportation of wood that would be required by the larger scale production.

Two different transportable kiln designs have been shown capable of producing lump charcoal from alien timber and one other kiln design, demonstrated to produce charcoal fines from brush material. The three kilns are:

- the TDRI metal drum kiln;
- the Tongan drum kiln; and
- the CUSAB kiln.

Field trials, conducted as part of an action research program, identified the operation of the Tongan drum kiln to be the simpler of the two lump charcoal producing techniques, therefore suiting operation by unskilled labour. TDRI kiln operation was found to require more skill in operation but a different wood packing arrangement was found to improve operation with alien wood species. The CUSAB kiln, like the Tongan kiln was found to be simple to operate, but produces a fine product needing expensive briquetting before it can be used.

Charcoal production costs of the small-scale technologies was found to be a function of labour costs, primarily indirectly through the labour costs of wood harvesting and preparation. The larger TDRI kiln benefited by being able to use longer timber than that required for the Tongan kiln, requiring less preparation but the low capital costs of the Tongan kiln offset this advantage, producing the cheapest charcoal from alien wood species tested.

Charcoal production costs associated with the small-scale kilns were found to be low enough to compete in the market place in Cape Town but may need direct marketing to retail outlets to be competitive in some cases. Integration of charcoal production into existing bush clearing programs was found to be economically feasible, even using the more expensive TDRI kiln. Simple modifications to the TDRI kiln allow it to double as a CUSAB kiln, which enables it to carbonise both timber and brush.

Although economically viable, the use of charcoal production in existing bush clearing operations, will require, but cover the costs of, a tenfold larger labour force. The low-cost Tongan drum kiln was considered best suited to clearing via establishment of small charcoal producing enterprises. The simple technology and low capital cost would allow easy entry into the business.

Few alternative uses for the alien biomass were found to be viable. Use as firewood, cut up into 'stick' form was found to be the major consumer, but selective felling of species makes this unsuitable for bush clearing. Possible supply of wood or charcoal to underdeveloped areas of South Africa reliant on diminishing local wood supplies for their domestic energy requirements was evaluated. The charcoal produced from alien species was found to be too expensive and would be unable to compete with coal, virtually throughout the country.

There is great potential for small-scale charcoal producers, particularly in the Cape where few production centres exist and where large tracts of unwanted, 'noxious weeds' are found. If correctly co-ordinated through organisations already involved in bush clearing, the use of small-scale operations could assist in the enormous task of alien vegetation control. The implementation will make clearing cheaper if not profitable, create a fuel source from waste and probably most important create significant job opportunities.

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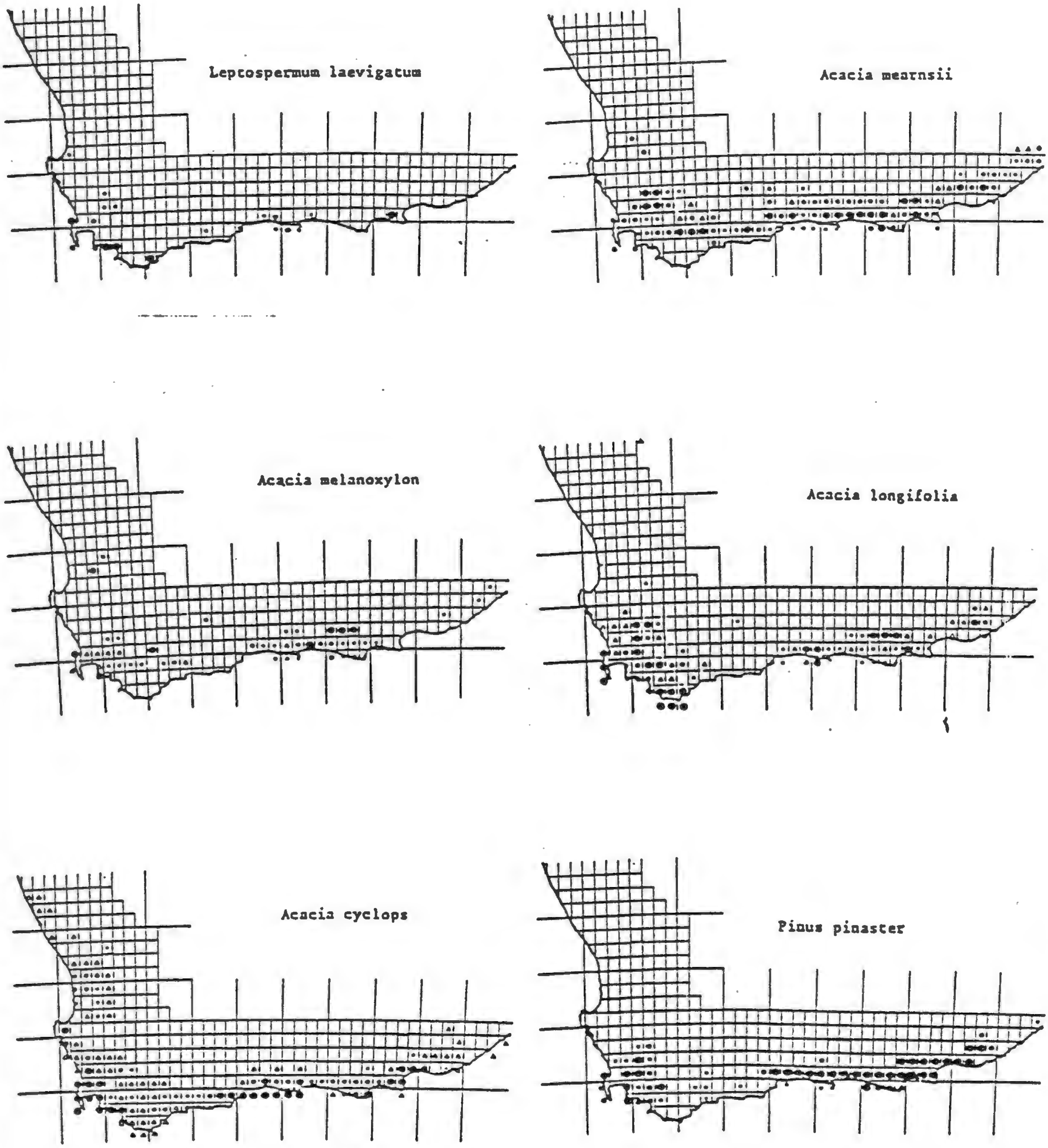
# APPENDICES

APPENDIX 2




Distribution of species according to quarter-degree grid squares in three categories: ( o ) only present as scattered plants; ( • ) moderate infestation; and ( ● ) dense infestation.

APPENDIX 3



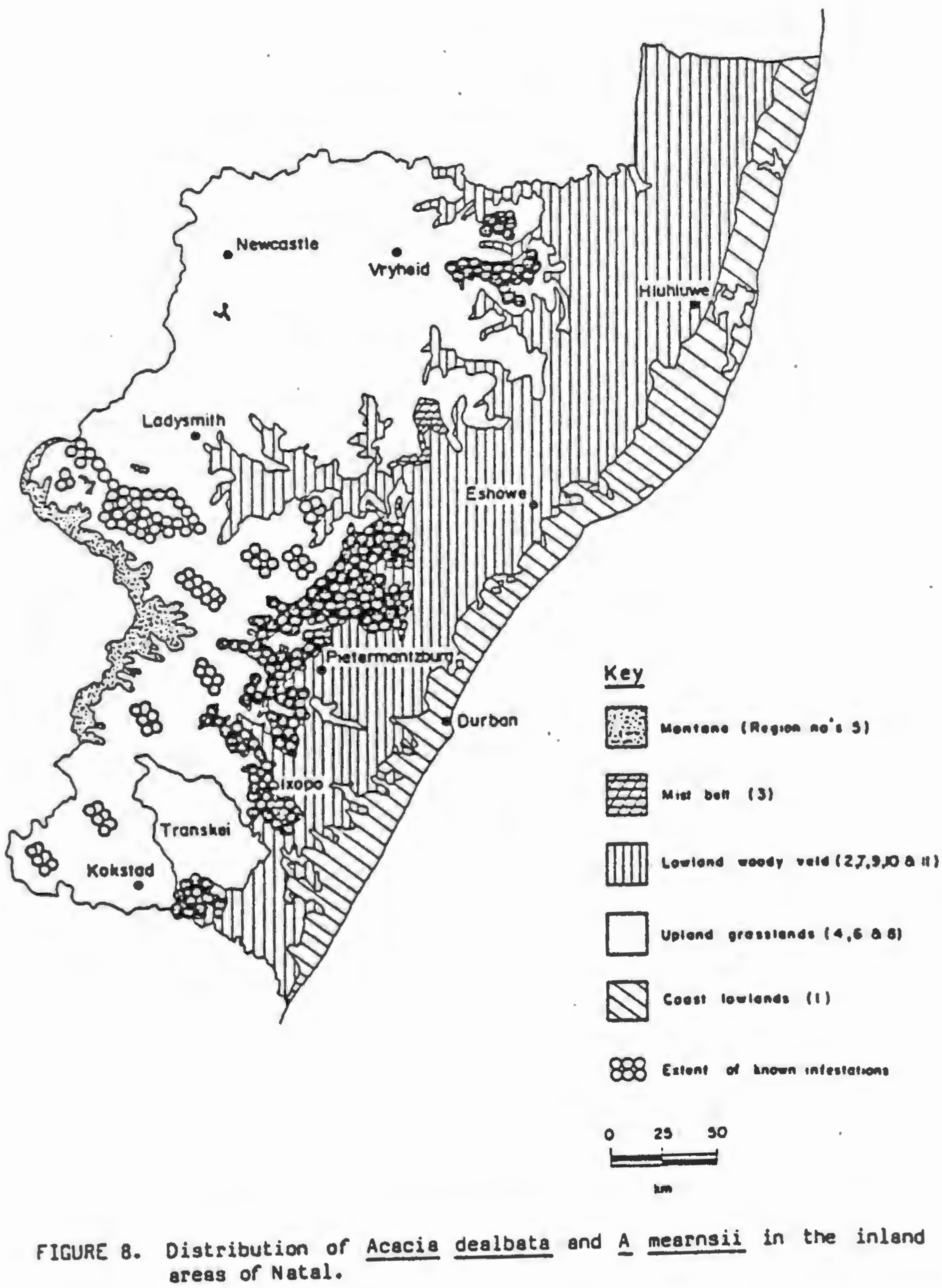



FIGURE 8. Distribution of Acacia dealbata and A mearnsii in the inland areas of Natal.

APPENDIX 4

KEY TO ZONATION

1. First priority - eliminate the infestations in the veld and phase out of urban situations in this region where the species poses a major threat to riverine vegetation.

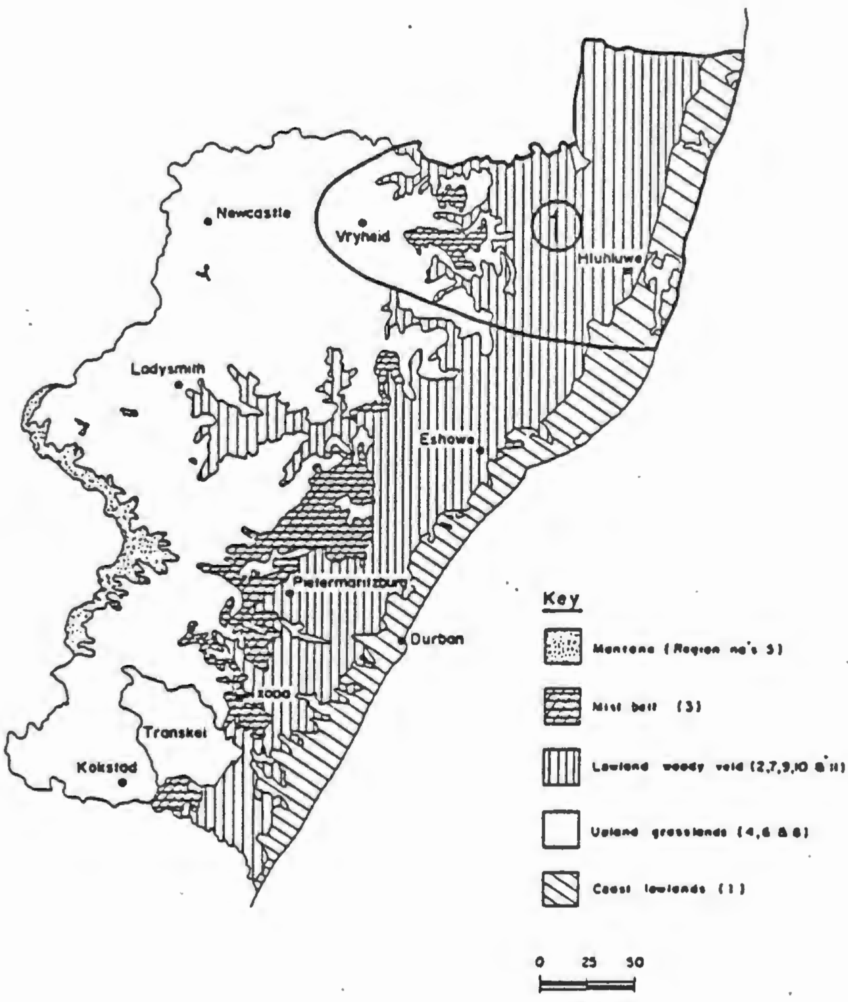



FIGURE 11. Suggested priority control area for Melia azederach in northern Natal.

# APPENDIX 5

KEY TO ZONATION

1. First priority - objective total elimination as not yet well established in the catchments north of Empangeni.
2. Second priority - objective total elimination as only small introductions to date in the Berg area.

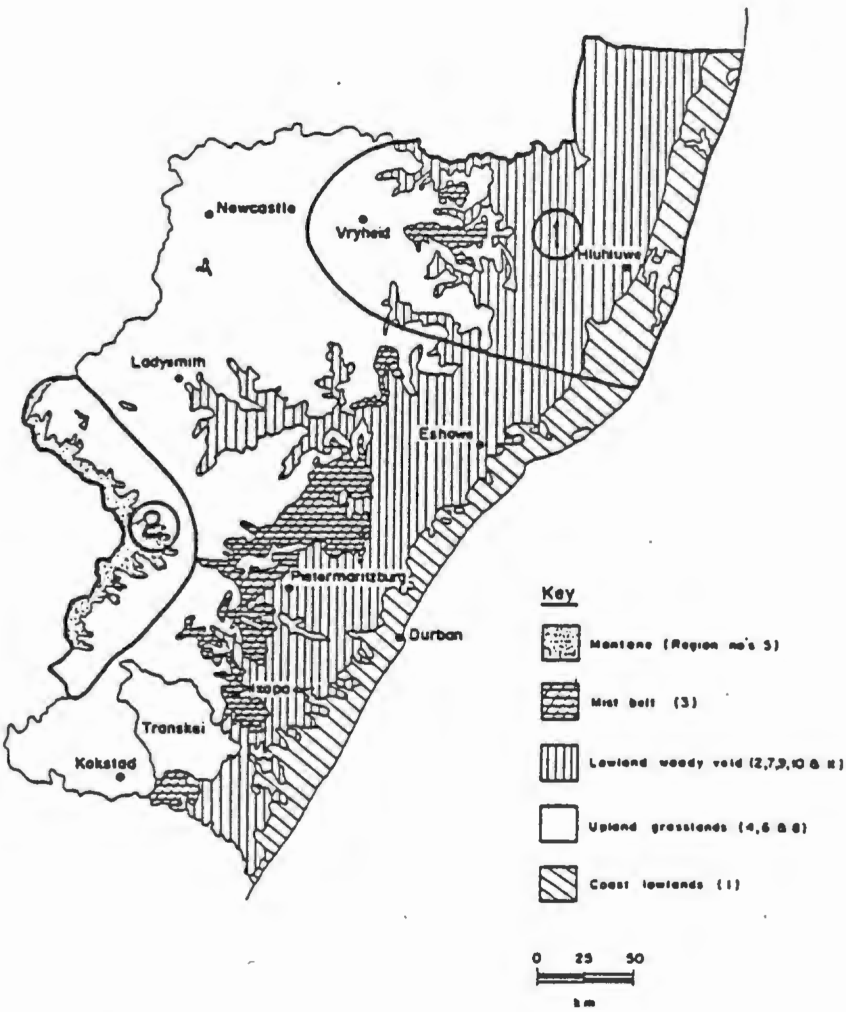
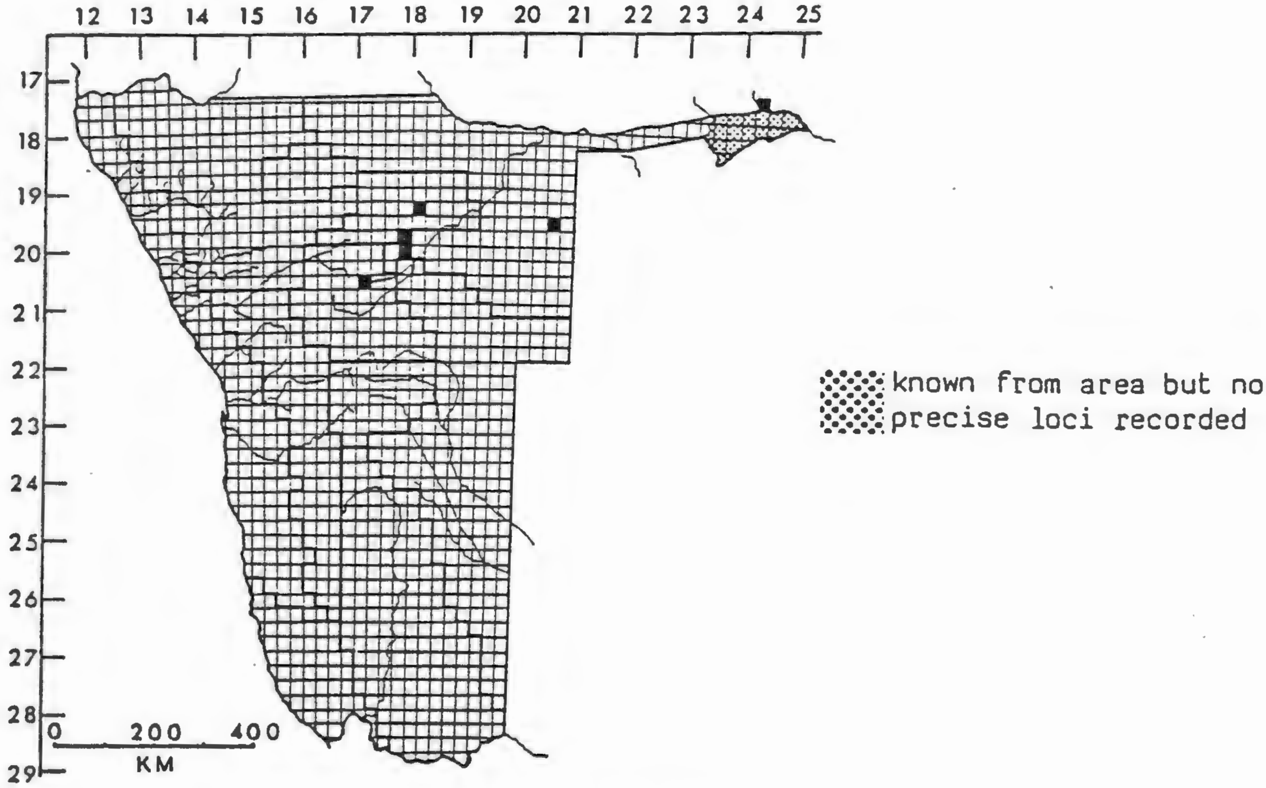
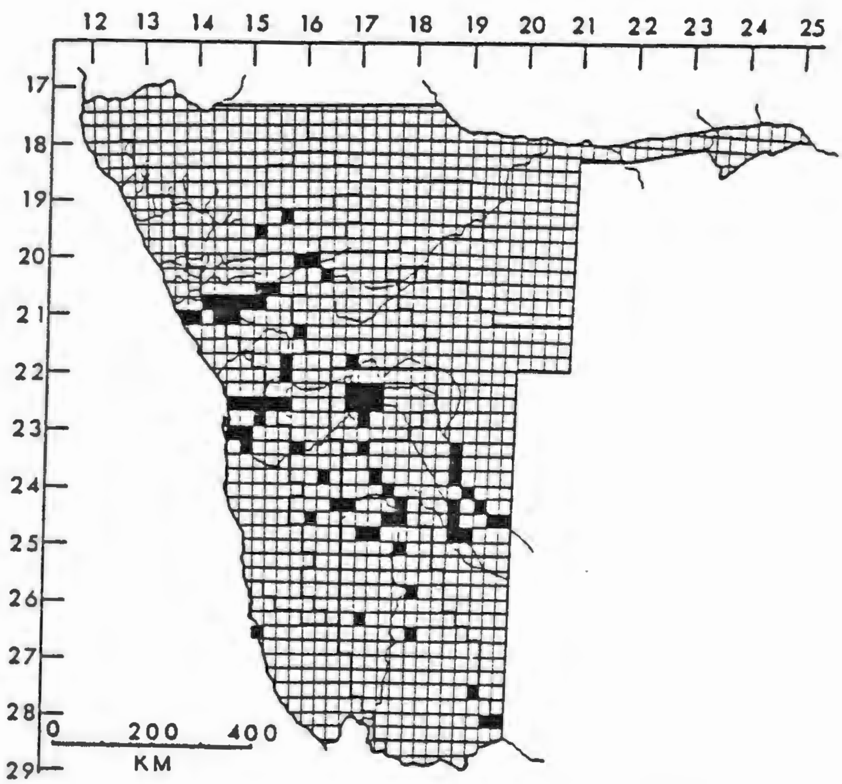



FIGURE 12. Suggested priority control areas for Sesbania punicea in Natal.

APPENDIX 6

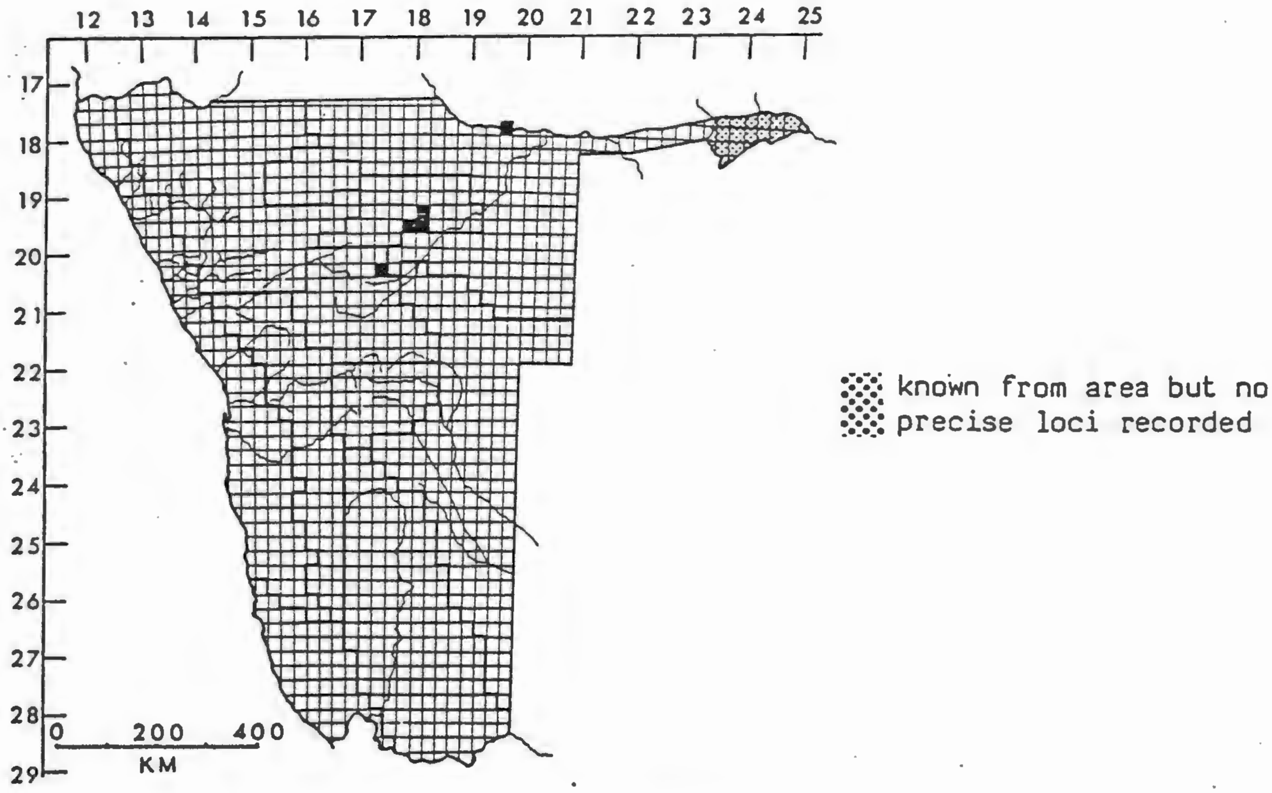



Distribution map of Melia azedarach.



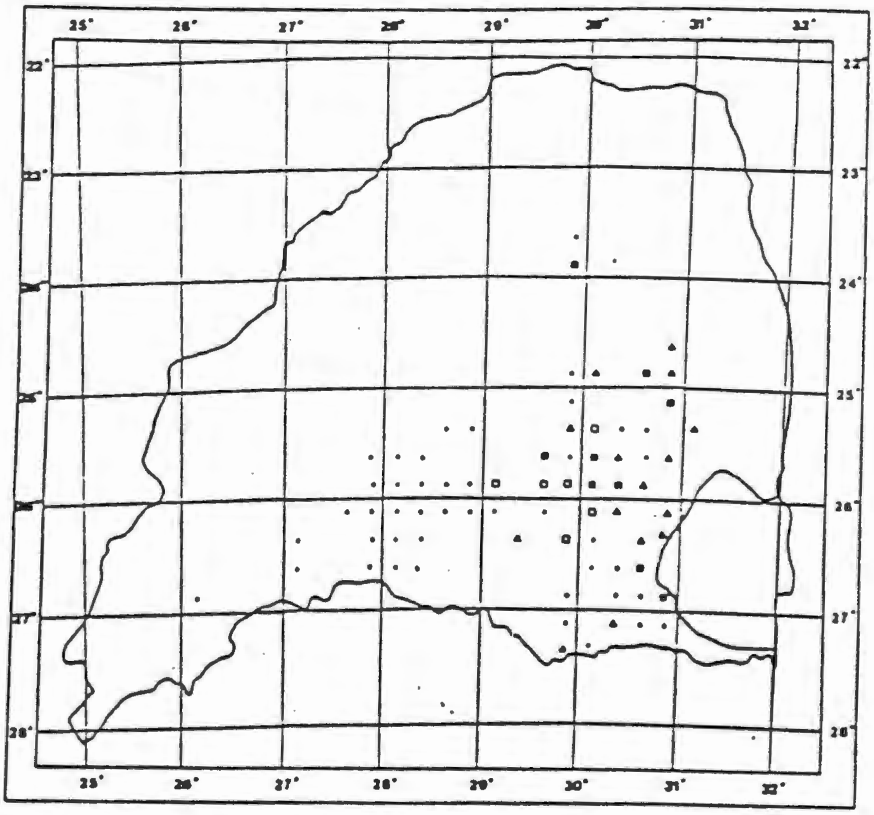

Distribution map of Prosopis spp.

APPENDIX 7




Distribution map of Lantana camara.

APPENDIX 8



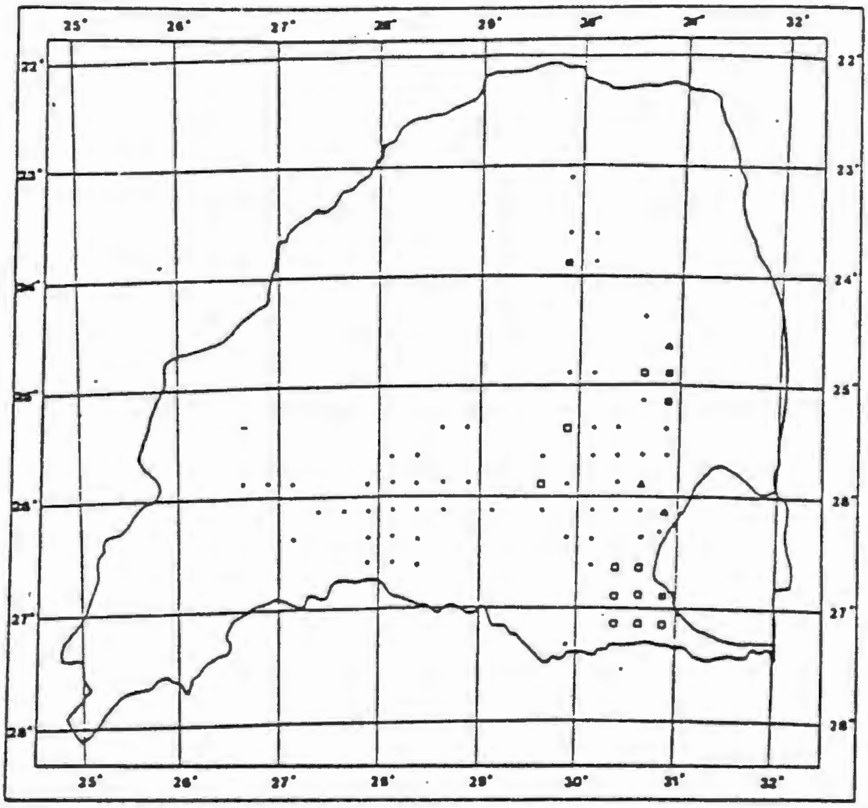
DISTRIBUTION AND HIGH ABUNDANCE AREAS OF *ACACIA DEALBATA.*

□ Roadside and veld habitats, abundance values 3 or more per 20 kms or 4 or more per 15 kms

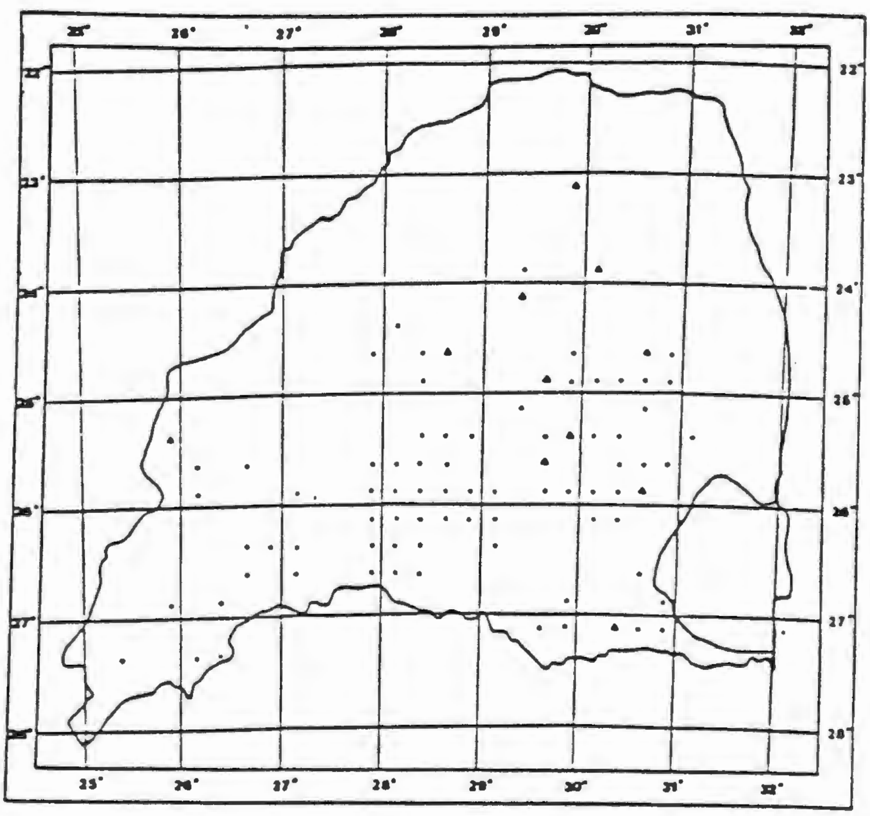
△ Streambank habitat, abundance values 4 or more

■ Streambank, roadside and veld habitats with aforementioned values

APPENDIX 9

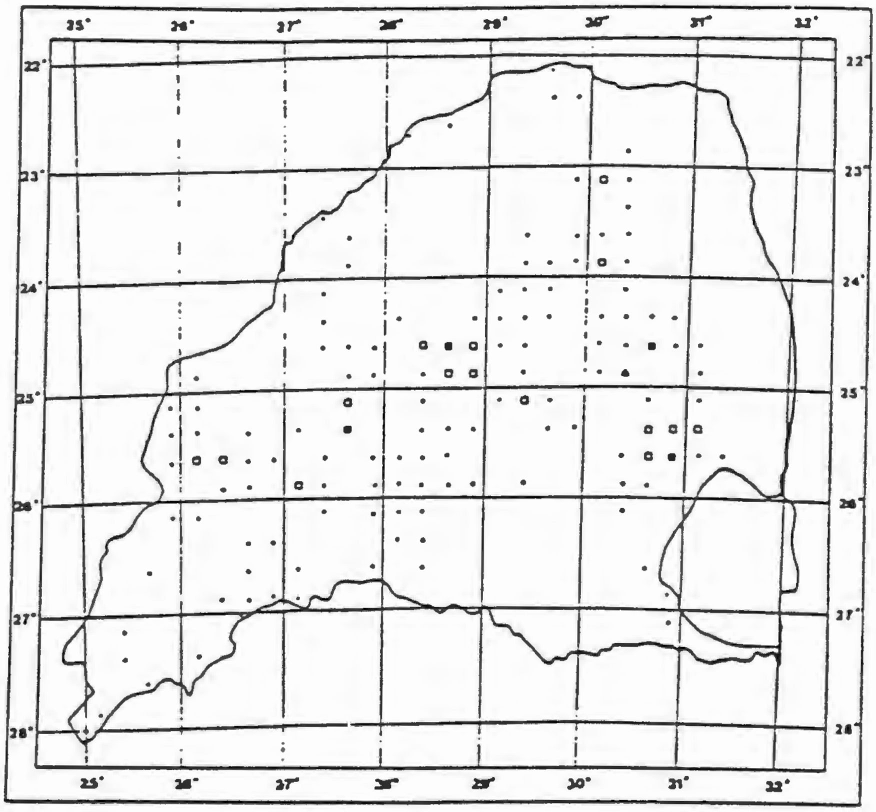


DISTRIBUTION AND HIGH ABUNDANCE AREAS OF *ACACIA MEARNSII.*

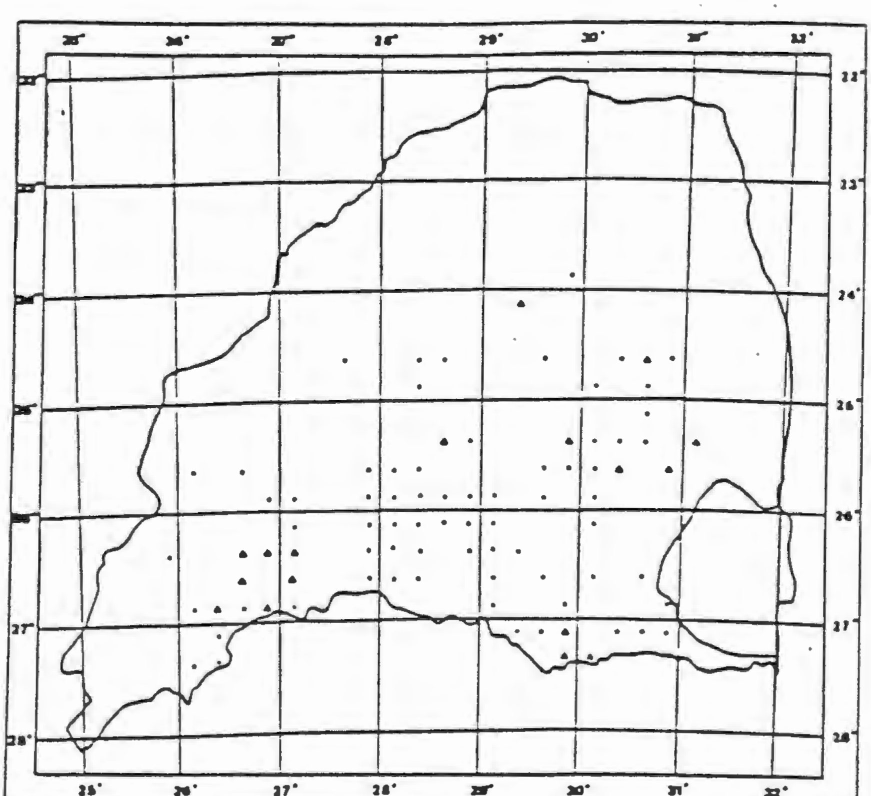


. DISTRIBUTION AND HIGH ABUNDANCE AREAS OF *POPULUS ALBA/CANESCENS.*

APPENDIX 10



DISTRIBUTION AND HIGH ABUNDANCE AREAS OF *MELIA AZEDARACH.*



DISTRIBUTION AND HIGH ABUNDANCE AREAS OF *SALIX BABYLONICA.*

# Charcoal production using a transportable metal kiln

A R Paddon and A P Harker

Paddon A R and Harker A P (1980)
Charcoal production using a transportable metal kiln. *Rural Technol. Guide, Trop. Prod. Inst.*, No. 12, 18pp. Price £1.00, including packing and postage.

Copies of the guide can be purchased from the Tropical Products Institute. They are available free of charge to public bodies in countries eligible for British aid.

The Tropical Products Institute recommends that charcoal production be carried out under the guidance of a Forestry Department or similar government body, to prevent the uncontrolled exploitation of woodlands for financial gain.

The use of transportable metal kilns in charcoal production is particularly suited for local authority reafforestation and land reclamation schemes.

Tropical Products Institute

# Contents

# Introduction

This guide describes how to operate a transportable charcoal kiln which will produce charcoal more quickly and efficiently than the traditional pit and earth clamp method.

The kiln is made from sheet metal and can be built by local craftsmen in a workshop which has basic welding, rolling, drilling and cutting facilities.

# Tools required for two-man operation

Chain saw or cross-cut saw

Shovels or spades (2)

Matchet

Axe

Wedges (2)

Sledge hammer

Wooden pole or plank

Sieve-chute

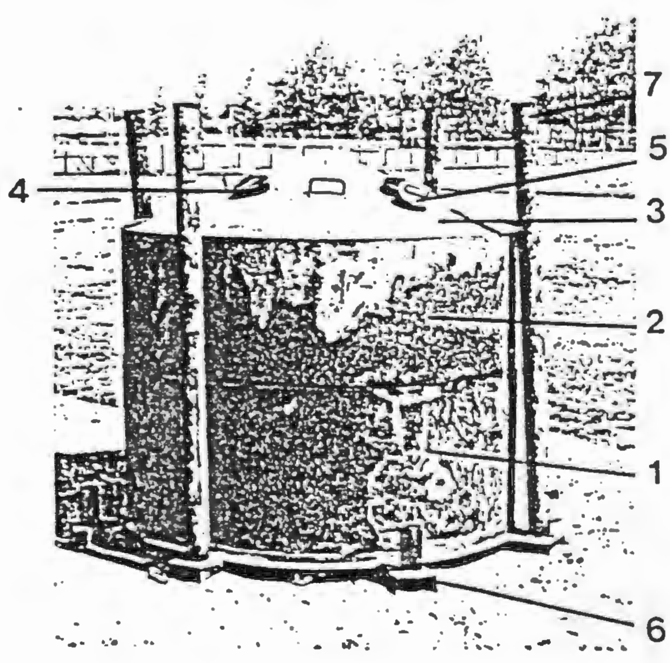
Sacks

Needle and string

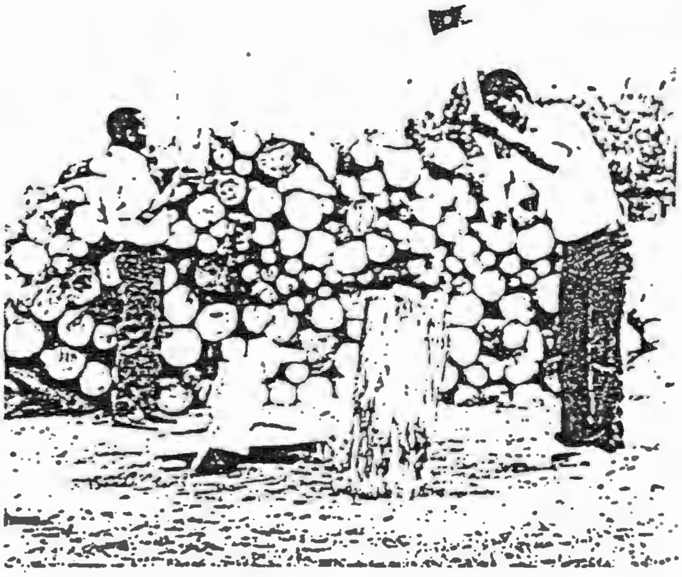
Industrial gloves

# Description of the kiln

The kiln consists of two interlocking cylindrical sections (1, 2) and a conical cover (3). The cover is provided with four equally spaced steam release ports (4) which may be closed off with plugs (5) as required. The kiln is supported on eight air inlet/outlet channels (6), arranged radially around the base. During charring, four smoke stacks (7) are fitted onto alternate air channels. The construction details of the kiln are given in Rural Technology Guide 13 to be published shortly.



# Preparation of the raw material

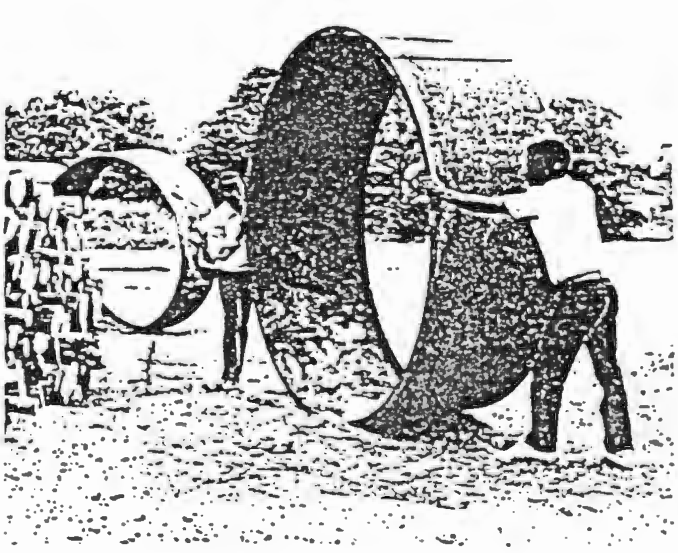


Fell the wood, cut up and stack it at least 3 weeks before kilning. This period allows the wood to dry out, thereby reducing the charring time and increasing the yield of charcoal.

The size of wood most suitable for the process is between 450 – 600 mm long and up to 200 mm in diameter. Wood with a diameter greater than this should be split before use.

Approximately 7 cubic metres of wood are required to fill the kiln.

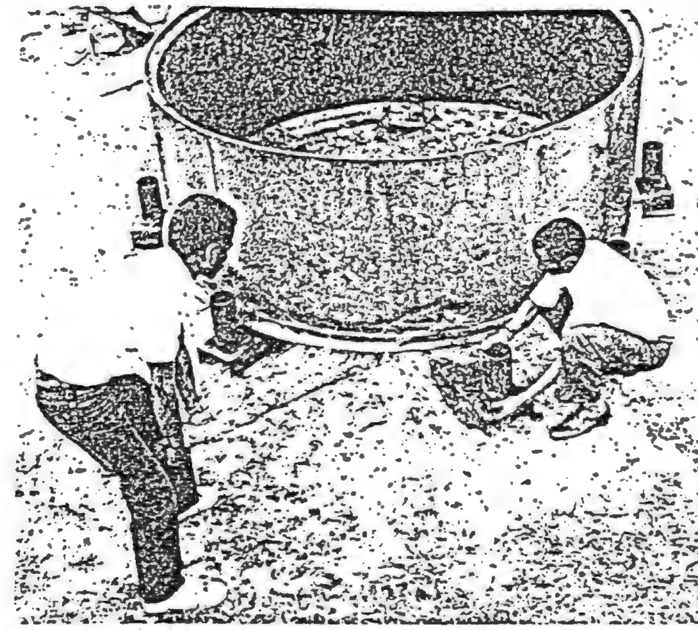
# Selecting the site



Choose a well drained and roughly levelled area 3 metres x 3 metres for the site of the kiln. Roll the bottom cylindrical section on to the site and position it upright after the area corresponding to the floor of the kiln has been made firm by stamping down.

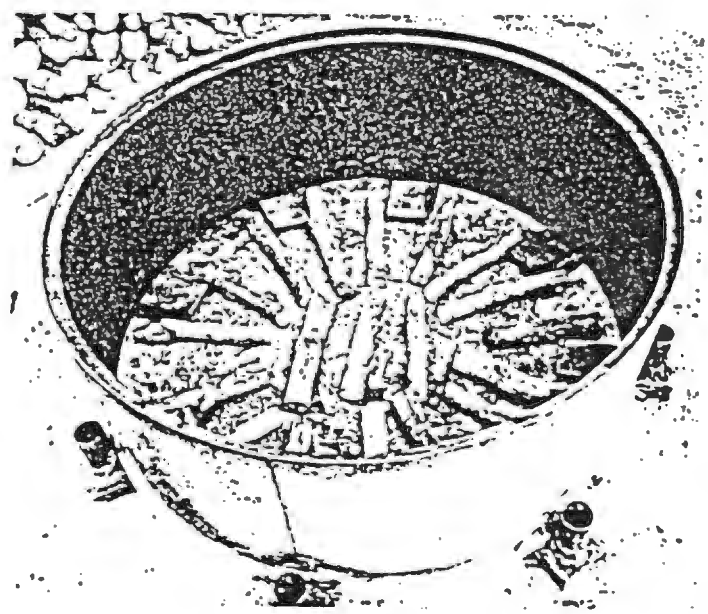
Loose earth or sand should be available close to the site for sealing off the air supply to the kiln as required during the operation.

# Assembly and loading of the kiln

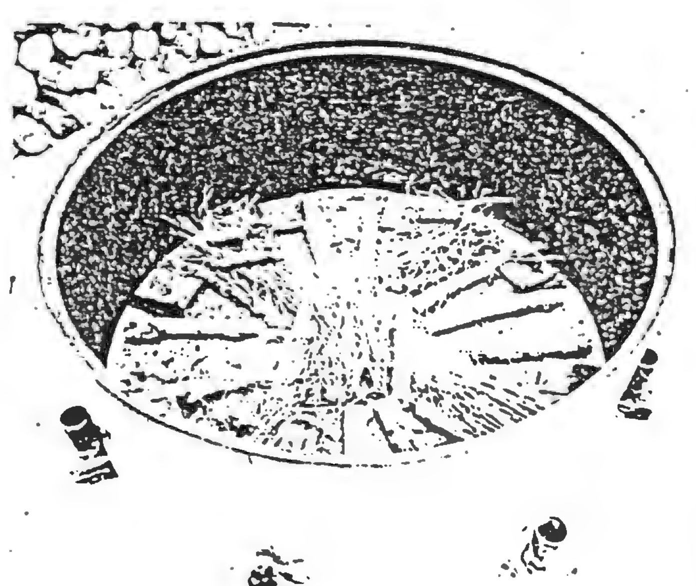


1. Using a wooden pole as a lever, arrange the eight air inlet/outlet channels radially at equidistant intervals underneath the bottom section of the kiln.

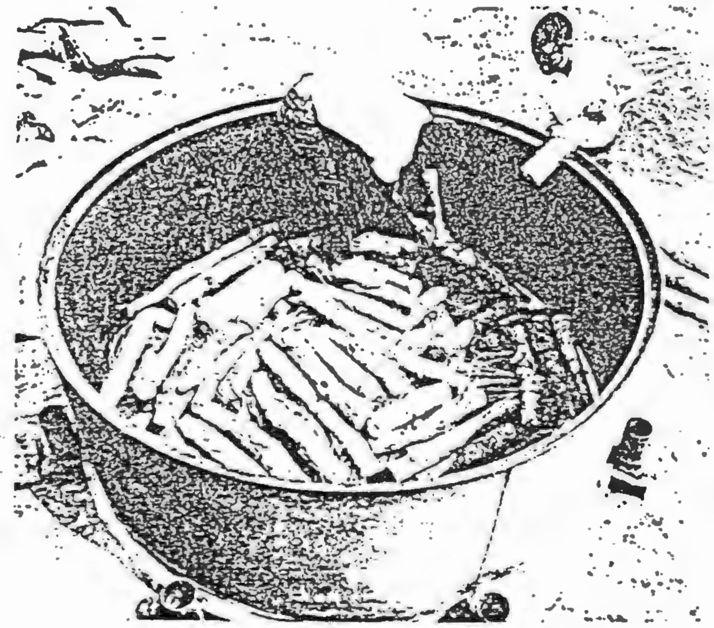
A minimum of 250 mm of air channel must protrude into the kiln to prevent overheating of the kiln wall.



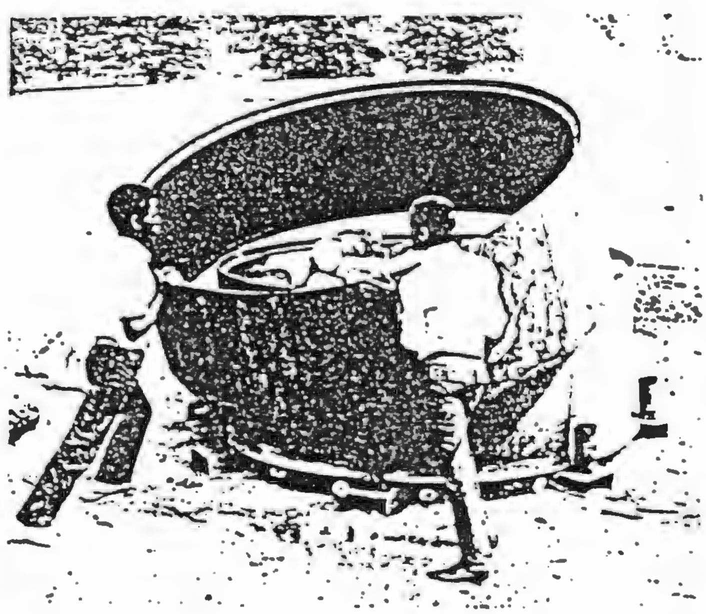
2. Make sure that the inlet/outlet air channels and the spaces between them are not blocked when the bottom of the kiln is loaded with wood. To do this, support the charge on "stringers" which are medium diameter (150 mm) pieces of cordwood arranged radially like the spokes of a wheel.



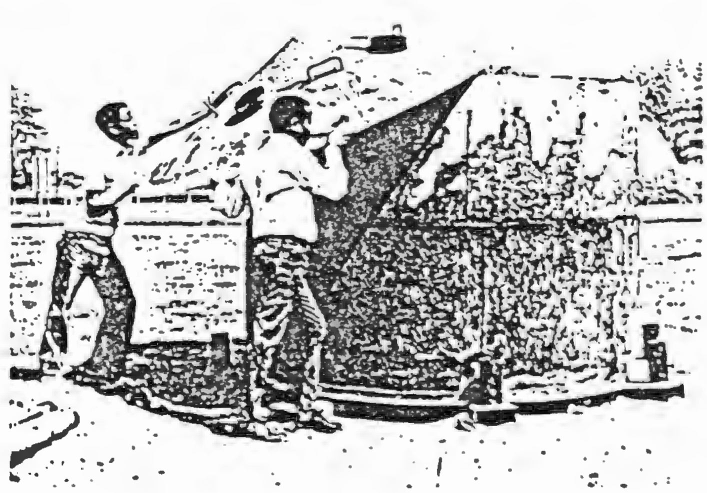
3. Place dry kindling wood together with any inflammable waste (paper, sump oil etc.) between the stringers from a point 50 mm from the edge of the bottom of the kiln to the centre so as to provide four lighting points.



4. Next place a layer of wood and "brands" (incompletely charred wood from the previous firing) across the stringers and air channels to form air ducts which will make it easier to light the charge.

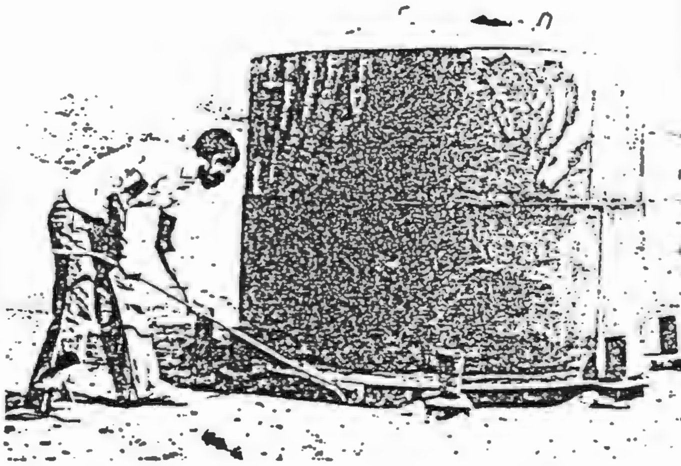


5. Load the bottom section of the kiln with successive layers of wood, filling in as many voids as possible and placing the larger diameter timber towards the centre of the kiln. When the bottom section has been filled roll the top cylindrical section alongside the kiln and push it up on to the supporting rim.

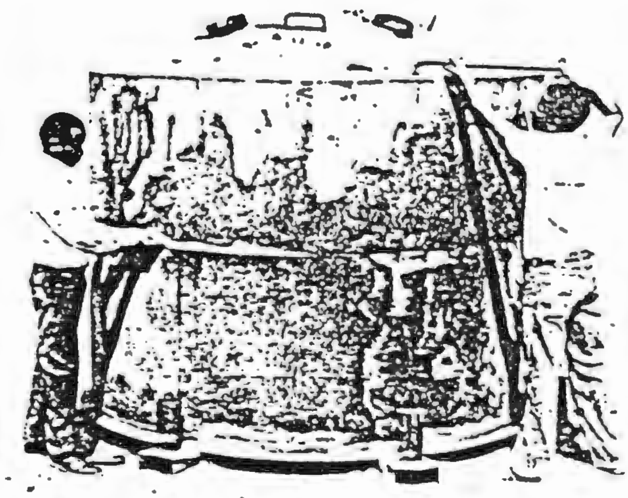


6. Continue loading until the wood forms a conical shape above the rim of the top section which will allow the cover to be located into the rim without hindrance. Then roll the cover alongside the kiln and push it up on to the supporting rim.

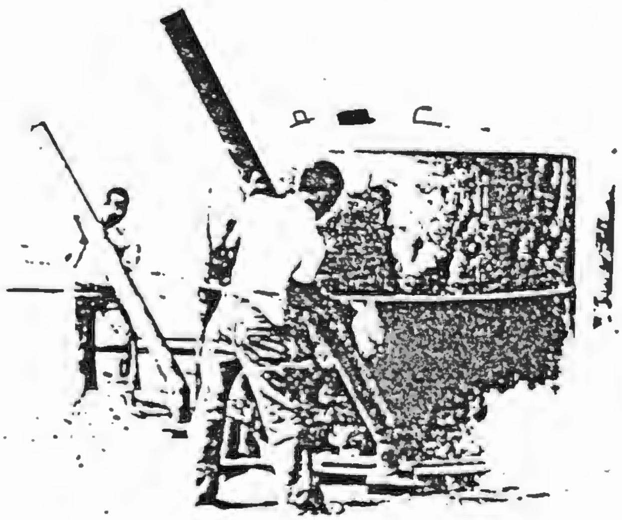
With two experienced men, the kiln takes about 2 hours to load.



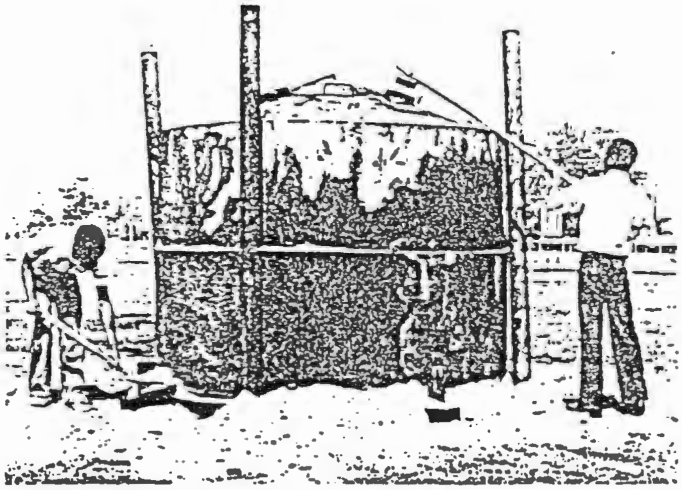
7. Make sure that all four steam release ports in the cover have been removed, then apply a flame to the prepared lighting points. Some areas of the kiln may burn more quickly especially on the windward side. Because of this, do not ignite the lighting point facing the wind until the lee side of the kiln is well alight.



8. Allow the kiln to heat up for 30 to 60 minutes until the bottom section is so hot that it is unpleasant to stand close to the kiln. During this period fill the joints between the main sections of the kiln with sand and place the smoke stacks in position over the support collars of alternate air channels.



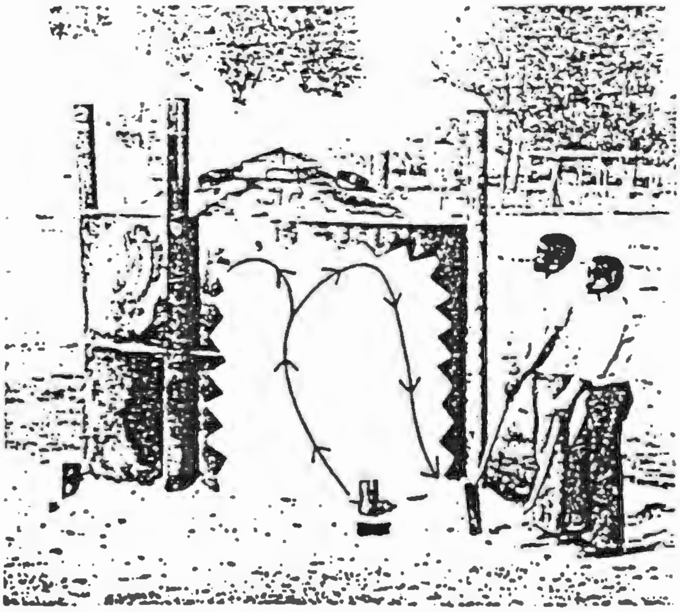
# Reducing the draught



As each sector of the kiln reaches the required temperature, cover the spaces between the air channels with sand or soil.

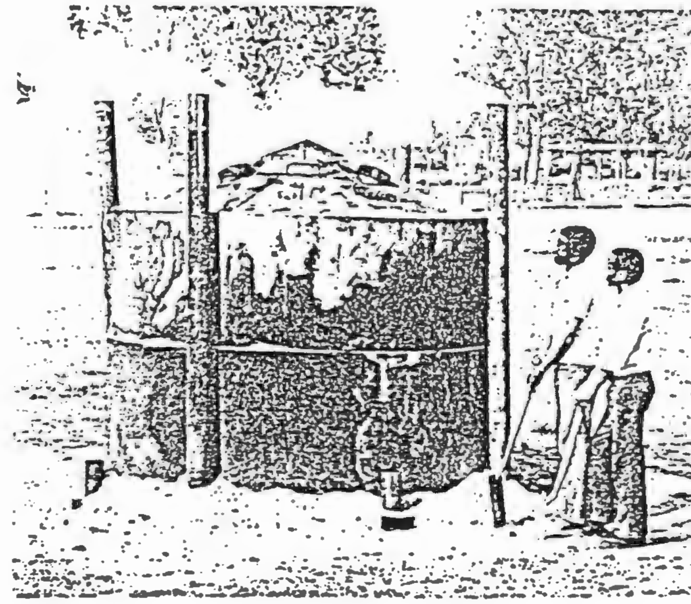
When all the spaces between the channels have been covered, seal the ends of the channels supporting the smoke stacks.

Then replace the steam release ports so that the smoke is drawn out of the base of the kiln by the four smoke stacks.



When the draught has been reduced air enters the kiln only through the inlet channels from where it flows up through the centre of the charge. The combustion gases are drawn down the outer edge of the kiln and are exhausted through the smoke stacks. As the air and exhaust gases flow in opposite directions, this condition is known as the Reverse Draught.

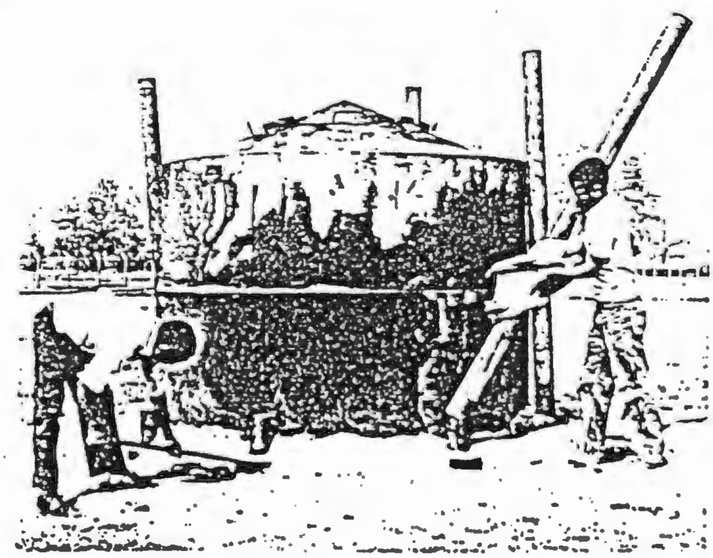
# Control of charring



1. After 15 – 30 minutes each stack should emit a column of thick white smoke.

If there is a slowing down of smoke production, remove the sand or soil temporarily from the lighting points next to the affected smoke stack to allow more air into the kiln at this point. When a satisfactory emission of smoke has again been achieved, close the lighting point.

2. During charring a certain amount of tar is deposited in the outlet channels and smoke stacks. This tar restricts the exhaust gas flow from the kiln and should be removed when there is a noticeable reduction in the quantity of smoke issuing from any of the stacks. Take off and clean the stack and remove any tar which has collected inside the outlet channel. At the same time, a long stick should be inserted through the channel into the centre of the kiln to make sure that there is no internal restriction to the exhaust gas flow.



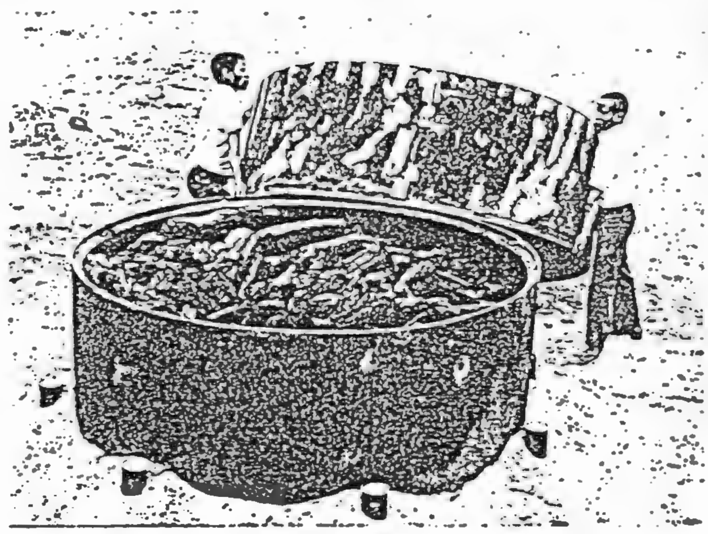
After 8 – 10 hours move the smoke stacks on to the adjacent air channels to convert air inlets to air outlets and vice versa. This creates a more even burn and reduces the formation of ash at the air inlets. Use a sack or industrial gloves to remove the stacks which will by this time be very hot.

# Cooling of the kiln

Charring is complete when the colour of the smoke from all chimneys takes on a bluish tinge and becomes almost transparent. This normally occurs 16–24 hours after lighting. The whole surface of the kiln should now be very hot (150–200°C) so that a spot of water applied to the side wall will evaporate immediately with a spitting noise. At this stage close the kiln completely by removing the smoke stacks and completely blocking all the air channels with soil or sand. Apply more soil or sand to ensure that the angle iron rims supporting the top section and cover and the steam release ports are fully sealed so that no air may enter the kiln.

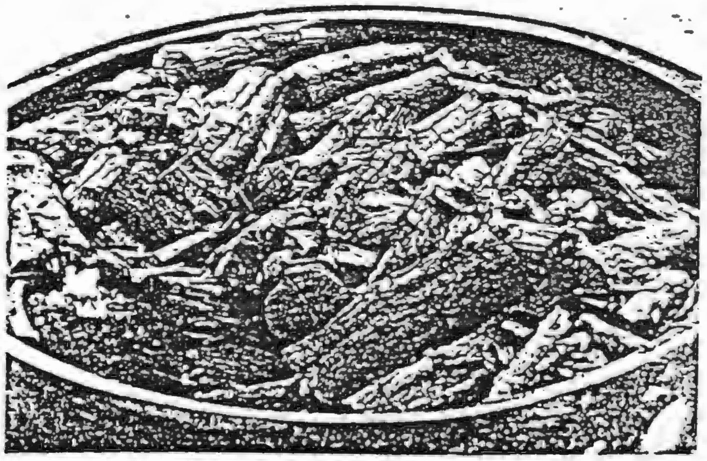
Allow kiln to cool for between 16 and 24 hours before opening and unloading.

# Unloading the kiln

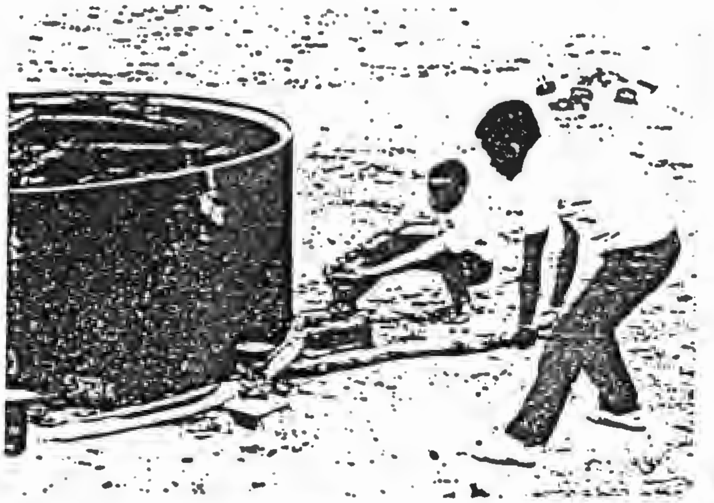


1. The kiln must not be opened before the outside surface is cool. Once the kiln is opened, make certain that it is emptied immediately to prevent any localised fires igniting the charcoal; otherwise the result could be serious damage to the kiln.

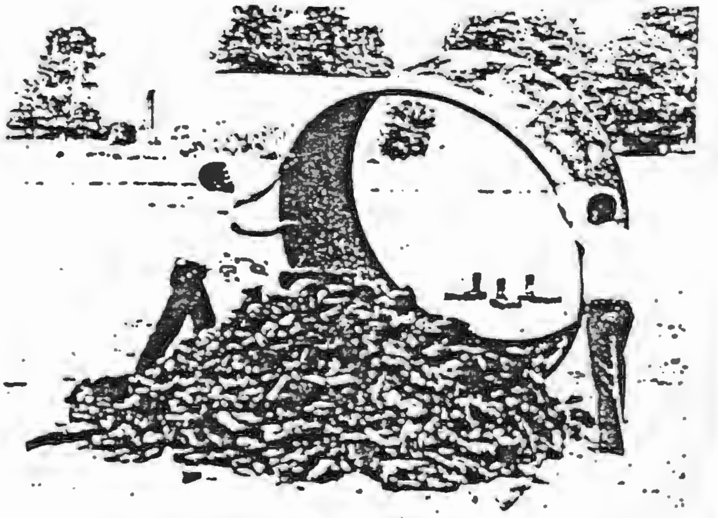
When the kiln is opened, if part of the charcoal is seen to be still alight, the kiln must be re-sealed for a further cooling period before it is unloaded.



During charring, the volume of wood will have been reduced, and it will therefore be easy to remove the cover and top section once the kiln has cooled.



2. To remove the bottom section, remove the inlet/outlet channels from one side of the kiln using a lever, and tip the section on to its side, leaving the charcoal free to be loaded into sacks. A bucket of water or a quantity of sand or soil should be on hand while unloading the kiln in order to quench any small fires that may break out.

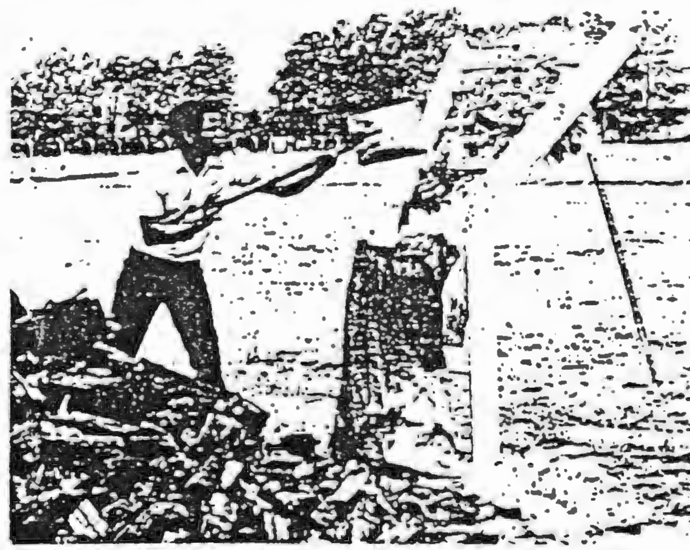


# Sack filling with charcoal

A sieve chute is used to separate the large charcoal pieces from the fines and to make sack filling easier. The construction details of the sieve chute are shown in the Appendix.

Unloading the kiln and filling the sacks with charcoal takes about 1 hour with 2 men.

The kiln will produce between ½ and ¾ tonnes of charcoal per batch depending on the density of the wood.



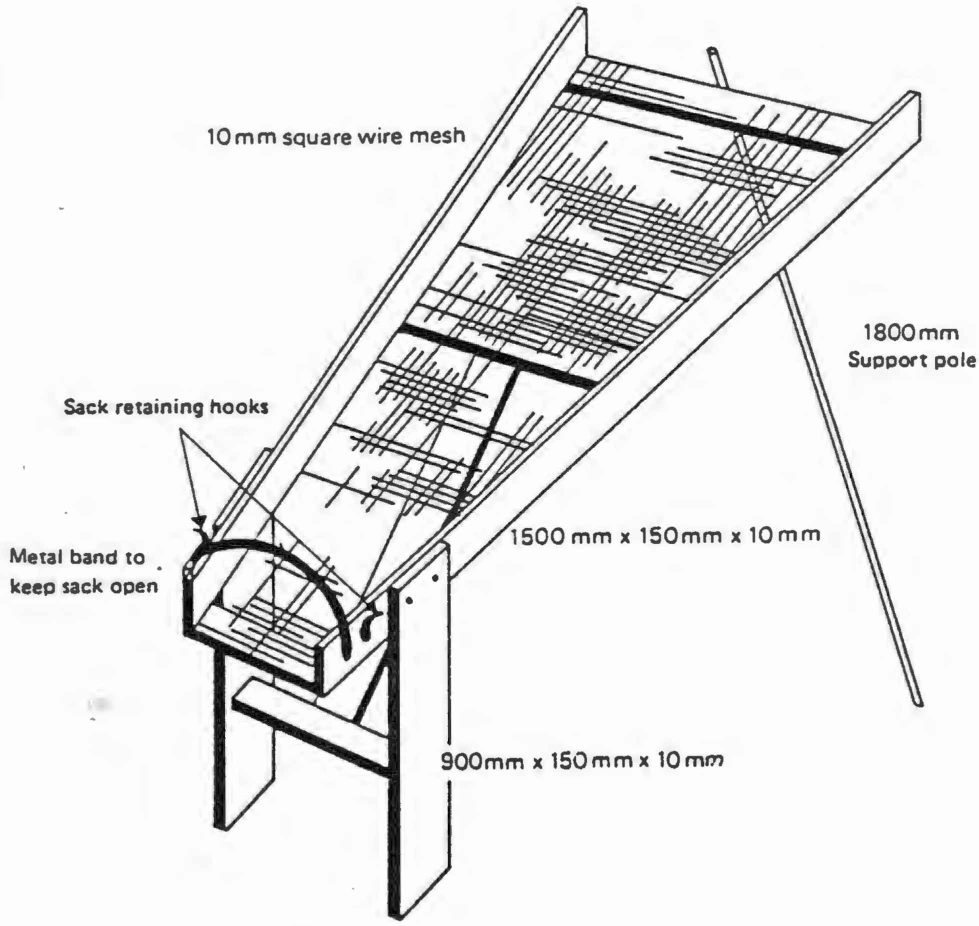
# Commercial operation

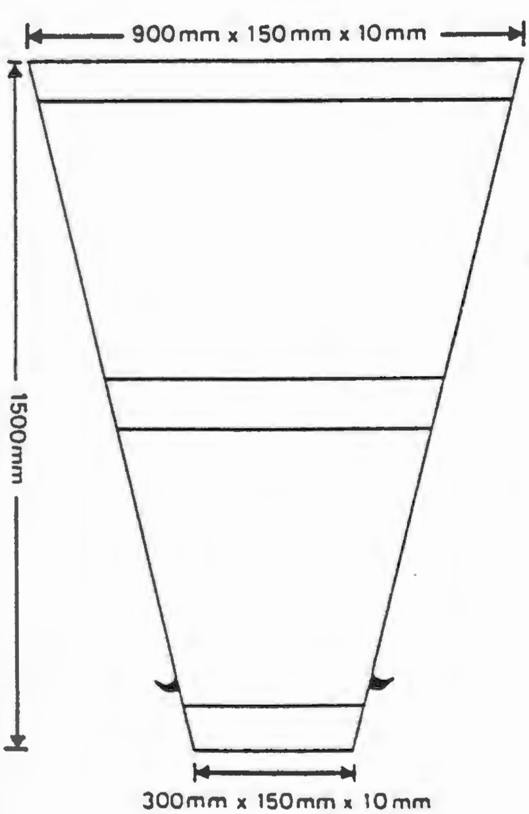
Two experienced men can operate two portable metal kilns producing 2 – 3 tonnes of charcoal per week. A suggested 5-day week work plan is outlined below:

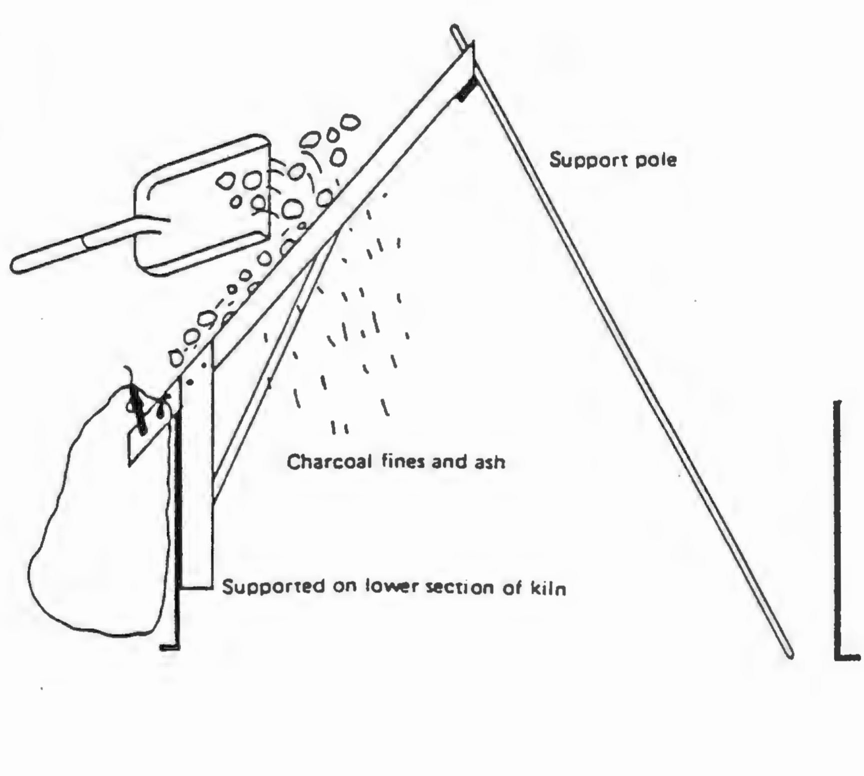
| | | | | |
|---|---|---|---|---|
| MONDAY | 08.00 – 10.00 | Kiln 1 and | Kiln 2 | Unload both kilns |
| | 10.00 – 12.00 | Kiln 1 | | Load kiln with wood |
| | 12.00 – 13.00 | Kiln 1 | | Light kiln and reduce draught |
| | 13.00 – 17.00 | Kiln 1 | | Control charring. Change and clean stacks at 16.30. |
| | | | Kiln 2 | Load kiln with wood |
| TUESDAY | 08.00 – 08.30 | Kiln 1 | | Change and clean stacks |
| | 08.30 – 11.00 | | | Prepare wood for next burn |
| | 11.00 – 12.00 | | Kiln 2 | Light kiln and reduce draught |
| | 12.00 – 17.00 | | Kiln 2 | Control charring. Change and clean stacks at 16.30. |
| | | Kiln 1 | | Shut down kiln when charring complete. Continue to prepare wood for next burn. |
| WEDNESDAY | 08.00 – 08.30 | | Kiln 2 | Change and clean stacks |
| | 08.30 – 14.00 | | | Continue to prepare wood for next burn. |
| | 14.00 – 15.00 | Kiln 1 | | Unload charcoal from kiln. |
| | 15.00 – 17.00 | Kiln 1 | | Start loading kiln with wood |
| | | | Kiln 2 | Shut down kiln when charring complete. |
| THURSDAY | 08.00 – 10.00 | Kiln 1 | | Finsh loading kiln with wood |
| | 10.00 – 11.00 | Kiln 1 | | Light kiln and reduce draught |
| | 11.00 – 13.00 | | Kiln 2 | Unload charcoal from kiln |
| | | Kiln 1 | | Control charring |
| | 13.00 – 15.00 | | Kiln 2 | Load kiln with wood |
| | | Kiln 1 | | Control charring |
| | 15.00 – 16.00 | | Kiln 2 | Light kiln and reduce draught |
| | 16.00 – 17.00 | Kiln 1 | | Change and clean stacks |
| | | | Kiln 2 | Control charring |
| FRIDAY | 08.00 – 09.00 | Kiln 1 and | Kiln 2 | Change and clean stacks |
| | 09.00 – 13.00 | Kiln 1 | | Shut down kiln when charring complete<br>Prepare wood for next burn |
| | | | Kiln 2 | Change and clean stacks at 12.30 |
| | 13.00 – 17.00 | | | Continue to prepare wood for next burn |
| | | | Kiln 2 | Close down kiln when charring complete |

## APPENDIX

### SIEVE-CHUTE FOR UNLOADING KILN



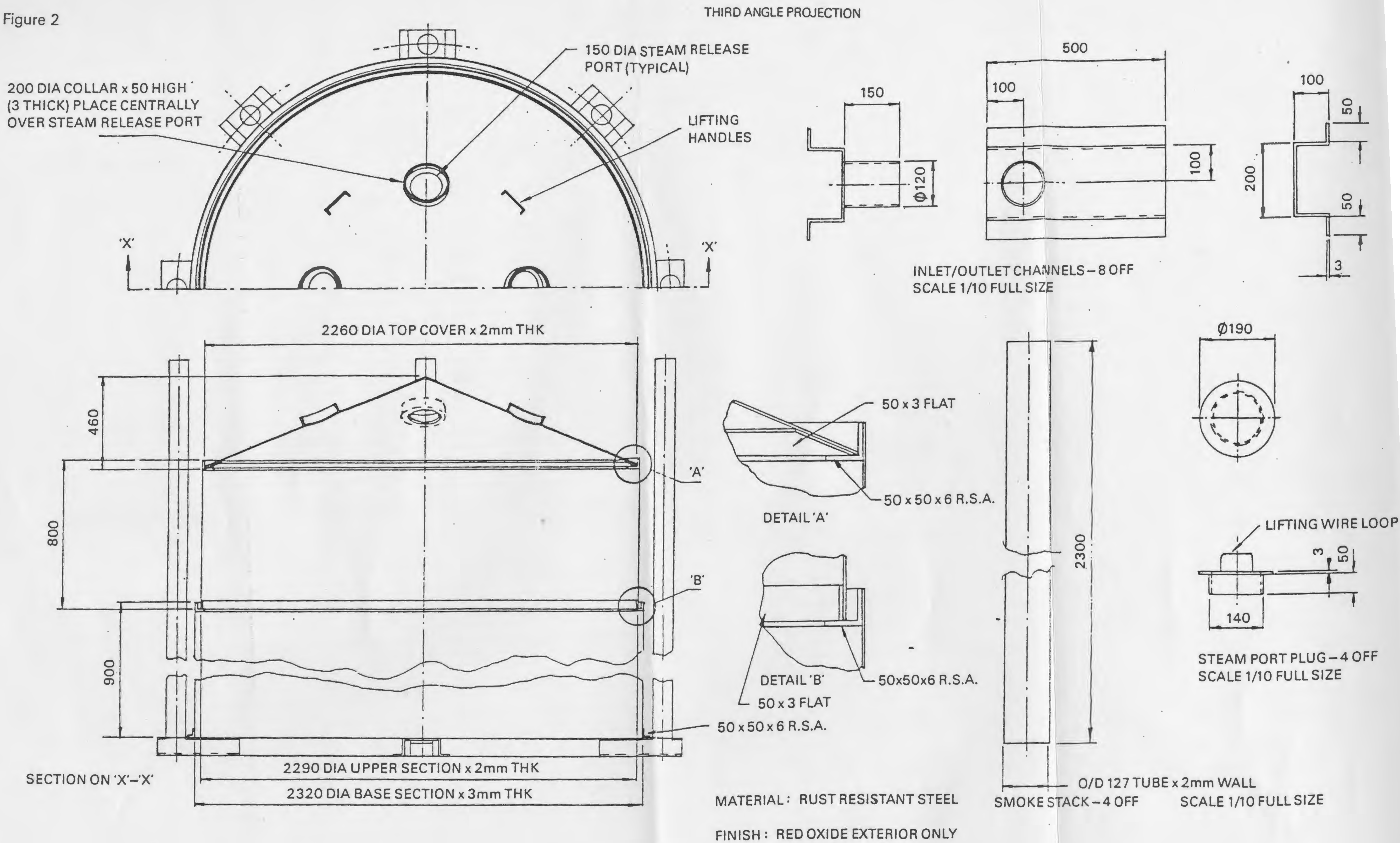



# List of Materials

| | Part | Material | Quantity |
|---|---|---|---|
| | | | *Sufficient to cut:* |
| Base section | Top and bottom rings | 50 mm × 50 mm × 3 mm mild steel (m.s.) angle | 6 pieces, each 2 430 mm long |
| | Body (Construction Method 1) | 3 mm m.s. sheet (Note 1) | 3 pieces, each 2 430 mm × 900 mm |
| | Body (Construction Method 2) | 3 mm m.s. sheet | 3 pieces each 2 480 mm × 900 mm. |
| Upper section | Top ring | 50 mm × 50 mm × 3 mm m.s. angle | 3 pieces, each 2 398 mm long |
| | Bottom ring | 50 mm × 50 mm × 3 mm m.s. strip | 3 pieces, each 2 398 mm long |
| | Body | 2 mm m.s. sheet | 3 pieces, each 2 448 mm × 900 mm |
| Top cover | Cover sectors | 2 mm m.s. sheet | 2 pieces, cut to dimensions shown in Fig. 6. |
| | Steam ports | 50 mm × 3 mm m.s. strip | 4 pieces, each 630 mm long |
| | Lifting handles | 10 mm diameter m.s. rod (concrete reinforcing bar) | 4 pieces, each 500 mm long |
| Steam port covers (4 per kiln) | Bodies | Either 50 mm × 3 mm m.s. strip | 4 pieces, each 440 mm long |
| | | *OR* 140 mm diameter steel pipe. (Use pipe if available) | *OR* 4 rings, each 50 mm wide |
| | Top discs | 3 mm m.s. sheet | 4 discs, each 190 mm diameter. |
| | Handles | 5 mm diameter steel rod (concrete reinforcing bar) | 4 pieces, each 180 mm long |
| Base channels (8 per kiln) | Channel sections | 3 mm m.s. sheet | 8 pieces, each 500 mm × 500 mm |
| | Spigots (Note 2) | Either 3 mm m.s. sheet | 8 pieces, each 375 mm × 150 mm |
| | | *OR* 120 mm diameter steel pipe | *OR* 8 pieces, each 150 mm long |
| Smoke stacks (4 per kiln) | | Thin-walled steel pipe | 4 pieces, each 2 300 mm long (Note 2) |
| | | *OR* 2 mm m.s. sheet | *OR* See instructions, page 13 to calculate quantities required. |

Figure 2


THIRD ANGLE PROJECTION
150 DIA STEAM RELEASE PORT (TYPICAL)
200 DIA COLLAR x 50 HIGH (3 THICK) PLACE CENTRALLY OVER STEAM RELEASE PORT
LIFTING HANDLES
'X'
'X'
2260 DIA TOP COVER x 2mm THK
460
800
900
'A'
'B'
SECTION ON 'X'–'X'
2290 DIA UPPER SECTION x 2mm THK
2320 DIA BASE SECTION x 3mm THK
50 x 50 x 6 R.S.A.
50 x 3 FLAT
50 x 50 x 6 R.S.A.
DETAIL 'A'
DETAIL 'B'
50x50x6 R.S.A.
50 x 3 FLAT
150
Ø120
500
100
100
100
200
50
50
3
INLET/OUTLET CHANNELS – 8 OFF
SCALE 1/10 FULL SIZE
2300
O/D 127 TUBE x 2mm WALL
SMOKE STACK – 4 OFF
SCALE 1/10 FULL SIZE
Ø190
LIFTING WIRE LOOP
3
50
140
STEAM PORT PLUG – 4 OFF
SCALE 1/10 FULL SIZE
MATERIAL: RUST RESISTANT STEEL
FINISH: RED OXIDE EXTERIOR ONLY

Note 1. We recommend using Corten 'A' or similar weathering steel for the sheet metal parts and to give a longer kiln life. Weathering steels contain up to 3% copper, chromium, vanadium and phosphorus. They form a durable oxide layer needing no further protection. If weathering steel is not available or if the kiln is to be stored for some time before use, paint the outside of the kiln with red oxide primer or other suitable rust inhibiting paint. Once the kiln is in use, the paint will be progressively burnt off but will give some protection against external corrosion.

Note 2. The steel pipe used for the smoke stacks should be of the thin-walled type (2 – 3 mm wall thickness). The sizes shown on the drawing (Figure 2) may be altered. Any diameter of pipe, from 100 mm – 150 mm can be used. The pipes must fit properly on to the spigots in the base channel (see page 13).

APPENDIX 12

## ECONOMIC COMPARISON BETWEEN RETORT AND KILN PRODUCTION OF CHARCOAL

SOURCE: GAYLARD + ASSOCIATES

BASIS OF CALCULATION - Production of 500 tonnes per annum of screened saleable charcoal from one 17,5 m³ retort or one 12 m long kiln. ( 555 tonnes pre-screening - see note 7 )

| | RETORT | KILN WITH GOOD EFFICIENCY | KILN WITH AVERAGE EFFICIENCY | |
|---|---|---|---|---|
| **CAPITAL COSTS** | | | | |
| Cost Price | 35 800 | 10 000 | 10 000 | |
| GST | 4 296 | 1 200 | 1 200 | |
| Delivery and Installation | 1 000 | 1 800 | 1 800 | (not |
| | 41 096 | 13 000 | 13 000 | |
| **ANNUAL COSTS** | | | | |
| Interest & Depreciation | | | | |
| Interest on Capital @ 18% | 7 397 | 2 340 | 2 340 | |
| Depreciation | 6 164 | 4 290 | 4 290 | (not |
| | 13 561 | 6 630 | 6 630 | |
| Raw Materials | | | | |
| Wood @ R18,00 per tonne (note 4) | 33 300 | 49 950 | 62 438 | (not |
| Labour @ R150,00 per month per labourer | 5 400 | 14 400 | 14 400 | (not |
| TOTAL ANNUAL COST (note 6) | 52 261 | 70 980 | 83 468 | |
| | R 104/ton. | R 142/ton. | | |

See notes overleaf for explanation of individual calculations

Notes

1. Delivery and Installation

The delivery cost will of course vary with distance from source, but is estimated at R500 per unit.

The retort requires minimal site preparation and is delivered in almost complete form. The cost of installation is therefore estimated at R500.

The kiln requires site assembly and brick walls and a base must be constructed. The cost of installation is therefore estimated at R1300.

2. Depreciation

The kiln is subject to acid attack due to condensation on the walls. The manufacturers of the most commonly used kiln quote an estimated lifespan of three years. Depreciation is therefore calculated at 33% per annum.

The retort does not allow acid condensation and, in addition, all critical components are fabricated from 3CR12 stainless steel. The lifespan is estimated at more than 10 years, but since this has not been demonstrated by a retort having been in operation for this length of time, a figure of 15% has been used for depreciation

3 Wood Quantity

The wood quantity required clearly depends on the yield obtained. Calculations are based on the yield from wood having a moisture content of about 20% and on the final fixed carbon level in the product being in the range 75% to 80%.

Under these conditions the retort has been shown to give yields of between 30% and 33% ( charcoal output as a percentage of wood feed by mass ). The calculation assumes a yield of 30%.

Kilns operating these conditions can, if operated with skill, produce a yield of 20%. However some operators obtain yields of as low as 10%, and an industry average has been reported to be 16%. The two cases presented represent 20% yield ( good efficiency ) and 16% yield ( average efficiency ).

4. Cost of Wood

The cost of wood has been taken at R18,00, which represents a standing cost of R3,00 and a cost for harvesting, transport and preparation of R15,00 per tonne. Some might argue that this is a high figure, but detailed analyses by the CSIR and others have found that where lower figures are used not all the attendant costs have been taken into account. The cost is borne out by the prices currently paid by the paper industry for wattle poles ( R25,00 to R30,00 per tonne FOR ).

5. Labour

It has been found that to operate a Gaylard retort requires a maximum of three labourers, whereas eight are required to operate a standard kiln. This is due to the larger quantity of wood which must be loaded into the kiln due to its lower yield, and also to the fact that the kiln requires constant attention in order to plug leaks with clay and to avoid overheating. In addition, the retort only requires attention during daylight hours, whereas the kiln must be supervised through the night.

6. Total Annual Cost

The total annual cost given represents the direct cost of charcoal production. Other costs such as overheads, packaging and transport of charcoal have not been included but can be assumed to be equal in all three cases.

7. Annual Production

The annual production of 500 tonnes assumes a retort or kiln output of 555 tonnes with 55 tonnes ( 10% ) being lost as fines during the screening process.

ALIEN WOOD SPECIES

ECONOMIC COMPARISON BETWEEN RETORT AND KILN PRODUCTION OF CHARCOAL

BASIS OF CALCULATION - Production of 270 tonnes per annum of screened saleable charcoal from one 17,5$m^3$ retort or (555 tonnes pre-screening)

| | RETORT | KILN WITH GOOD EFFICIENCY |
|---|---|---|
| **CAPITAL COSTS** | | |
| Cost Price | 35 800 | 10 000 |
| GST | 4 296 | 1 200 |
| Delivery and Installation | 1 000 | 1 800 |
| | 41 096 | 13 000 |
| **ANNUAL COSTS** | | |
| Depreciation | | |
| Depreciation | 6 164 | 4 290 |
| Raw Materials | | |
| Wood @ R34 per tonne | 34 000 | 51 000 |
| Labour @ R400 per month per labourer | 14 400 | 38 400 |
| TOTAL ANNUAL COST | 95 960 | 107 140 |
| | R355/ton | R397/ton |

REPORT NO. GEN 132

# THE USE OF ALIEN WOODY BIOMASS FOR LOW COST SMALL-SCALE CHARCOAL PRODUCTION

FINAL REPORT

G D H SHAW SEPTEMBER 1989