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# COSTS AND BENEFITS OF PROPOSED TREE PLANTING PROGRAMME FOR SATISFYING KENYA'S WOOD ENERGY REQUIREMENTS

PART I

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## Costs and benefits of proposed tree planting programme in Kenya.

### SUMMARY

Wood,while thought of as a traditional fuel,may be used as a transitional energy form and indeed capitalising on existing technical knowledge,be converted into modern fuels that could assist in the rapid development of Kenya's economy.It is an indigenous resource that grows relatively rapidly; besides providing energy it can stabilise the soil,protect water catchment areas,provide fertiliser,fodder and food and afford considerable employment opportunities for both skilled and unskilled workers.

In the Kenyan context,woodfuel is the cheapest source of energy being two to four times cheaper than bio-gas and paraffin(kerosene)and up to 6 to 7 times cheaper than liquid petroleum gas and electricity.What is more,the wood stoves at present are much more inefficient than the other types of stoves but it is more than possible to double their efficiency thus making woodfuel even cheaper.In terms of foreign exchange the price difference is much more pronounced,for delivered woodfuel has less than 20% of their cost in the form of foreign exchange but for other commercial fuels about 75% of their cost is foreign exchange.

One drawback to woodfuel is that it is a low cost high bulk product and in the freshly felled form it cannot be transported over long distances without making it uneconomic.However,the more it is dried,the further it can be transported and if it is converted to densified wood or charcoal the economic transport radius could be increased to as much as 140Kms. by road or 360Kms. by rail.

The cost of growing fuelwood in Kenya is at present much more expensive than in neighbouring Tanzania and indeed it is on par with costs in the U.K. This is because of very low task rates which have continued from the days when workers only worked for less than a morning in the forest(and the rest of the day in their shamba) and were paid accordingly.Now they work all the time in the forest on the same task rate but on full pay.Given good management,labour productivity could easily increase to a figure approaching the upper Tanzanian value and a new set of task rates has been assumed.Costs and returns have been worked out based on these assumed rates and for various options such as agro-forestry,replanted forest,fodder/wood production,industrial plantation,the return on invested capital is usually more than 10% whereas with the present average Kenyan costs it is about 5%.All the various models are described in detail and are used as a basis for determining the cost of the proposed policy option.



Felling and extraction costs are described so that it is possible to work out a delivered roadside cost and to compile a manpower budget.While the money returns from investment are low,because of the low stumpage price for fuelwood,the returns to government and consumer are high.If an adequate supply of fuelwood is not guaranteed then by the year 2000 the government may have to pay an additional Kshs.13,500 million in foreign exchange to import paraffin and the consumer would have to pay an extra Kshs.9000 million,representing the price difference between woodfuel and paraffin. What is more, one hectare of fuelwood could save Kshs.4300 in foreign exchange with existing wood stoves and up to Kshs.14,300 with improved stoves, this is nearly as much as coffee earns per hectare in foreign exchange.So from a government viewpoint,investing in fuelwood plantations and agro-forestry schemes should be a top priority.

The policy proposal calls for the equivalent of 1.43 million hectares of forest land to be planted by the year 2000,the bulk of which will be in either agro-forestry schemes on farms,replanted forests or managed forests so only 204,000 hectares around towns and industries will change their land use.By the turn of the century such a proposal will cost,in 1982 prices, Kshs.2700 million.It will give employment to nearly 100,000 people and in a steady state,yield nearly 25 millions tonnes of wood per year as well as supplying fertiliser,food and fodder.To provide an equal amount of energy from hydro electricity would cost 24 times as much and from paraffin 4 times as much and both of these options have high foreign exchange components in their costs.Therefore,by following the wood route,Kenya could ensure the cheapest supply of energy,create employment,protect the water catchment areas,stabilise the soil,enhance the quality of life of the people and assist the economic growth of the nation.

COSTS AND BENEFITS OF PROPOSED TREE PLANTING PROGRAMME FOR SATISFYING KENYA'S WOOD ENERGY REQUIREMENTS

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## Chapter I. The cost of wood energy

### 1. Introduction

Kenya, like many other developing countries, is facing an energy crisis just as severe, if not more so, than the developed nations of the world. In the past it has relied on indigenous wood to supply the bulk of its energy, indeed, even today wood energy supplies over seventy percent of the country's energy requirements. However, very little effort has been made to replace the trees cut down to supply this energy and in consequence, Kenya's tree resources are dwindling rapidly. This decline in tree stock would have been more rapid if there had not been a switch to more convenient and more intensive energy forms, namely oil products and electricity. But these energy forms while facilitating rapid economic development require a considerable amount of foreign exchange either to purchase the oil or to buy the capital equipment to generate the electricity, and Kenya is facing and will continue to face difficulties in earning enough foreign exchange to purchase the oil and capital equipment.

In the eyes of many people the use of wood energy is equated with backwardness and the promotion of wood energy as a principal energy form is relegating its people to the drudgery of collecting and using this energy and is condemning the country to slow economic growth. However, even though wood is a traditional fuel, the reason why it has been used since time immemorial is that it is a convenient store of energy and if properly managed a renewable source of energy. For many rural people wood is the preferred source of energy; once this source has been exhausted then the people turn to burning crop wastes and dung, usually to the detriment of the soil and once these



have been exhausted then the land is abandoned and the country has lost an asset either temporarily or permanently. The reason that the collection of wood has become a drudgery is because supplies near to the house have become exhausted and more time and effort has to be spent gathering and carrying the wood back home. This trend could and should be reversed by ensuring that trees are grown on farm or in close proximity to the farm, and growing trees species that will complement rather than compete with the pastoral and agricultural crops.

Wood either in the unmodified form or as charcoal cannot compete for convenience with paraffin (kerosene), gas or electricity. There is always the inconvenience of handling a bulk material and the waiting period until the fire is properly lit, also it is more difficult to regulate and extinguish once the cooking or heating task has been performed. However, wood can usually more than compete on price and ways of improving its convenience and efficiency are known. Also it is an indigenous resource that saves foreign exchange and creates employment. Therefore it seems prudent to plan for its continued use and to encourage more convenient and efficient methods of production and consumption.

Wood, besides being a traditional fuel, can also be used as a transitional fuel and indeed could be a fuel and a chemical feed stock of the future. Already it is used as a boiler fuel in many industries, particularly wood based industries in wood rich temperate countries. It can be used in thermal power stations provided an adequate and continuous supply is guaranteed near at hand. Modified wood in the form of charcoal has as high if not higher energy value than coal and can be used as a substitute for coal. Wood and charcoal, when turned to water and /or producer gases, can be used to drive stationary or mobile conventional engines, and similarly when subjected to conditions of heat and pressure, wood can be turned into liquid fuel, such as

methanol (wood alcohol) or petrol. The latter processes cannot compete with conventional oil at present but they are not far away from the economic threshold. However, the producer/water gas is presently in use and is the motive power for water pumps, vehicles and boats. So, relying on wood for energy should not condemn a country to backwardness. Indeed, if properly managed and imaginatively used, it can help with the rapid economic development based on the indigenous resources of labour and capital. That is not to say that oil, electricity and gas should not be fully used for economic development; indeed, the proposals put forward in the main report envisage that the share of these energy forms will increase from their present 25% to 35% by the year 2000. However, what the report stresses is that wood is an indigenous energy source, if judiciously grown it can be the most convenient energy form, and if properly managed can be the cheapest source of energy while at the same time, saving foreign exchange, providing employment, food, fodder and fertilizers and most importantly, protecting the environment.

## 2. The cost of wood energy compared to other energy forms

The government's selling price for fuelwood is between Kshs 15 and 20 per standing cubic metre ($ 1.5 to $ 2.0 per $m^3$). If it is assumed that on average an air dry tonne of wood (15% moisture content dry basis or 13% mc wet basis) contains 1.4 $m^3$ then the standing cost per air dry tonne is between Kshs 21 and 28[1]. The cost of felling, cross cutting and stacking is about Kshs 25 per $m^3$ so the forest roadside price of cut and stacked wood is about Kshs 45 per $m^3$ or Kshs 63 per air dry tonne.

(1) It is difficult to be more exact about the standing price of fuelwood because wood is sold stacked at a price of Kshs 11.75 per stacked $m^3$. usually in measures of 1 m x 1.5 m x 2 m or 3 stacked $m^3$. The conversion of stacked measure to solid measure depends on the tightness of stacking and the exactness of the measures.

The delivered price of this wood within a 50 km radius of the market should not be more than Kshs 150 per tonne. However, the selling price of cut firewood in Nairobi, where this wood is mainly bought by the medium and upper income people for heating, not cooking, is between Kshs 200 and 300 per tonne (air dry) but off-cuts sold for cooking vary between Kshs 150-250 per tonne. Likewise charcoal sells at about Kshs 1000 per tonne, although the official selling price is Kshs 875 per tonne (see table 5) - (35/- per 41 kg bag including sack, wt 1 kg). Outside Nairobi firewood is traded at about Kshs 100 per tonne and charcoal Kshs 600-800 per tonne (official price Kshs 425-625 pt).

For other fuels the Nairobi price is as follows: paraffin, Kshs 3.80 per litre; liquid petroleum gas (LPG), Kshs 102.75 per 15 kg canister (Kshs 6.85 per kg) and electricity an average price of Kshs 0.70 per KWh. However, LP gas is in short supply and paraffin is problematical in some areas outside Nairobi. It is difficult to compare the above energy forms in all their different end uses, but cooking is the largest household use of energy, accounting for between 60% and 75% of all energy used in a typical household or the equivalent of approximately 1 $m^3$ of airdry wood (15% mc) per person. If this figure is used as a standard then the equivalent amount of other fuels to supply the same amount of energy to the cooking pot is shown in Table 1a, together with the market price and estimate foreign exchange cost.

16.0 MJ per kg and the stove efficiency is 7%. Thus 710 x 16 x .07 = 795 M Joules is transferred to the pot.

(2) The cost of biogas energy (60% methane, 40% carbon dioxide) has been adapted from P 120 of the US National Academcy of Sciences book "Methane generation from human, animal and agricultural wastes, NAS Washington 1977. See appendix 1 for cost breakdown

(3) These are the best estimates available but considerable work has to be done on measuring efficiencies. There is no absolute measure for it varies depending on what food is being cooked.



Footnotes continued

(4) The cost of stoves has not been included in this table.
An estimate of stove costs for the various energy forms is as follows, Table laii:

Table laii Cost of various stoves in Kenya (1982)

Units Kshs

| Energy Form | Stove type | Cost | of which foreign exchange | Stove type | Cost FE | of which |
|---|---|---|---|---|---|---|
| Wood | three stones | NIL | NIL | mud/cement* & metal top | 400 | 150 |
| Densified wood/ charcoal | metal stove | 30 | 5 | burnt clay & metal cover | 60 | 15 |
| Biogas | simple burner | 30 | 10 | manufactured burner | 200 | 115 |
| Paraffin | wick) - small | 47 | 30 | pressure | 175 | 100 |
| | burner) - large | 199 | 115 | stove | | |
| LP gas ** | single ring | 580 | 330 | double ring | 1580 | 900 |
| electricity *** | single ring | 600 | 350 | double ring | 1200 | 700 |

* The mud/grass or mud/cement stove will have two openings, a water heater and a storage place for drying wood

** LP gas bottle costs about Kshs 500 of which estimated FE Kshs 350

*** Wiring the house is expensive; the cheapest cost will be at least Kshs 1000 of which estimated FE Kshs 700.

(5) The delivered G Joule cost to the stove is much cheaper for woodfuels than for other energy forms. This is a reflection of the inefficiencies of the wood stoves but also the fact they are indigenous fuels. These 'cheap' fuels could be made even cheaper by improving the stove designs and it seems logical that a considerable effort be made into the designing and marketing of efficient stoves, boilers and other wood fuel using devices.

Table 1a gives the price range for various fuels assuming current stove efficiences, these are low for woodfuels and relatively high for commercial fuels. Therefore there is far more scope to improve the efficiencies of woodfuel stoves than other stoves. The table also illustrates the importance of burning dry as opposed to green wood (70% mc). If green wood is burnt, especially on an inefficient stove then it becomes the most expensive energy form in total cost terms but still has an advantage over other non wood fuels in foreign exchange terms.

Even if the most inefficient stove types were assumed for fuelwood at 15% mc, densified wood and charcoal and compared to the most efficient types for other energy forms then only biogas has a cost advantage over the above three energy forms and paraffin over charcoal. Even for biogas it is assumed that the dung from 2-3 cows is collected every day together with 13.5 litres of water. This is unlikely in an urban setting and in a rural setting wood is usually not bought but collected. The capital cost for collecting wood is practically zero; whereas the capital cost for a 2 cubic metre biogas plant is estimated to be about Kshs 8300. This is reflected in the foreign exchange costs. All non wood energy forms have higher foreign exchange costs than wood, varying from about twice as much for biogas to six times as much for LPG.

The cost of the various energy forms delivered to the pot varies from fuel to fuel, if this is standardized on the paraffin costs, the market price for delivering an equal quantity of energy to the pot at a fixed price can be evaluated. This is shown in Table 1b:

Table 1b The cost of energy from different sources to supply an equal quantity of energy to the pot (795 MJ) at a fixed price of Kshs 156

| Energy form (1) | Stove efficiency % | Units required | Pot price Kshs | Estimated FE cost Kshs | Unit price Kshs per unit | Cost at the stove Kshs GJ (2) |
|---|---|---|---|---|---|---|
| Wood 15% mc | 10 | 497 kg | ) | 17 | 0.31 kg | 20 |
| Wood 70% mc | 10 | 795 kg | ) | 27 | 0.20 kg | 20 |
| Densified wood | 20 | 237 kg | ) | 37 | 0.66 kg | 39 |
| Charcoal | 20 | 120 kg | ) 156 | 20 | 1.30 kg | 39 |
| Bio-gas | 50 | 72 $m^3$ | ) | 57 | 2.17 $m^3$ | 97 |
| Paraffin | 50 | 41 l | ) | 117 | 3.80 l | 97 |
| LP gas | 60 | 29 kg | ) | 149 | 5.38 kg | 119 |
| Electricity | 75 | 294 KWh | ) | 144 | 0.53 KWh | 147 |

If the average stove efficiencies are as assumed in table 1b, then the price of wood (15% mc) could be increased to Kshs 310 per tonne, that for densified wood to Kshs 660 p.t. and for charcoal to Kshs 1300 p.t. Therefore there is scope to increase the stumpage price for woodfuel or increase the economic collecting radius.

Even at these prices the delivered price at the stove varies from one type of energy to another because different stove efficiencies have been assumed ranging from 10% for fuelwood up to 75% for electricity. If it is assumed that all the stove types have an efficiency of 50% then the market price for the same price delivered to the pot is as shown in Table 1c.

(1) For energy values see table 1a

(2) The calculate values may differ slightly from actual values shown here.

Table 1c The cost of energy from different sources to supply an equal amount of energy to the pot (795 MJ) at a fixed price of Kshs 156 and equal stove efficiencies of 50%

| Energy form | Stove efficiency % | Units required | Pot price Kshs | Estimated FE cost Kshs | Unit price Kshs per unit | Cost at the stove Kshs/GJ (1) |
|---|---|---|---|---|---|---|
| Wood 15% mc | ) | 99 kg | ) | 3 | 1.58 kg | ) |
| Wood 70% mc | ) | 159 kg | ) | 5 | 0.98 kg | ) |
| Densified wood | ) | 95 kg | ) | 15 | 1.64 kg | ) |
| Charcoal | ) 50 | 48 kg | ) 156 | 8 | 3.25 kg | ) 97 |
| Bio-gas | ) | 72 $m^3$ | ) | 57 | 2.17 $m^3$ | ) |
| Paraffin | ) | 41 l | ) | 117 | 3.80 l | ) |
| LP gas | ) | 35 kg | ) | 180 (2) | 4.46 kg (2) | ) |
| Electricity | ) | 442 Kwh | ) | 216 (2) | 0.35 Kwh(2) | ) |

(1) The calculated values may differ slightly from the actual values shown here

(2) The unit price is lower than the market price, hence the foreign exchange cost is more than the pot price.

When the efficiency of all the cooking devices is the same then it is possible to pay Kshs 1580 per tonne for fuelwood, (15% mc), Kshs 1640 for densified wood and Kshs 3250 for charcoal. Also the foreign exchange costs for wood fuels are very low as compared to the other energy forms. Therefore if the efficiencies of woodfuel stoves could be increased to figures approaching 50% then there are considerable savings to be made in foreign exchange costs and also the price to the grower of woodfuel could be increased substantially. If the government invested a relatively small amount of money into the improvement of wood burning and charcoal stoves then they could save a considerable amount of energy (1) and could increase the stumpage price to the grower and/or reduce the relative market price for the consumer.

(1) If the relative price of wood energy decreased because of an increased stove efficiency then some people using other fuels such as paraffin, LP gas and electricity may switch to woodfuels, hence there may be no saving of wood energy but there would be an overall saving of money and foreign exchange.



Already prototype stoves made of burnt clay and mud have been produced that give an efficiency of about 30% for fuelwood and 15% for charcoal. These are described in a separate paper on stoves. However, if these efficiencies can be achieved in commercial production, and the main report assumes that they can, then table 1d shows the price that can be paid by the consumer for an equal "pot price" or the pot price the consumer would pay assuming the prices as per table 1a.

**Table 1d** The cost of energy from different sources to supply an equal amount of energy to the pot (795 MJ)A) at a fixed price of Kshs .156 or B) the pot price at the current market prices for energy

| Energy form | Stove efficiency % | Units required | Pot price A) Kshs | Unit price A) Kshs per Unit | Delivered cost at stove Kshs GJ | Est FE both options Kshs | Unit price B) Kshs per unit | Pot price B) Kshs | Delivered cost at stove Kshs GJ |
|---|---|---|---|---|---|---|---|---|---|
| Wood 15% mc | 30 | 166 kg | ) | 0.94 kg | 59 | 6 | 0.20 kg | 33 | 12 |
| Wood 70% mc | 30 | 265 kg | ) | 0.59 kg | 59 | 10 | 0.20 kg | 53 | 20 |
| Densified wood | 45 | 105 kg | ) | 1.49 kg | 87 | 19 | 0.50 kg | 53 | 30 |
| Charcoal | 45 | 53 kg | ) 156 | 2.94 kg | 87 | 10 | 1.00 kg | 53 | 30 |
| Bio-gas | 50 | 72 $m^3$ | ) | 2.17 $m^3$ | 97 | 57 | 1.80 $m^3$ | 130 | 82 |
| Paraffin | 50 | 41 l | ) | 3.80 l | 97 | 117 | 3.80 l | 156 | 97 |
| LP Gas | 60 | 29 kg | ) | 5.38 kg | 116 | 149 | 6.85 kg | 199 | 152 |
| Electricity | 75 | 294 Kwh | ) | 0.53 Kwh | 146 | 144 | 0.70 Kwh | 206 | 195 |



If the pot price remained constant irrespective of energy type then the price of fuelwood could increase to Kshs 940 per tonne (15% mc), densified wood to Kshs 1490 per tonne and charcoal to Kshs 2940 per tonne, and the government would have to subsidise LP gas and electricity. On the other hand if the price of woodfuels remained as at present than the pot price for the housewife with improved stoves would be one third of the present value (a two-third saving) and for densified wood and charcoal there would be a reduction to 44% of present consumption.

## 3. Returns to the grower of wood energy

Therefore, while woodfuels at today's prices and today's stove efficiencies are competitive with other energy forms, stove improvements could make these fuels even more competitive still. However, with the government stumpage price for fuelwood about Kshs 20 per $m^3$ investment by the farmers in fuelwood schemes is not a very attractive proposition unless they are involved in the marketing process as well. As will be demonstrated in section 4, the returns on capital investment are usually greater than 10% per year, and under agro-forestry systems can be as much as 40% p.y. but the actual net money income per hectare per year (at Kshs 20 per $m^3$) is low. Under a pure fuelwood scheme it is of the order of Kshs 460 to Kshs 540 per ha, depending on the level of overhead costs, if the trees are sold standing. If the farmer fells and extracts the wood to the 'farm gate' then the net income should be in the region of Kshs 760 to Kshs 1140 per hectare per year. If the farmer is near to the market, say 35 kms away, and can actually deliver the wood to the retailer (or pay for the delivery) then the net income could range from Kshs 1980 to Kshs 2360 p ha p year. Finally, if the market is on the doorstep then the net income would be increased by a further Kshs 1070 delivered to the retailer and by 1710 if the wood was sold directly to the customer. So the maximum net average yearly

income the farmer could expect for fuelwood sold directly to the customer at Kshs 200 per tonne (Kshs 143 per $m^3$) (15% mc) is Kshs 4070 per hectare. Of course at a market price of Kshs 310 per tonne - a price which is still competitive with other fuels (table 1b) - then the maximum income would be increased by a further Kshs 2360 to Kshs 6430 p ha p year, but this means the farmer has to be involved in the distribution and marketing of the product. But for most farmers it is the net farm gate price that is crucial and assuming a stumpage price of Kshs 20 per $m^3$ this is only about Kshs 1000 per ha per year. Therefore, it is not a very attractive proposition to the private individual to invest in fuelwood plantations if wood is the only return. However, trees are grown on farms because they bring other benefits such as an improved micro-climate, soil protection, fertilizer input, fodder and food. Also wood can and is sold at a higher price than Kshs 20 per $m^3$ for poles and sawnwood. If the farmer has fodder producing trees then the net annual income could be increased by Kshs 600 per ha even at a low value at Kshs 0.30 per kg for pods or Kshs 0.15 for leaves[1], there could also be an imputed value of about Kshs 130 per hectare per year for fertilizer if the farmer green mulches the leaves from nitrogen fixing trees on his agricultural land. Therefore, the 'farm gate' price of these products could bring an additional net income of Kshs 900-1000 per hectare per year which make tree growing a more attractive proposition. This is especially so in an agro-forestry context where multi-purpose trees are grown as an integral part of the farming system. The trees have to be chosen with care, planting ones

[1] These are the assumed 'standing' values; the farm gate price could be double these values, but the cost of collection has to be deducted which could be in the region of Kshs 300 per ha but all these costs and prices are rather uncertain.



that compliment rather than compete with the farm crops and of course, planting at a density that will not unduly interfere with the other crops. Then the income, or imputed value, derived from these trees, are a bonus to the agricultural income.

## 4. Returns to the country from growing wood energy

From the national point of view, investing in woodfuel plantations should be an economic proposition simply because of the enormous saving in foreign exchange that is being made.

In 1980 an estimated 0.63 tonnes of charcoal were consumed. If the average selling price in Nairobi is assumed to be Kshs 1000 per tonne (in 1982 prices) then its 'Nairobi' market value is Kshs 630 million. Because Nairobi has the highest price for charcoal the actual 'Kenya' market value may be in order of Kshs 540 million (see table 5) out of which the foreign exchange component is about Kshs 90 million. If all charcoal using people were forced to switch to the next cheapest substitute, namely paraffin, because charcoal was no longer available, then an extra 215 million litres of paraffin would have to be imported[1]. This would cost the people about Kshs 818 million (.982 prices) and the country would have to pay approximately Kshs 613 in foreign exchange to purchase this energy. This means the people would have to pay an additional Kshs 278 million (51%) more than they are paying for charcoal and the country would have to find a further Kshs 523 million (US$ 48 million) in foreign exchange. This would add about 33% to the net import bill for petroleum products and increase the trade deficit by about 13%. So the use of an indigenous energy form is saving both the people and the country a considerable amount of money and foreign exchange - about US$ 48 million per year!

[1] This figure is based on the cooking equivalent as per table 1b. It is also assumed that the next cheapest commercial fuel, namely paraffin, is the substituted fuel.

## 5. Shadow prices of wood energy and shadow stumpage price

If foreign exchange costs are paramount to government then 'shadow' unit market prices for each fuel can be derived by equalising this cost component. This will indicate how valuable each energy form is to government. Tables 1b and 1c can be reworked whereby the estimated foreign exchange component of all fuels are equalized and this is shown in table 1e.



**Table 1e** The shadow cost of energy from different sources to supply an equal amount of energy (795 MJ) at the pot at a fixed foreign exchange cost of Kshs 117 (1) assuming a) current stove efficiencies, b) projected stove efficiencies

| Energy form | Alternative A - Shadow price | | | | FE | Alternative B - Shadow price | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Stove efficiency % | Units required | Shadow pot price Kshs | Unit shadow price Kshs per unit | both options Kshs | Stove efficiency % | Units required | Shadow pot price Kshs | Unit shadow price Kshs per unit |
| Wood 15% mc | 10 | 497 kg | 1074 | 2.16 kg | ) | 30 | 166 kg | 3042 | 18.33 kg |
| Wood 70% mc | 10 | 795 kg | 676 | 0.85 kg | ) | 30 | 265 kg | 1825 | 6.89 kg |
| Densified wood | 20 | 237 kg | 493 | 2.08 kg | ) | 45 | 105 kg | 961 | 9.15 kg |
| Charcoal | 20 | 120 kg | 913 | 7.61 kg | ) 117 | 45 | 53 kg | 1825 | 34.43 kg |
| Bio-gas | 50 | 72 $m^3$ | 320 | 4.45 $m^3$ | ) | 50 | 72 $m^3$ | 320 | 4.45 $m^3$ |
| Paraffin | 50 | 41 l | 156 | 3.80 l | ) | 50 | 41 l | 156 | 3.80 l |
| LP gas | 60 | 29 kg | 122 | 4.21 kg | ) | 60 | 29 kg | 122 | 4.21 kg |
| Electricity | 75 | 294 kwh | 127 | 0.43 kwh | ) | 75 | 294 kwh | 127 | 0.43 kwh |

(1) The foreign exchange cost of paraffin has been used as a standard.

Under present use methods the shadow market price "for equal expenditure of foreign exchange" is Kshs 2160 per tonne for fuelwood, Kshs 2080 per tonne for densified wood and Kshs 7610 for charcoal. This is a tenfold increase for fuelwood, a sevenfold increase for charcoal and a fourfold increase for densified wood. There is also a twofold increase for biogas but the shadow price for LP gas and electricity is less than the current market price indicating that these fuels are being subsidized at present, if the foreign exchange cost of paraffin is taken as the standard for comparison. If stove efficiency for the woodfuels is increased to the targets as indicated under B in table 1e, then the shadow prices for these fuels become extremely high ranging from an eighteenfold increase for densified wood to a 92 fold increase for fuelwood! Even so, the shadow price per KJoules delivered at the stove for fuelwood is only twelve times more expensive than paraffin and for densified wood five and a half times in the improved stove (B) option. Under present use patterns (A option) the shadow K Joule price is 40% more expensive for fuelwood, 30% more expensive for densified wood and 140% more expensive for charcoal in delivered pot terms. These figures point to the fact that the Government should be making a considerable investment into fuelwood and charcoal stove improvements and also into fuelwood plantations for "shadow" foreign exchange and shadow market prices are extremely high for woodfuels. If the "shadow" unit prices for fuelwood are as per tables 1d and 1e (under the assumption that the fuelwood stove could be increased to 30% efficiency) - namely Kshs 940 per tonne for an equal pot price, and Kshs 18330 per tonne for an equal foreign exchange cost, - then shadow stumpage prices can be worked out and these are shown in table 2. Also shown is the price that could be paid under existing conditions (Kshs 310 per tonne, table 1b) if the price at the pot was equal for all energy forms and likewise the



foreign exchange equalisation cost (Kshs 2160 per tonne - table 1e) under existing use conditions.

Table 2 Shadow stumpage price for fuelwood under various assumptions

Units Kshs/t at 15% mc unless otherwise stated

| | A | B | C | D |
|---|---|---|---|---|
| Shadow retail price for fuelwood | 310 | 940 | 2160 | 18330 |
| Profit margin 10% | 31 | 94 | 216 | 1833 |
| Wholesale price | 279 | 846 | 1944 | 16497 |
| Profit margin 5% of selling price | 16 | 47 | 108 | 917 |
| Price to wholesaler | 264 | 799 | 1836 | 15580 |
| Transport cost 74 kms (see table 3a) | 106 | 106 | 106 | 106 |
| Forest gate price | 158 | 693 | 1930 | 15474 |
| Felling and extraction and drying costs | 35 | 35 | 35 | 35 |
| Standing price (shadow stumpage price) | 123 | 548 | 1895 | 15435 |
| Shadow stumpage price per $m^3$ | 88 | 470 | 1354 | 11029 |
| Existing government stumpage price/$m^3$ | -------- 15 to 20 ------- | | | |

Key: A Fuelwood shadow market price - existing stove efficiency
B " " " " - anticipated stove efficiency
C " shadow foreign exchange equalisation price - existing stove efficiency
D " " " " " " - anticipated stove efficiency

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Under existing use conditions the shadow stumpage price for fuelwood is of the order of Kshs 90 per $m^3$ as opposed to an actual price of Kshs 20 per $m^3$. If foreign exchange costs were taken into consideration then the shadow "foreign exchange equalisation" stumpage price would be a staggering Kshs 1350 $m^3$ which puts into perspective how important woodfuels are in the saving of foreign exchange. The annual net saving of one hectare of fuelwood plantations giving a yield of 30$m^3$/ha/year (21 tonnes) is of the order of Kshs 4100 when compared to the foreign exchange cost of paraffin and even more for LPG and electricity. If improved stoves could be introduced and are acceptable then the shadow

stumpage price increases to Kshs 470 per $m^3$ and the shadow "f.e. equalisation" stumpage price shoots up to Kshs 11,000 per $m^3$. This latter figure when translated into net saving of foreign exchange per ha. of fuelwood gives a figure of Kshs 14,100 again when compared to the f.e. cost of paraffin. This latter sum approaches the average net foreign exchange earnings of tea and coffee, which are in the region of between Kshs 15,000 and 20,000 per ha per year, so from the point of view of saving foreign exchange, investing in fuelwood plantations should be given top priority.

With a shadow stumpage price of Kshs 90 per $m^3$ the average net annual income would be about Kshs 2650 per ha and give a return on capital investment (financial yield) of nearly 40%. With the introduction of improved stoves then the shadow stumpage price jumps to Kshs 470 per $m^3$ and the shadow net annual income increases to Kshs 14,500 per hectare. Such a shadow income points to the fact that the government should be investing heavily in fuelwood plantations and could be giving a subsidy to farmers to grow trees for fuel;—the planting of energy trees on farms should receive top priority. From a national point of view the saving of foreign exchange should be paramount, but the government will need aid and assistance to undertake the proposed tree planting programme outlined in the main report. However, the small foreign exchange component in the growing of trees does not make itself very attractive to donor agencies who usually like to see a sizeable proportion of any project in the form of foreign exchange (or from their point of view in local currency). Nevertheless, there is scope for aid especially in the form of trained manpower, and the financing and support of training and research institutions, for good management is the key to successful woodfuel (and other programmes). There is also scope for and projects in the manufacture and distribution of various forms of forestry and wood energy equipment ranging from simple well-designed hand tools, to vehicles run on producer gas, woodfired boilers, briquetting machines, densifying plants and kilns etc. It also must be remembered that the saving of foreign exchange on importing energy will release money to be spent on capital equipment which should accelerate development and encourage trade.

## Chapter II The cost of production and distribution of various forms of wood energy.

### 1. Introduction

Wood, especially green wood, is a high bulk, relatively low energy product. That is why in order to compete with other energy forms it has to be grown cheaply and near the consumer, or converted into higher energy forms such as densified wood, charcoal, acetylene(1), producer gas/water gas(2), methanol(3) and sulphur free petrol. Tropical countries have climatical advantage over temperate countries in that the theoretical growing season is all the year round, also, perennial plants such as trees have an advantage over annual plants, for example maize, in that they can make more use of their all year growing season. Thus trees are ideally suited to take full advantage of the tropical climate. However, in many areas of the tropics, water is a limiting factor, although trees can take more advantage of the available water than annual plants because of their deep rooting system. Nevertheless, in many of the dry areas in Kenya, it does not pay in a strict economical sense to grow woodfuel, unless the area is remote and the trees are grown to meet a local demand. The economic limit for woodfuel growth under present cost conditions is about $10m^3$ per hectare per year(7.5 tonnes/ha/yr.). Such a production would just cover costs without earning any interest on invested capital at a selling price of 15/- per $m^3$(standing). In many of the dry areas the most that can be hoped for is $5m^3$/ha/yr(4.2t/ha/yr) and so other factors such as soil conservation, erosion control and water catchment have to be brought into the arguement to justify the planting trees. Also, many of these areas are remote from the main population centres, and as will be demonstrated shortly, transport economics make them very unattractive as potential supply areas of woodfuel.

### 2. Economic transport distances - wood

What are the transport radii for production of wood energy? At the present only three forms of wood energy will be considered, namely, fuelwood, densified wood and charcoal. Densified wood is the same as fuelwood except it has been dried down to a low moisture content, usually about 12% MC(dry basis) and cut into small pellets for use in boilers or modified jikos(charcoal stoves)

(1) Acetylene-$C_2H_2$-is generated by dripping water onto Calcium carbide-$Ca_2C_2$ Calcium carbide is made by passing electricity through a mixture of lime $Ca(OH)_2$ and charcoal(Carbon).

$$2Ca(OH)_2 + 2C \xrightarrow{\text{electricity}} Ca_2C_2 + 2H_2O \uparrow + O_2 \uparrow \; : \; Ca_2C_2 + 2H_2O \rightarrow 2Ca(OH)_2 + C_2H_2 \uparrow$$

(2) Producer gas is a mixture of CO, $CH_4$ and $H_2$ plus inert gases with CO being the principal gas, whereas water gas has the above gases but $H_2$ is dominant.

(3) Methanol, $CH_3OH$, was formerly known as wood alcahol for wood was the main feed stock.



and compressed in order to reduce the air space in the wood. Both densified wood and charcoal require the raw wood to be modified, thus entailing some form of industrialisation.

If it is assumed that the standing price for fuelwood is Kshs.15 per $m^3$ and that the roadside price for wood felled, cross-cut and stacked is Kshs.45 per $m^3$, then it is possible to work out a transport radius for the above three types of wood energy, provided we know the market price for the products. One other thing that is very important to know is that wood when freshly felled, has ahigh moisture, and to transport this wood means that a lot of water is being carried; not only that, if green wood is burnt, then much of the wood's energy is required to drive off the moisture and therefore less energy is available for cooking and heating. This is why it is important from both the transport and burning point of view to first air dry the wood. Appendix 2 gives a table of the weight of Eucalyptus saligna at different ages and dried for different lengths of time. One $m^3$ of 5 year old E.saligna has a moisture content(dry basis) of 160% and weighs 1.6 tonnes, whereas after 18 weeks the moisture content is reduced to 20% and the weight is 0.7 tonnes. Likewise, the available energy of one $m^3$ when freshly cut is 5.72 Giga Joules per tonne (9.09 GJ per $m^3$) and 15.9 GJ per tonne(11.19 GJ per $m^3$ )after 18 months. Five year old E.saligna is less dense that 10 year old E.saligna Also, the moisture content of the green wood decreases with age, therefore, on a volume for volume basis, the wood has alower moisture content with increasing age and a higher energy value. Of course, on a weight for weight basis, the wood has the same energy value, but compared to the older wood, the younger wood requires more volume to give an equal weight. All this is illustrated in Appendix 2, but it is worth reiterating that green wood is expensive to transport and also inefficient to burn. If wood cannot be dried down to 15-20% due to climatic, security, time or pathogenic constraints then it may pay to force dry and densify the wood or turn it into charcoal, but of course, making charcoal from 'wet' wood needs more tonnage per tonne produced than making it from dry wood. Table 3 illustrates the economic radius for transporting wood at different moisture contents, assuming that the forest roadside price is 45/- per $m^3$. A more detailed calculation is shown in Appendix 3.

Table 3a Economic radius for transporting wood of different moisture contents at a standard selling price of Kshs.12.50 per Giga Joule ++

| Moisture content % | 160 | 80 | 40 | 20 | 15 | 10 |
|---|---|---|---|---|---|---|
| Roadside price per tonne Kshs. | 28 | 41 | 53 | 62 | 64 | 67 |
| Market price per tonne Kshs. | 72 | 117 | 159 | 190 | 200 | 211 |
| Profit margin 15% Kshs. | 11 | 18 | 24 | 28 | 30 | 32 |
| Economic road transport distance Kms | 33 | 58 | 69 | 73 | 74 | 75 |
| " rail " " " | 82 | 145 | 174 | 182 | 186 | 187 |
| Price per Giga Joule Kshs. | 12.50 | | | | | |

Table 3b Economic radius for transporting wood of different moisture contents at a standard selling price of Kshs.200 per tonne ++

| Moisture content % | 160 | 80 | 40 | 20 | 15 | 10 |
|---|---|---|---|---|---|---|
| Roadside price per tonne Kshs. | 28 | 41 | 53 | 62 | 64 | 67 |
| Market price per tonne Kshs. | 200 | 200 | 200 | 200 | 200 | 200 |
| Profit margin 15% Kshs. | 30 | 30 | 30 | 30 | 30 | 30 |
| Economic road transport distance Kms | 142 | 129 | 99 | 79 | 74 | 69 |
| Economic rail transport distance Kms | 355 | 322 | 249 | 196 | 186 | 172 |
| Price per effective G.J. Kshs. | 35 | 22 | 16 | 13 | 12.5 | 12 |

For all various assumptions see Appendix 3

From table 3 it will be seen that at a standard selling price of Kshs.12.50 per Giga Joule (200/- per tonne at 15% MC) the maximum,economic road transport distance is about 75 Kms. and that for rail about 190 Kms. Howevever,for green wood these distances are reduced to 33 and 82 Kms. respectively for road and rail. If wood was sold at a flat rate of Kshs.200per tonne irrespective of it's moisture content,then wood with the highest moisture content has the greatest economic transport radius,for example.green wood(160% MC) has a radius of 142 and 355 for road and rail respectively.This is twice as much as wood at 10% MC but this wood is three times more valuable than the former in terms of energy output. However,what table 3 does illustrate is that woodfuelis a high bulk,low cost product and to be of economic use it has to be grown near the user. Production costs of modified wood and its economic transport distance modified,then the economic transport distance can be increased,this is shown in table 4b for densified wood and charcoal.Densified wood is wood that is slightly modified by drying it down to about 10% MC (dry basis) cutting it up into easily handled pieces,compressing and bagging it,whereas charcoal is completely modified



wood,the hydrogen and oxygen being driven off just leaving the carbon behind which has approximately twice the energy value as wood on a weight for weight basis. Of course,as soon as wood is modified,then this involves capital expenditure. Table 4a gives the capital costs involved for production of densified wood and charcoal. The costs for the densified wood plant have been modified from a densifier plant already working in the Philipines which densifies pineapple waste.The capital costs of this plant are high, and it may be possible to have much simpler equipment,for example,machines run off wood gas(producer gas) that would chip the wood into small pieces.These small pieces are then left to dry and transported to the compressor where they are densified and briquetted. Much work needs to be done on the various densifying options.Three types of charcoal kilns are considered.A retort,brick kilns and earth kilns.The capital and running costs for these kilns and for the densifying plant are given in detail in Appendix 4,But table 4 gives a summary,assuming that an equal quantity of energy is produced,namely,1.764 Peta Joules($10^{15}$ Joules).

Table 4a Capital Investment and employment for the production of 1.764 Peta Joules of energy

| | Densified Wood | Charcoal Production | | | |
|---|---|---|---|---|---|
| | | Retorts (1)(2) | Brick Kiln | Earth Kilns High(3) | Earth Kilns Low (3) |
| Input $m^3$ | 144800 | 239850 | 319800 | 639600 | 639600 |
| Output tonnes | 105000 | 50300 | | | |
| Capital cost | | Millions of Kshs. | | | |
| Total | 98.4 | 183.4 | 23.3 | 1.6 | 2.1 |
| Foreign exchange | 72.1 | 130.1 | 6.7 | 0.5 | 1.1 |
| Local | 26.3 | 53.3 | 21.6 | 1.1 | 1.0 |
| Employment(man years) | 150 | 384 | 400 | 1421 | 2843 |
| Capital cost per job 1000Kshs. | 656 | 478 | 58 | 1.1 | 0.7 |

(1) The retorts briquette 25% of the charcoal which is produced in the form of powder and fines.It is also possible for the brick kilns to produce briquettes but this has not been considered here.

(2) The retorts also produce 13,325 tonnes of wood tar at Kshs.872 per tonne and a surplus of 9.6 million $m^3$ of wood gas at Kshs.677 per 1000 $m^3$. It is assumed that these products are sold ex factory for Kshs.1000 per tonne for tar and Kshs.677 per 1000$m^3$ for the wood gas.The economics of the retort depend on these by-products being sold. If there is no market for them or they cannot fetch the prices assumed then the viability of the retort is questionable.

(3) Production by earth kiln is somewhat uncertain.The lower figure is based on two men producing 30 tonnes per year,whereas,the upper figure is based on two men producing 60 tonnes per year.The lower figure was obtained from a student project in Tanzania,but it is thought that this is on the low side, hence the upper figure.

Table 4b Production costs, ex factory price, market price and maximum economic radius for transporting densified wood and charcoal.

| | | Units | Densified wood | Charcoal Production | | | |
|---|---|---|---|---|---|---|---|
| | | | | Retort | Brick Kiln | Earth Kiln high | Earth Kiln low |
| Output | | tonnes | 105000 | 53300 | | | |
| Production(1)(2) costs | Kshs | tonne | 282 | 504 | 506 | 442 | 647 |
| | Kshs | GJoule | 16.8 | 15.2 | 15.3 | 19.5 | 13.4 |
| Selling price ex factory:15%mark up | Kshs | tonne | 325 | 580 | 580 | 510 | 745 |
| | Kshs | GJoule | 19.3 | 17.5 | 17.5 | 15.4 | 22.5 |
| Price to wholesaler | Kshs | tonne | 425 | 850 | | | |
| | Kshs | GJoule | 25.3 | 25.7 | | | |
| Retail price | Kshs | tonne | 500 | 1000 | | | |
| | Kshs | GJoule | 29.8 | 30.2 | | | |
| Maximum economic transport radius | Road | (Kms) | 80 | 144 | 108 | 136 | 42 |
| | Rail | (Kms) | 200 | 360 | 270 | 340 | 105 |

(1) The production units are based near the supply of the wood. For densified wood the unit is within 35Kms of the wood, for the retort 20Kms radius, the brick kiln 12Kms and for the earth kiln production is where the trees are felled.

(2) The wood raw material has been costed at 15/- per $m^3$, felling and extraction at 25/- per $m^3$ and unskilled at 20/- per day with increased labour charges for skilled labour etc.

Compared to wood (table 3a) the economic transport radius for charcoal is about double and for densified wood marginally increased. However it must be noted that the price per Giga Joule for these two modified wood forms is more than double, but they are more convenient to handle and the cooking appliance is about twice as efficient.Much more wood raw material is required for charcoal production than densified wood, 4.4 times more in the case of charcoal produced by the earth kiln, and where land is at a premium then roundwood or densified wood may be the best choice. However, from an employment and investment point of view, charcoal produced in brick and earth kilns are better than densified wood. Even so, compared to commercial fuels such as paraffin, gas and electricity, the wood raw material must be grown near to the consumption unit at the selling price assumed in table 4b. While this selling price is much lower than the commercial fuels(table 1) the official price of charcoal is even lower still.This is shown in table 5.



Table 5 Official price of charcoal - Kenya Gazette April 1982

Units Kshs

| Wholesale price Per bag(40Kg charcoal) | Retail price | Retail cost per GJ | Wholesale price Per tonne | Retail price | Area |
|---|---|---|---|---|---|
| 25 | 35 | 26.4 | 625 | 875 | Nairobi |
| 20 | 25 | 18.9 | 500 | 625 | Mombasa,Kisumu etc. |
| 18 | 23 | 17.4 | 450 | 575 | Embu,Machakos,Meru etc. |
| 16 | 21 | 15.9 | 400 | 525 | Eldoret, Malindi, etc. |
| 14 | 19 | 14.4 | 350 | 475 | Isiolo,Marsabit, etc. |
| 12 | 17 | 12.8 | 300 | 425 | Other areas |
| Estimated country average | | 22.8 | 540 | 755 | |

Comparing table 5 to table 4 it will be seen that lowest production costs for charcoal - Earth kiln(high)- of Kshs 442 is still higher than the lowest retail price for other areas of Kenya - Kshs 425. However, in the production figures in table 4b the wood raw material has been costed at Kshs 15 per $m^3$. Generally the Earth kiln charcoal producer does not pay for the wood raw material and so if this cost is excluded, the charcoal price then becomes Kshs 262 and Kshs 467 for the two Earth kiln production alternatives. Also the producers tend to put in brands(semi burnt charcoal), bark charcoal(which has a lower energy value), charcoal fines, soil, stones and water etc. to make up the weight, so each bag may only contain 35 Kgs of charcoal lumps(5% M.C.) and 5 Kgs of make weight. If the wood is to be paid for and Kenya cannot go on living on it's tree capital for much longer, and if a bag of charcoal is to contain 40 Kgs of burnable charcoal(5% M.C.), then the retail price will have to be increased to somewhere in the region of Kshs 40 per bag unless the government intends to subsidise charcoal and firewood. Even at that price, as table 1 has shown, it is more than competetive with commercial fuels, and this justifies investment in wood as a cheap and indigenous energy source.

Wood can be, and is,used as a boiler fuel in industry, both for direct motive power and to generate electricity. There is need to look into boiler design that will take various fuels and also boiler sizes that can provide a range of power from small to large.

4. Other wood fuels and their uses

There are many more fuels, both liquid and gaseous, that can be obtained from wood. A separate study has been made on producer gas and this gives encouraging results. Calcium carbide for acetylene production is not produced in Kenya, but of

course, acetylene is used extensively for welding. However, it could be a paraffin substitute for it gives an intensive white light. It can be made by passing "excess night electricity" from the hydro electricity capacity through a mixture of lime and charcoal. A feasibility study should be undertaken to see if Calcium carbide can be made cheaply, and if so, whether cheap burners can also be made. Such a product is safe and could improve immensely the quality of life in the rural areas.

Methanol, or to use it's traditional name, wood alcohol, is a liquid fuel that can be used for motive power as well as a chemical feedstock. However, Kenya has already embarked on Ethanol plants and therefore, at least in the foreseeable future, methanol manufacture is a non-starter even though it may be slightly cheaper to produce than ethanol and it does not use a potential food as it's raw material. However, what is important to determine, is whether there is a shortage of the fuel that is going to be substituted and whether the alcohol production will save foreign exchange.

Diesel and L.P. gas are the fuels that are in short supply not petrol and therefore it is substitutes for these fuels that should be looked at closely. Palm oil, producer gas and acetylene could be possible substitutes for these products and initial studies could be undertaken on the economics of substitute fuels. Likewise low sulphur petrol could be made from woody biomas, but it is too expensive at the moment to produce it. However, when oil starts to run out and the relative price increases, then production will start becoming economic. But for all these manufacturing processes from densified wood through to petrol produced from wood, it is necessary to have an adequate and guaranteed supply of wood raw material in close proximity to the processing plant, and this must be planned for in advance. Likewise wood energy for household consumption must be planned for and grown near the consumption centres, this is why the main report has emphasised agro-forestry systems, peri-urban plantations and fuelwood plantations in the high potential areas near the urban centres. The cost of such schemes can now be looked at in detail.

## Chapter III Forestry costs and returns in Kenya

### 1. Silvicultural costs - Fuelwood plantation full cost

Forestry costs in terms of man days and money values were collected from various Government Forestry department projects throughout Kenya by examining and analysing the monthly report forms. These costs showed not only considerable variations from project to project, but significant variations within projects from year to year. By and large however, when compared to forestry costs in Tanzania, they were much higher and even higher than private forestry costs in Scotland, U.K. This can be observed by examining Kenya's average cost for various operations with those from two forest stations within Tanzania and costs from the U.K. These are tabulated in table 6.



Table 6 Establishment cost per hectare in Kenya, Tanzania and the U.K.

Units: man days or man day equivalent.

| Year | Operation | Tanzania(1) Low | Tanzania(1) High | Kenya(2) Average | Kenya(2) Assumed | Yr. | Operation | U.K.(3) |
|---|---|---|---|---|---|---|---|---|
| | Nursery | | | | | | Nursery | |
| 0 | Raising plants (incl o/h) 1600pl | 5.0 | 9.8 | 32.0 | 12.0 | 0 | 1600 plants | 4.5 |
| | Forestry | | | | | | Forestry | |
| 0 | Clearing | 7.0 | 11.6 | 21.0 | 12.0 | 0 | Fencing | 4.3 |
| 0 | Staking | 3.7 | 5.0 | 10.0 | 6.0 | 0 | Clearing | 0.9 |
| 0 | Pitting | 2.2 | 4.2 | 22.0 | 10.0 | 0 | Draining | 3.6 |
| 0 | Planting | 5.0 | 9.2 | 16.0 | 12.0 | 0 | Ploughing | 2.7 |
| 0 | Weeding | 2.0 | 4.0 | 8.0 | 4.0 | 0 | Planting | 2.0 |
| | | | | | | | Weeding | 0.1 |
| 0 | Initial establishment & weeding | 19.9 | 34.0 | 78.0 | 44.0 | 0 | F E & Weed. | 13.5 |
| 1&2 | Weeding | 0.8 | 2.9 | 19.0 | 7.0 | 2-4 | Weeding | 1.0 |
| 1&2 | Beating up (replacing dead plants) | 1.9 | 2.3 | 5.0 | 4.0 | 2-4 | B.U. | 0.3 |
| 1&2 | Weeding and beating up Total | 2.7 | 5.2 | 24.0 | 11.0 | 2-4 | W + B.U. | 1.3 |
| 0 | Cost of plants for planting | 5.0 | 9.8 | 32.0 | 12.0 | 0 | Plant costs | 4.5 |
| 1&2 | Cost of plants for B. U. | 0.5 | 1.0 | 3.2 | 1.2 | 2-4 | B.U. plants | |
| 0-3 | Total establishment costs | 28.1 | 50.0 | 137.2 | 68.2 | 0-4 | Est. costs | 19.7 |
| 0-3 | Overhead costs as a % of direct costs (4) | 149 | 144 | 150 | 150 | 0-4 | O/H costs ≈ Direct costs | 55 |
| Daily pay for labour Kshs(5) | | 20 | | | | Daily pay Kshs(6) | | 200 |
| Total establishment costs including O/H Kshs | | 1397 | 2438 | 6910 | 3410 | Total est. incl. O/H Kshs | | 6107 |

Table 6 FOOTNOTES

The Tanzania costs are three year averages. The low costs are from West Kilimanjaro and the high costs are from Mount Meru - both government forests.

The assumed costs are the costs that the author thinks can be achieved. They are about half the Kenya average costs, but 40% more that the Tanzania high costs.

The U.K. costs are average costs for medium and large private estates in Scotland. The fencing, clearing and ploughing includes the machine or material costs in labour equivalent terms.

Overhead costs include local supervision, office staff and equipment, office rent, vehicles, machines and materials not directly used in establishment operations, road construction, fire patrol etc. and a proportion of regional, H.Q. and research costs.

The pay for casual labour is between Kshs 10 & 15 per day, but the rate of Kshs 20 assumes that the employees are permanent and includes employer's share of pension contribution etc.

1980 Weekly wage for foresters - £57.50 = Kshs 1094
1980 Stumpage price for small diameter wood £2.30 per $m^3$ = Kshs 44/$m^3$.

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From table 6 it can be seen that labour inputs are the lowest per hectare in the U.K. and also the overhead costs are low, but because the daily pay is approximately ten times more than in East Africa, the total cost is higher than in Tanzania and the assumed Kenya cost, but lower than the average Kenyan costs. Why are the Tanzanian costs so much lower than the Kenyan costs? It is possible that their supervision is better, but this is arguable. No, the real reason is that the Kenyan task rates are totally unrealistic. They were established when the labour force was only part time, working part of the morning in the forest and the rest of the day on their farms. Today the labour force is supposedly full time but the task rates have not altered. Clearly, the labour productivity is extremely low and the task rates must be altered to make the labour force competitive. If they are not, then the forestry department will make a loss or only a marginal return if the stumpage price of the fuelwood is 15/- per $m^3$(1) Table 6 also gives an assumed establishment cost for Kenya, which it is thought could be achieved given good management and realistic task or piece rates.

(1) The stumpage prices for pulpwood poles and sawn wood are higher, and if financial yield calculations are carried out then these products would probably give a higher yield, indicating that the fuelwood price is being subsidised.



Table 7 Costs and returns per hectare from a fuelwood crop on a ten(and fifteen) year rotation(5 rotations in all) grown in areas of high to medium(15 yr R) rainfall.

Units Kshs: cost and returns per hectare in constant 1982 terms(1)

| Year | Operation | Tanzania Low | Tanzania High | Kenya(10yrR) Average | Kenya(10yrR) Assumed | Kenya 15 Assumed |
|---|---|---|---|---|---|---|
| 0 | Initial establishment | 497 | 875 | 2200 | 1120 | 113 |
| 1 | Weeding & Beating up | 44 | 84 | 424 | 144 | 1[illegible] |
| 2 | Weeding | 20 | 40 | 120 | 100 | 10 |
| 0-10 | Overheads per year | 76 | 131 | 400 | 200 | 15 |
| 10,20,30,40) | Weeding and | 28 | 48 | 100 | 80 | [illegible] |
| 11,21,31,41) | coppice reduction | 20 | 40 | 60 | 60 | [illegible] |
| 11-50 | Overheads per year | 35 | 63 | 115 | 100 | [illegible] |
| 0-50 | Direct costs | 753 | 1351 | 3384 | 1924 | 192 |
| 0-50 | Overhead costs | 2236 | 3961 | 9000 | 6200 | 5[illegible] |
| 0-50 | Total costs | 2989 | 5312 | 12384 | 8124 | 38[illegible] |
| 7 | Thinning volume 50 $m^3$ | | | Income 750 | Income 1000 | 45 $m^3$ |
| 10 | Felling volume 250 $m^3$ | | | at 15/- -3750 | at 20/- -5000 | 180 $m^3$ |
| 17,27,37,47 | Thinning vol. 65 $m^3$ | | | $m^3$ 975 | $m^3$ 1300 | 55 $m^3$ |
| 20,30,40,50 | Felling vol. 250 $m^3$ | | | 3750 | 5000 | 180 $m^3$ |
| 0-50 | Revenue at 15/- per $m^3$ | 23,400 | | | | 17[illegible] |
| 0-50 | Net revenue | 20411 | 18088 | 11016 | 15276 | 0-75 [illegible] |
| | Net discount revenue at 10% | 1767 | 815 | -3046 | -198 | -1[illegible] |
| | Financial yield(IRR)% | 20 | 13½ | 4½ | 9½ | |
| 0-50 | Revenue at 20/- per $m^3$ | 31200 | | | | 23[illegible] |
| 0-50 | Net revenue | 28211 | 25888 | 18816 | 23076 | 14[illegible] |
| | Net discount revenue at 10% | 2773 | 1821 | -2040 | 808 | -12[illegible] |
| | Financial yield(IRR)% | 25 | 22½ | 7½ | 13 | 6[illegible] |
| 0-50 | Yield total $m^3$ | 1560 $m^3$ | | | | 0-75 1165 $m^3$ |
| | Average annual yield $m^3$ | 31.2 $m^3$/ha/yr(2) | | | | 15.5 $m^3$/ha/[illegible] |
| | Average annual yield t | 22.4t/ha/yr | | | | 11.9t/ha/[illegible] |

(1) All social costs such as housing, public buildings and public roads have been excluded from these costs, as has the cost of land. Also, it is assumed the planting takes place on a large enough scale so that the cost of project buildings etc. are only a small part of overheads.

(2) Assume 1.4$m^3$ = 1 tonne at 15% M.C.

(3) Assume 1.3$m^3$ = 1 tonne at 15% M.C.

Table 7 gives the costs and returns for a fuelwood plantation grown on a ten year rotation, with a further four rotations coming from suckers. A more detailed breakdown of costs and returns plus a labour budget is given in Appendix 5. It must be stressed that these costs are the costs directly associated with the establishment of the forest. All social costs such as housing, public buildings and public roads have been excluded. If they were included they could more than double the costs. Also excluded is the cost of the land. While this is a legitimate cost, it will only be applicable where there is a change of land used, for example, the peri-urban plantations, so as to make the various options comparable it has been excluded from the various models.

With the cost and price structure, assume as in table 7, the returns on investment, in high rainfall area, assuming average Kenyan costs, even at a stumpage price of Kshs 20 per $m^3$, are less than 10% and are under 5% with a price of Kshs 15 per $m^3$. If in fact the annual yield from the crop was 16.5$m^3$ per hectare(11.8 tonnes air dry) rather than 31.2$m^3$(1) as assumed, the income would just cover costs. These kinds of yields can be expected in medium rainfall areas. However, if costs can be reduced to the ones assumed for Kenya, then the return on invested capital should be of the order of 10%, and the average annual break even volume is 11$m^3$/ha. If costs similar to those in Tanzania can be achieved then the returns on invested capital are between 13 1/2 and 25%, depending on the cost and price assumptions. So, given reasonable management, and plantations in the high potential areas, where the greatest demand for wood energy is, then even at a stumpage price of Kshs 15 per $m^3$, the returns on investment should be attractive to government and even private individuals. However, there is the problem of the initial waiting period of seven years as stated in the model in table 7.

It is possible to have shorter rotations, or, initially to have shorter rotations and then gradually build up to the ten years rotation. This may mean a sacrifice of volume for an earlier return, but it can be partially overcome by much denser planting, but of course this will increase the establishment costs, for at a planting distance of 1 metre x 1 metre, there will be 10,000 trees per hectare as opposed to 1600 p.p.h. as assumed in the model, so initial establishment costs could be about five times more than in the model.

1) This is the average annual yield of stem wood(26 $m^3$/ha.)and branch wood 5.2$m^3$/ha., total 31.2$m^3$/ha. - 22.3 t/ha. It is assumed that the initial yield in the first ten years is slightly less than subsequent yields.



There is a considerable amount of work to be done on volume production and returns at different spacing distances, for rotations of one year to say five years. Also from a wood energy point of view wood density is the most important factor. Juvenile wood is less dense than mature wood so density over time needs also to be investigated. Examples of shorter rotations will be given later on, but the knowledge about yields on very short rotations is still very uncertain.

Table 7 also gives the costs and returns for medium rainfall areas on a 15 year rotation. The average yield is 11.9t/ha/yr nearly half that of the high rainfall area, thus the net revenue and financial yields are much lower. Unless these medium rainfall areas are near the markets or perhaps if the high rainfall potential sites are required for other purposes it is marginal to invest in these areas.

2. Fuelwood plantation shamba system (Taungya)

A variation of the fuelwood plantation model mentioned above is to first let the workers farm the land for up to four years before the trees are planted. In Kenya, this is known as the Shamba system, whereas in south east Asia, it is known as Taungya. The farmers pay a nominal rent for the time they grow agricultural crops exclusively and then for a further two years they grow crops between the planted trees. They are paid for staking, pitting andplanting operations, but not of course for the cleaning operations nor the weeding in the first and second years. Beating up and weeding in the third year is also paid for. A detailed cost and return schedule is given in Appendix 6 together with a manpower budget. The advantage of this system is that food is initially produced on the land and the labour and overhead costs are reduced, the disadvantages are that there is a four year delay in fuelwood production and the yields may be depressed initially due to soil exhaustion and live pruning of the trees. However the anticipated financial yield is increased over the full cost model and this is shown in table 8.

3 Agro-forestry model

In the main report, the main emphasis for providing wood to the rural community has been put on farm trees, that is, providing the bulk of the energy requirement on the door step. If this could be achieved, then the task of felling and collecting the fuel would be greatly reduced and more time would be available to concentrate on improving farm yields. However, many people have the idea that treed and agricultural crops are mutually exclusive and therefore, if land is devoted to trees there is less land available for food. But certain tree species, rather than compete with the agricultural crops, complement them and may in fact increase the yield. Trees also have a relatively deep rooting system and pump up from the lower soil horizons, mineral elements that have been leached from the surface layer. When the leaves are shed, these elements are returned to the soil.

Table 8 Costs and returns per hectare from a fuelwood crop on a ten(and fifteen) year rotation(5 rotations in all)established by the shamba system in areas of high to medium(15yr R) rainfall: 4 years of agriculture before planting.

Units Kshs. costs and revenue in constant 1982 terms.

| Year | Operation | Tanzania Low | Tanzania High | Kenya Average | Kenya Assumed | Kenya15yr R.Assumed Yr(0-75) |
|---|---|---|---|---|---|---|
| | **Costs** | | | | | |
| 0-50 | Direct costs | 577 | 1021 | 2404 | 1524 | 1524 |
| -4to50 | Overhead costs | 1970 | 3495 | 7150 | 5500 | 6100 |
| -4to50 | Total costs | 2547 | 4516 | 9554 | 7024 | 7624 |
| | **Returns** | | | | | |
| -1to-4 | Rent at 15/- p.y. | 60 | | | | 60 |
| 0-50 | Fuelwood at 15/- per $m^3$ | 23400 | | | | 17475 |
| -4to50 | Total revenue | 23460 | | | | 17535 |
| -4to50 | Net revenue | 20913 | 18944 | 13906 | 16436 | 9911 |
| | Net discount revenue at 10% | 2022 | 1284 | -1588 | 233 | -970 |
| | Financial yield % | 22½ | 16 | 7½ | 11½ | 6 |
| -1to-4 | Rent at 15/- p.y. | 60 | | | | 60 |
| 0-50 | Fuelwood at 20/- per $m^3$ | 31200 | | | | 23300 |
| -4to50 | Total revenue | 31260 | | | | 23360 |
| -4to50 | Net revenue | 28713 | 26744 | 21706 | 24236 | 15736 |
| | Net discount revenue at 10% | 3028 | 2290 | -582 | 1239 | -566 |
| | Financial yield % | 26 | 19½ | 9½ | 14½ | 8½ |
| -4to50 | Total yield $m^3$ | 1560 $m^3$ | | | | 1165$m^3$ |
| | Average annual yield $m^3$ | 28.9$m^3$/ha/yr | | | | 14.7$m^3$/ha/yr |
| | Average annual yield t | 20.6t /ha/yr (1) | | | | 11.3 t/ha/yr (2) |

(1) Assume 1.4$m^3$ = 1 tonne at 15% M.C. (dry basis)

(2) Assume 1.3$m^3$ = 1 tonne at 15% M.C. (dry basis)

If the trees are nitrogen fixers, the leaves will be rich in nitrogen as well. As for taking away land from agriculture, this is true to a certain extent, but if trees are lightly branched and let much of the sunlight through, then some crops can be planted right up to the stem, and the area occupied by the tree stem is minimal. A fully stocked plantation will have a stem area of about 100$m^2$ per hectare, so a farm scattered with trees to the equivalent of say 15% cover should not have more than 20$m^2$ per hectare which is 0.2% of the land, just a fraction of the area. For this minimum sacrifice, the farmer in return could satisfy the wood energy requirements, obtain fodder from the trees, improve the microclimate and the fertility of the soil.

Many farmers are already planting trees on their farms, what is required is to give the farmers better advice and to supply them with suitable farm tree seeds and seedlings. It may even pay the government to give the farmers a subsidy for planting and tending trees, for as has been demonstrated in table 1, wood energy, especially fuelwood, is the cheapest form of energy and if this was not available, the next cheapest form would be paraffin, which is at least twice as expensive in terms of foreign exchange! The least the government could do is to strengthen the extension service, issue pamphlets about tree planting and introduce into the school sylabus courses on tree planting on the farm.

Tree and shrub planting can take on many forms, - along roads and boundaries, on steep slopes and on land not being used for agricultural crons, along rivers, around houses as windbreaks, along contours, as strips throughout the field and as scattered trees for shade etc. Where trees are planted in groups or wood lots, then the cost described in table 7 can be used as a standard. The costs and returns shown in table 9a are appertaining to agro-forestry systems in high rainfall areas, where the trees are an intimate part of the farming system. It is assumed that there are 240 trees per hectare, about 15% crown cover, but as explained previously, only about 0.2% ground cover. Two alternatives are given, the first is where tree seeds are planted and the second is where seedlings are planted.

Appendix 7 gives more details of the costs and returns as well as a labour budget. It is assumed that the branches are lopped off the trees and spread on the land as a fertiliser. The woody parts of the branches are used as fuel. The rotation is 6 years but the branch wood is available from the 2nd to 3rd year. After the first rotation the trees come up from suckers for a further four rotations giving a cycle of thirty years.

Table 9a Costs and returns per hectare of farm land and per hectare of forest forest equivalent land for an agro-forestry tree system in a high rainfall area on a six year rotation(5 rotations in all).

Units Kshs. Costs and returns in constant 1982 terms based on Kenya assumed costs.

| Year | Operation | Seeds planted Farm 15%crown cover | Seeds planted Forest equivalent (1ha.) | Seedlings planted Farm 15%crown cover | Seedlings planted Forest equivalent (1 ha) | Yield - seeds planted |
|---|---|---|---|---|---|---|
| | Costs | | | | | -Farm- |
| 0-30 | Assumed direct costs | 122 | 813 | 230 | 1533 | a)Total |
| 0-30 | Overhead costs(1) | 310 | 2067 | 310 | 2067 | 134m³ |
| 0-30 | Total costs | 432 | 2880 | 540 | 3600 | b)per yr |
| | Returns | | | | | 4.5m³ |
| 0-30 | Assumed income fw at 15/-m³ | 2010 | 13400 | 2025 | 13500 | 2.8t (2) |
| 0-30 | Assumed " fert at 20/-ha | 480 | 3200 | 500 | 3333 | Forest equiv. |
| 0-30 | Total assumed revenue | 2490 | 16600 | 2525 | 16833 | a)Total |
| | | | WOOD ALONE | | | 893m³ |
| 0-30 | Net revenue(assumed) | 1578 | 10520 | 1485 | 9900 | |
| | NDR at 10% | 351 | 2340 | 261 | 1740 | b)per yr |
| | Financial yield | 40½ | 40½ | 22 | 22 | 29.8m³ |
| | | | WOOD AND FERTILISER | | | 18.6t |
| 0-30 | Net revenue(assumed) | 2058 | 13720 | 1965 | 13233 | Yield |
| | NDR at10% | 483 | 3220 | 410 | 2733 | -seedlings planted. |
| | Financial yield | 51 | 51 | 28½ | 28½ | -Farm- |
| | Returns | | | | | a)Total |
| 0-30 | Assumed income fw at 20/-m³ | 2680 | 17867 | 2700 | 18000 | 135m³ |
| 0-30 | Assumed " fert at 20/-ha | 480 | 3200 | 500 | 3333 | b)per yr |
| 0-30 | Total assumed revenue | 3160 | 21067 | 3200 | 21333 | 4.5m³ |
| | | | WOOD ALONE | | | 2.8t |
| 0-30 | Net revenue(assumed) | 2248 | 14987 | 2160 | 14400 | Forest equiv. |
| | NDR at 10% | 522 | 3480 | 438 | 2920 | a)Total |
| | Financial yield | 49 | 49 | 29 | 29 | 900m³ |
| | | | WOOD AND FERTILISER | | | b)per yr |
| 0-30 | Net revenue(assumed) | 2728 | 18187 | 2600 | 17333 | 30.0m³ |
| | NDR at 10% | 654 | 4360 | 567 | 3913 | 18.8t |
| | Financial yield | 60 | 60 | 35 | 35 | |

(1) Most of the overhead costs are not costs to the farmer but costs to the government in the form of help and advice.

(2) Assume 1.6m³ = 1 tonne at 15% M.C. This wood is lighter than wood on the ten year rotation because it contains more juvenile wood.



All the direct labour has been fully costed at Kshs 20 per day and likewise a figure of Kshs 15-20 per m³ has been put as the revenue from the fuelwood. It will be seen that the returns to the farmer are much higher than under the straight plantation model, especially if it is considered that much of the overhead cost is not a cost to the farmer but to the government. If the fertiliser input, which has been assessed at Kshs 20 per hectare(1) is included in the years when mulching is undertaken, then the returns are even higher. If seeds can be established easily, then this will give a much greater return and of course there will be a saving of labour in the initial establishment phase. For the above model, it is estimated that, if seeds are used, a total of six man days are required to establish and tend 240 trees per hectare over the thirty years, and 10.3 man days if seedlings are used. Of course, there will be labour requirements for branch mulching and thinning which could amount to 240 man days per hectare spread over the thirty years. Also it will be assumed that there will be 3 man days per hectare of extension advice during the thirty year period. However, there is most likely to be a considerable saving of time in collecting wood, for with this system, the fuel is on the farm. It is estimated that to cut and collect 6 tonnes of air dry wood,(the yearly consumption of a family of six), requires only 20 days. This is less than half an hour per day or the equivalent of Kshs 1 if labour is costed at Kshs 20 per day. Therefore, it can be seen that there are substantial gains to be made especially for the women and children by growing fuel trees on farm.

The anticipated yield is some 2.8 tonnes per hectare per year. The main report gives an expected yield of 4.0 tonnes per hectare per year, but this assumes that there will be 0.2 ha. of wood lot on one hectare of land which will give 4.4t/ha/yr(6.2m³/ha/yr). In addition there will be fuelwood from hedges etc. which amounts to 0.4t/ha/yr(0.6m³/ha/yr). So from 2 hectares of farm land, one of which is under agro-forestry, we obtain 2.8 tonnes of fuelwood from agro-forestry trees and 0.4 tonnes from hedges etc., and from the other hectare the yield is 4.4t from the wood lot and 0.4 tonnes from hedges etc., thus for the two hectares the yield is 3.2t + 4.8t or on average, 4 tonnes per year. Of course there can be many combinations of the above three components. For an agro-forestry system alone, 4 tonnes per hectare could be obtained from the equivalent of 21.5% tree crown cover which is equivalent to about 30 m² of stem cover per hectare or 0.3%. Under present consumption patterns 4 tonnes of wood per year is sufficient for four people, but if an improved wood-burning stove were introduced, then the above quantity of wood may be sufficient for six people.

If the costs and returns are compared to the Kenya assumed costs and returns (table 7) over the same time period and excluding the imputed returns of the fertiliser, then the agro-forestry costs are 27% less and the revenue is only 4%

(1) This is per farm hectare; per forest hectare it is Kshs 133.

less, this is one of the reasons why the financial yield is so much more for agro-forestry but the main reason is that the returns start to come in at a much earlier date.

Table 9b Costs and returns per hectare of farmland and per hectare of forest equivalent land for an agro-forestry tree system in medium rainfall areas on a six year rotation( 5 rotations in all).

Units Kshs. Costs and returns in constant 1982 terms based on Kenya assumed costs.

| Year | Operation | Seeds planted Farm 15%crown cover | Seeds planted Forest equivalent (1 ha) | Seedlings planted Farm 15%crown cover | Seedlings planted Forest equivalent (1 ha ) | Yield - seeds planted |
|---|---|---|---|---|---|---|
| | Costs | | | | | -Farm- |
| 0-30 | Total costs(See table9a) | 432 | 2886 | 540 | 3600 | a)Total $78m^3$ |
| | Returns | | | | | |
| 0-30 | Assumed income at 15/-$m^3$ | 1175 | 7830 | 1185 | 7900 | b)per yr $2.6m^3$ |
| 0-30 | Assumed " fert" 20/-ha | 288 | 1920 | 300 | 2000 | 1.7t(1) |
| 0-30 | Total assumed revenue | 1463 | 9750 | 1485 | 9900 | |
| | | | WOOD ALONE | | | Forest equiv. |
| 0-30 | Net revenue(assumed) | 743 | 4950 | 645 | 4300 | a)Total $520m^3$ |
| | NOR at 10% | 133 | 887 | 31 | 207 | b)per yr |
| | Financial yield | 25 | 25 | 12 | 12 | $17.3m^3$ |
| | | | WOOD AND FERTILISER | | | 11.6t |
| 0-30 | Net revenue(assumed) | 1031 | 6870 | 945 | 6300 | Seedling planted |
| | NOR at 10% | 225 | 1500 | 133 | 887 | -Farm- |
| | Financial yield | 33 | 33 | 16 | 16 | a)Total $79m^3$ |
| | Returns | | | | | |
| 0-30 | Assumed income at 20/-$m^3$ | 1566 | 10440 | 1580 | 10533 | b)per yr $2.6m^3$ |
| 0-30 | " " fert at 20/-ha | 288 | 1920 | 300 | 2000 | |
| 0-30 | Total assumed revenue | 1854 | 12360 | 1880 | 12533 | |
| | | | WOOD ALONE | | | |
| 0-30 | Net revenue(assumed) | 1134 | 7560 | 1040 | 6933 | Forest equiv. |
| | NOR at 10% | 232 | 1547 | 131 | 875 | a)Total $524m^3$ |
| | Financial yield | 32½ | 32½ | 17½ | 17½ | |
| | | | WOOD AND FERTILISER | | | b)per yr |
| 0-30 | Net revenue (assumed) | 1422 | 9480 | 1340 | 8933 | $17.5m^3$ |
| | NOR at 10% | 324 | 2160 | 233 | 1553 | 11.7t |
| | Financial yield | 39 | 39 | 26½ | 26½ | |

(1) Assume $1.5m^3$= 1 tonne at 15% M:C. This wood is lighter than wood grown on a 10 year rotation but denser than the quicker grown wood on the agro-forestry high rainfall areas.

It is also proposed to undertake agro-forestry schemes on 'medium rainfall' farmlands. On these areas, yield will be lower - an estimated 2.5 tonnes per hectare per year ($3.5m^3$/ha/yr) for a 15% tree crown cover. It is anticipated that the costs will be



similar to those on the high rainfall areas and therefore, the returns will be less and these are shown in table 9b.

The agro-forestry system shown in table 9b yields between 1.7 and 1.8 tonnes per hectare per year whereas the main report gives an expected yield of 2.5 tonnes per hectare. However, this assumes that, as in the high rainfall areas, there will be a 0.2 ha. woodlot on one hectare of farm land. This would yield 2.75t/ha. per year on average. In addition, on each hectare there would be hedgerows and miscellaneous trees giving an annual yield of 0.25t/ha. So for two hectares of farm land, one under agro-forestry and the other traditional farming systems with a 0.2 ha. woodlot, plus hedges etc. on each area, the yield will be 5.0t/a per two hectares or 2.5 tonnes per hectare per year. If the land was entirely under agro-forestry systems, then each unit area would have to have the equivalent crown cover of 21.5%. This is equal to about 30 square metres of stem cover or 0.3% of the land area. This per hectare yield of wood from farm land on medium rainfall areas is sufficient for 2.6 people under present use conditions; if improved stoves could be introduced then the same yield would satisfy nearly four people.

The two most important points about agro-forestry systems are firstly, the yield from the trees is obtained without any detriment to the farm crops, indeed the protective nature and fertilising capacity of the trees could enhance the farm yields. Secondly, the fuelwood and poles etc. are grown on farm, this reduces the collecting time and burden, particularly for women and children, and thus gives them more time for farm work, study and leisure. If trees were grown on farm in sufficient numbers to provide fuelwood, then less than half an hour a day would be spent cutting and collecting the fuel for a family of six.

4. Peri-urban plantation

Peri-urban plantations have been suggested for a number of reasons such as a green belt round cities to break up the concrete jungle; to act as a forest park where the urban people can go for relaxation; to provide employment for the urban population; but of course the main reason is to provide fuelwood to the urban population. Burning fuelwood is more economical than using charcoal but of course if people are to be persuaded to switch back to fuelwood, efficient wood-burning stoves will have to be developed that are not only functional but good to look at. Also the wood will have to be neatly packaged, be easy to light but slow to burn. Therefore, if wood is going to be acceptable by the urban population much research work has to be done on stove development and marketing of fuelwood and/or densified wood.

Peri-urban plantations will mean a change of land use and therefore the individual land owners must be convinced that it will pay them to go in for fuelwood plantations or government will have to aquire the land. One of the most successful private urban fuelwood plantations is around Addis Ababa. Small -

for the Athi plain fuelwood model and this table can be compared to tables 7-9 Further details of the model can be found in Appendix 8.

**Table 10** Costs and returns for a peri-urban fuelwood/fodder or fuelwood crop alone on a fifteen year rotation( 5 rotations in all) grown on a medium to dry rainfall area such as the Athi plains.
Units Kshs. costs and returns per hectare in constant 1982 terms based on the Kenya assumed costs.

Units Kshs.

| Year | Item | Sale of wood only: Seeds planted | Sale of wood only: Seedlings planted | Sale of wood Pods and honey: Seeds planted | Sale of wood Pods and honey: Seedlings planted | Yield |
|---|---|---|---|---|---|---|
| 0-75 | Direct costs | 1554 | 2234 | 5294 | 5894 | Trees a)Total 1165m³/ha |
| 0-75 | Overhead costs | 11400 | 11400 | 15200 | 15200 | b)per yr 15.5m³/ha |
| 0-75 | Total costs | 12954 | 13634 | 20494 | 21094 | |
| 0-75 | Wood revenue at 15/-per m³ | 17475 | | 17475 | | 11.1t/ha |
| 0-75 | Pods revenue at 300/-t(1) | – | | 37500 | | Pods a)Total |
| 0-75 | Honey " at 1/-kg (2) | – | | 1350 | | |
| 0-75 | Total revenue | 17475 | | 56325 | | 125t/ha |
| 0-75 | Net revenue | 4521 | 3841 | 35831 | 35231 | b)per yr 1.7t/ha |
| | Net discount revenue at 10% | -1446 | -2125 | 1073 | 473 | |
| | Financial yield % | 3½ | 2 | 13 | 11 | Honey |
| 0-75 | Wood revenue at 20/-per m³ | 23300 | | 23300 | | a)Total 1350kg |
| 0-75 | Pods revenue at 300/-t(1) | – | | 37500 | | b)per yr 18kg/ha |
| 0-75 | Honey " at 1/-kg (2) | – | | 1350 | | |
| | | 23300 | | 62150 | | |
| 0-75 | Net revenue | 10346 | 9666 | 41656 | 41056 | |
| | Net discount revenue at 10% | -1042 | -1722 | 1477 | 877 | |
| | Financial yield % | 6 | 4½ | 13½ | 12 | |

(1) The anticipated yield after 5 years is 2 tonnes per hectare per year.

(2) The yield of honey is conservatively estimated at 20kgs. per hectare per year. after 3 years.

The full labour budget for such a scheme is given later, but on average, such a project will employ about 2.2 people even ten hectares over it's lifetime starting at 2 people per 10 hectares in the first year and finishing with 2.2 people per 10 hectares in the final year. So such a plantation scheme has a considerable job creating potential. For a modest capital outlay of about Kshs.2580 one job will be created in the establishment, felling or pod-picking sections of the



holders found that fuelwood was the most profitable crop and so, much of the land around Addis was converted to plantations. This enterprise ensured that the capital of Ethiopia at last settled in one place. Previously it had moved several times when the economic supply of fuelwood became exhausted.

A successful government fuelwood plantation is around Mbeya in southern Tanzania, but now this is too small to meet the town's requirements and is need of expansion, but the idea of peri-urban fuelwood plantations is not new and has been profitable around a number of towns. In Kenya it is envisaged that all the main towns would have such plantations around them, but at the same time, people and organisations should be encouraged to plant trees in their own gardens and in public areas, not only to beautify the cities but to supply some tree products to the urban areas.

Of course Nairobi, being the largest city, is the prime candidate for such plantations. Already it has about 2100 hectares of fuelwood plantations, but this is not nearly enough. Several areas spring to mind where plantations could be sited. The Ngong hills, on the west and south sides of Nairobi national park, on the Athi plains east of the airport to near the Thika road and for the northern and western sides of the city on land designated for building, but which will not be built on for at least ten years. The Ngong hills are a water catchment for town towards Namanga but the rivers from these hills are now seasonal, thus jeopardising the continual supply of water. The south western boundary of Nairobi national park is being encroached upon and the animals will soon have no exit to the Athi plains. If this park is not to become a zoo, this boundary must be kept free of human interference. One of the best ways is to have block of trees with passages to allow animals access in and out of the park.

The Athi plains from the airport to the Thika road contain abandoned sisal estates as well as poor pasture land. The soil type is mainly black cotton soil, which is very difficult to work. These soils could be made more productive by growing nitrogen fixing trees on them such as *Prosop is* spp. These trees have protein rich pods (34-39% protein,7-8% oil) and are used as a feedstock for animal feed factories in several countries. The pods themselves can be eaten directly by the animals but the hard seed is indigestible unless it is first milled. A peri-urban plantation model has been based on this species. The assumed rotation is fifteen years as it is to be grown in an area of medium to low rainfall. Because the seeds are to be collected for milling, the plantations will have to be fenced and the black cotton soil should be first ploughed and phosphate and perhaps potassium fertilisers applied. Experiments should be undertaken to determine the best way to establish these black cotton soils. By itself, the fuelwood yield from these plantations is barely profitable, but once it is combined with animal feed and honey production, then the financial yield(internal rate of revenue) is estimated to be more than 10%. Table ten gives the costs and returns.

scheme. And of course jobs will be created in the animal feed processing, and distribution of fuelwood, feed and honey.

The Athi plain model need not necessarily be confined to peri-urban areas but it must be within fairly easy reach of the consumption centres.

5. Industrial plantations

These plantations are suggested in order to provide fuelwood to industries using considerable quantities of fuel such as agricultural crop drying(tobacco and tea). The wood-based industries(pulp and paper) and processing industries (cement). It has also been suggested that a steel industry based at the coast be built using charcoal produced near the coast. However, the large areas that are available for tree plantations are in the rain shadow and it is doubtful if such areas will produce more than $5m^3$/ha/yr. With this kind of production, an area in the region of 1 million hectareswill be needed. If it was purely a woodfuel plantation such an investment could not be financially viable. Even if such species as Prosopis were planted and the pods were collected for animal feed,the financial viability is still questionable. Also the haulage costs of the wood, charcoal and pods may also be relatively expensive and the costs and returns of the whole project must be carefully studied, otherwise, it is likely to become an expensive investment. Generally speaking, unless the yield in of the order of $10m^3$/ha/yr the income will not cover expenditure unless there are other sources of income from leaves, pods and gums etc. The main model for this industrial plantation has already been described under fuelwood plantation full cost or shamba system, however, there is another model which can be used in low-lying areas and as a peri-urban plantation around Mombasa and perhaps even Kisumu. This is based on Leuceana leucocephala in the moister parts of the coast and Prosopis spp. in the drier areas. The fuel could be grown for industry and/or household use and the Leuceana leaves and Prosopis pods for animal feed.The Leuceana leaves could also be used as a mulch. The rotation chosen is 5 years, But with collection of leaves/pods and fuelwood, starting after one or two years. Therefore, it is also envisaged that farmers would grow such crops. They could also be inter-cropped with the pigeon pea[1] or lab-lab[2] etc., but this is not considered here. Table 11 gives the costs and returns for such a model and Appendix 9 gives a detailed breakdown of these costs and returns.

(1) pigeon pea - Cajanus cajan
(3) lab-lab bean - Lablab purpureus (Dolichos lablab or Lablab niger)



Table 11 Costs and returns per hectare for an industrial fuelwood plantation (peri-urban and farm woodlot) on a five year rotation (5 rotations in all) grown in a) a high rainfall area b) a medium rainfall area in low elevation areas eg. Kisumu or the coast.
Units Kshs. Costs and returns in constant 1982 terms based on Kenya assumed costs.

| Year | Operation | High rainfall Seed | High rainfall Seedling | Medium rainfall Seed | Medium rainfall Seedling | Yield |
|---|---|---|---|---|---|---|
| | Costs | | | | | High Rainfall |
| 0-25 | Direct costs | 5034 | 5634 | 5374 | 5974 | |
| 0-25 | Overhead costs | 3200 | 3200 | 3200 | 3200 | a) Total wood |
| 0-25 | Total costs | 8234 | 8834 | 8574 | 9174 | $350m^3$ |
| | Returns | Assumed species Leucaena sp.(1) | | Prosopis sp.(1) | | b) per yr |
| 0-25 | Wood at 15/-per $m^3$ | 5250 | | 3600 | | $14.0m^3$ |
| 0-25 | Leaves at 150/-per t | 11435 | | — | | 10.0 t |
| 0-25 | Pods at 300/-per t | — | | 9375 | | c) Leaves Total |
| 0-25 | Honey at 1/-per kg | — | | 350 | | 76.2t |
| 0-25 | Total revenue | 16685 | | 13325 | | d) per yr |
| | | | | | | 3.0t |
| 0-25 | Net revenue | 8451 | 7851 | 4751 | 4391 | Medium Rainfall |
| | N D R at 10% | 958 | 358 | -670 | -1026 | a) Total wood |
| | Financial yield | 14½ | 12 | 8 | 6½ | |
| | Returns | | | | | $240m^3$ |
| 0-25 | Wood at 20/-per $m^3$ | 7000 | | 4800 | | b) per yr |
| 0-25 | Leaves at 150/-per t | 11435 | | — | | $9.6m^3$ |
| 0-25 | Pods at 300/-per t | — | | 9375 | | 6.9t |
| 0-25 | Honey at 1/- per kg | — | | 350 | | c) Pods total |
| 0-25 | Total revenue | 18435 | | 14525 | | 31.2t |
| 0-25 | Net revenue | 10201 | 9601 | 5951 | 5351 | d) per yr |
| | N D R at 10% | 1509 | 909 | -299 | -655 | 1.2t |
| | Financial yield | 17½ | 13½ | 9 | 8 | e) Honey Total |
| | | | | | | 350kg: 14kg/y |

(1) These trees would not be grown for wood alone. In that case the rotation would be ten years for the high rainfall using a more productive species or 1 - 2 years using Calliandra spp. and Sesbania spp.For the medium rainfall area the rotation would be 15 years and the returns from this rotation would only be about 5%.

As is to be expected, the higher the rainfall, the greater is the financial yield. All of the model variations except planting seedlings of Prosopis on a medium rainfall area yield more than 8 % on the money invested despite the relatively low yield of fuelwood; and of course in spite of the relatively low stumpage value of between Kshs.15-20 per $m^3$. Most of the models have shown that

even at this low price, given adequate management, the returns on invested capital is 10% or more and therefore they should be considered as viable, economic propositions. What is more, these tree planting schemes give an energy which is cheaper than all the other acceptable energy forms.

## 6. Managed near and far forests

Kenya's gazetted forest area amounts to some 1.7 million hectares, of which about 1.3 million hectares is actual forest. In addition there is about 0.1 million hectares of non-gazetted forests. Plantations account for less than 0.2 million hectares, bamboo and scrub just over 0.3 million hectares and natural forest 0.9 million hectares. The proposals in the main report suggest that slightly more than 0.3 million hectares of natural forests, scrub/bamboo or gazetted forest area that does not contain trees, be converted into fuelwood plantations. This would account for 18% of the gazetted forest and still leave at least 0.35 million hectares under tree cover. The present natural forests are hardly managed, commercially valuable trees are extracted either legally or illegally but no effort is made to encourage the regeneration of certain species.

The inventories that have been taken in the past, limit volume determination to trees of breast height diameters of 15cms. and above, and therefore the actual total stem volume growing the forest is more than what is recorded. In many areas there is a profusion of small diameter trees which have been considered as valueless, however, these do have value as fuelwood and poles. If active management took place within the high forests then much more volume could be removed without affecting the growing stock. Indeed, the growing stock volume may even be enhanced. Certain valuable species could be encouraged by selective thinning or even underplanting, and the average age brought down by removing the mature and over mature, plus the dead and dying trees. The current growing stock of trees with a diameter of 15cms. and upwards is estimated to be 175m$^3$ per hectare (stem and branch wood) or 146m$^3$/ha stem wood only and the yield 3% of this total or 5$^1/_4$ m$^3$/ha/yr ( 4.4m$^3$/ha stem wood) However, only about 1m$^3$/ha is removed as sawn logs or peeler logs. With active management, especially considering all the trees with a diameter of less than 15cms. (dbh) the yield could be at least doubled. Even if all the wood was sold only for fuel at Kshs.15 per m$^3$ this would bring in an extra income of at least Kshs. 106 million per year if all the 850,000 ha were managed, and at Kshs.20, Kshs.143 million.Of course there would be need for managers and subordinate staff to look after the forests. Somewhere in the region of 200 graduates would be required and 4000 subordinate staff. This management would cost in the region of Kshs.90 million per year, giving a surplus of Kshs.20 million. Apart from giving employment to 4200 people in the management, a further 27700 would find employment felling and extracting the wood to roadside, plus their supervisors, an estimated 1100. Then there is employment in densified wood



and charcoal manufacture and in transport, so it can be seen that management of the natural forests can meet some of the projected increase in demand for fuelwood and other wood products, and lead to the creation of a considerable amount of employment. Of course, ninety graduates cannot be trained overnight and there will also be a demand for them in proposed fuelwood plantations and agroforestry programmes, but if the intake into the university forestry school is doubled, then within ten to fifteen years the various programmes could be satisfied. A commensurate increase would also be required in the forest school at Londiani and the training of extension staff at Londiani and Egerton Agricultural College and other agricultural training centres.

The bamboo and scrub areas of just over 0.3 million hectares are the most likely areas, at least on paper, to be converted to fuelwood plantations because they generally have low stocking and low yield. However, even these areas could benefit from management. According to the Spartan Air Services/Forestry Department inventory of 1968, there are more than 200,000 hectares of bamboo, either in pure stands or in combination with trees or scrub. If this area is correct, then Kenya has a larger area of bamboo than Japan, which is estimated to have 130,000 hectares. It is not known how much bamboo is cut for fuelwood and poles, but there is no systematic management of Kenya's bamboo. On the other hand, the sustained annual yield from Japan's bamboo forests is about 275,000 tonnes or 2.24 tonnes per hectare. Of course, the Bamboo species are different, but with good management it should be possible to obtain at least 1 tonne per hectare and bamboo can be used for a variety of industries as well as being burnt. It may also be a good idea to introduce bamboo on farms, for it is a quick-grown woody plant, excellent for poles and reasonable fuel.

Therefore, proper management of the natural forests could assist in satisfying the fuelwood demand, bring into use a relatively untapped source and create job opportunities in the rural areas.

## 7. Summary of returns

Various systems have been described in this section and they can be summarised in the following table. ( 12 )

As is to be expected, the returns in the high rainfall areas are more than in medium rainfall areas and similarly, the shorter the rotation the higher the returns. In most medium rainfall areas, the anticipated financial yield(internal rate of return) or return on invested capital is below 10%, but even in these areas the return can be increased by growing trees that will yield other products such as fertiliser, fodder, honey and even food. However, when working out the returns attributed to fertiliser and fodder, as these commodities are not traded, the selling price ex-tree has had to be estimated using the price of artificial fertilisers and animal feed as standards. Therefore there is some uncertainty about these prices and financial yields.

The rotations for the various tree species vary from five years to fifteen years, but it is possible to grow some tree species on a one to two year rotation, for example, Calliandra calothyrsus, Sesbania bispinosa and S.grandiflora. These are grown at low elevation (up to 1500m) and in high rainfall areas, above 1000mm (except S. bispinosa above 550mm) in India and Indonesia. The reported yields for Calliandra are 35-65m$^3$ per ha per year and for Sesbania spp. 20-25m$^3$/ha/a. These trees also fix nitrogen and can be used as fodder. They grow from seed or cuttings and coppice profusely. No information is available about the growth of these species in Kenya, although trials have just started or are planned. If these species prove to be successful, then the returns on invested capital for wood alone may be in excess of 30% and such species will mean that yields will be obtained each year from the outset. Thus farmers, especially those living near urban centres may find it profitable to grow these trees. Also, such species seem to be excellent agro-forestry trees for the lowland areas because the leaves can be used as a mulch on the land, thus increasing agricultural yields, and as fodder/food. However, these short rotation species will not be used for costing the various schemes proposed in the main report, as information about them is rather hypothetical. Nevertheless, if they are successful they may radically change the lowland agro-forestry and fuelwood plantation practices.

Table 12 Financial yield for various tree planting and forest management models

| System - | FullCost | | Shamba | | Agro-forestry | | | | | | | | Forestry/Fodder | | | | Forestry/Fodder | | | | ManagedForest |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planting | SL | SL | SL | SL | S | SL | S | SL | S | SL | S | SL | S | SL | S | SL | S | SL | S | SL | Natural regeneration |
| Rainfall | H | M | H | M | H | H | H | H | M | M | M | M | M | M | M | M | H | H | M | M | H |
| Rotation | 10 | 15 | 10 | 15 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 15 | 15 | 15 | 15 | 5 | 5 | 5 | 5 | 40-80 |
| Selling wood only | " | " | " | " | " | " | | | | | " | " | " | " | | | | | | | " |
| SellingWood + other products | | | | | | | " | " | " | " | | | | | " | " | " | " | " | " | ? |
| Financial yield % | | | | | | | | | | | | | | | | | | | | | |
| Stumpage 15/-m$^3$ | 9½ | 4 | 11½ | 6 | 40½ | 22 | 51 | 28½ | 25 | 23 | 12 | 16 | 3½ | 2 | 13 | 11 | 14½ | 12 | 8 | 6½ | 9 |
| Stumpage 20/- m$^3$ | 13 | 6½ | 14½ | 8½ | 49 | 29 | 60 | 35 | 32½ | 39 | 17½ | 26½ | 6 | 4½ | 13½ | 12 | 17½ | 13½ | 9 | 8 | 54 |
| Area suitable for | Replanted forests Industrial ptns. Peri-urban ptns. Farm + village woodlots | | | | High potential agricultural areas | | | | Medium potential agricultural areas | | | | Medium potential peri-urban areas Medium potential farmland and Industrial ptns. | | | | Low elevation — Replanted forest Industrial ptn. Peri-urban ptn. | | | | Natural forests |

Key: S-seeds, SL-seedlings: H-high rainfall areas M-medium rainfall areas: ptn.-plantations

## Chapter IV Felling and extraction costs

The selling price of the standing tree has been stated to be between Kshs.15 and 20 per cubic metre and the forest roadside price to be Kshs.45 per $m^3$. The standing price has been fixed by the Kenya government based on the stacked cubic metre price of Kshs.11/80, but of course the roadside price is not a fixed price, it is based on the estimated cost of felling, snedding, that is removing the branches, cross-cutting into metre lengths, debarking, extracting to the roadside or pick-up point and stacking. All the above costs have been based on manual labour using bow saws and axes and head-loading the fuel to the roadside. The cutting of small diameter trees, that is, trees up to about 20cms in diameter at breast height, (dbh)(1) is most economical with correctly sharpened saws and axes. A panga, even a sharpened one, is not as good as a well balanced axe, but there are few good axes in the country at present, but also the pangas leave much to be desired for cutting wood. Nevertheless, they are universal, but an effort should be made to introduce suitable tools for cutting wood. Extraction to the roadside could be undertaken with a two-wheeled, inverted U frame - the sulkie -and tests in Tanzania have shown that this reduces extraction costs significantly and of course the extraction distance is increased. It is assumed that the wood is cut into one metre lengths for ease of handling and is debarked to facilitate drying and also to leave mineral elements on site. It is most important from a transporting cost viewpoint that as much of the water in the wood is driven off before the transportation to consumer or processing centre. It may even be economic to split the wood or even slice-chip it using a stationary engine run off producer gas. Such a process would accelerate drying and cut down the capital cost of densifying. The cost of all the above manual operations has been estimated at Kshs.20 per $m^3$ with an additional Kshs.5 for supervision and up to Kshs.5 as a profit margin. This assumes that on average $1m^3$ can be felled, cross-cut, extracted and piled in a day. These figures have been obtained from cost studies in Tanzania and observations in Brazil for a tree size of about 18cms.(dbh)(1) which is the average diameter for fuelwood trees grown on a ten year rotation in high rainfall areas, and fifteen years in medium rainfall areas. If the dbh is less than 18cms. then the cost will be more per $m^3$ and less if the average dbh of the trees is more than 18cms. Various studies have been undertaken of harvesting man-made forests and some of these studies have been collected and collated in an FAO publication( 1976 ) entitled, "Harvesting man-made forests in developing countries". This book reviews the various operations and draws production curves for felling and cross-cutting, debarking and extraction. It also gives reduction factors to apply for terrain, experience, body weight, nutritional level and heat stress. Table 13 gives the amount of wood in cubic metres that can be felled, debarked and extracted manually per eight hour day under temperate conditions using well trained people and under tropical conditions with skilled labour and taking into account the various reduction factors mentioned above. All these factors are detailed in Appendix 10.

(1) dbh = diameter at breast height - 1·3 m.

Table 13 Felling, cross-cutting, debarking and extraction of various diameters of wood in plantation grown trees using hand labour.

Crop specifications

| | | | | | |
|---|---|---|---|---|---|
| Diameter of tree | (cms) | 3(1) | 10 | 18 | 20 |
| Total volume per 1000 trees | ($m^3$) | 1.9 | 26.5 | 203.0 | 275.0 |
| Plants per hectare | (No) | 10000 | 1600 | 1600 | 1600 |
| Age of crop | (Yrs) | 1.5 | 4 | 10 | 13 |
| Average annual yield/ha | ($m^3$) | 12.9 | 10.6 | 37.6 | 34.2 |
| **Temperate countries, trained manpower** | | | | | |
| Operation | | Units $m^3$ per 8 hour day per person | | | |
| Felling, snedding and cross-cutting | | 2.05 | 3.66 | 17.17 | 20.38 |
| Debarking | | 1.66 | 3.67 | 3.67 | 3.66 |
| Extraction | a) 40 metres | 4.76 | 4.76 | 4.76 | 4.76 |
| | b) 100 metres | 2.38 | 2.38 | 2.38 | 2.38 |
| All operations combined | a) 40 metres | 0.77 | 1.32 | 2.61 | 2.73 |
| | b) 100 metres | 0.66 | 1.03 | 1.68 | 1.74 |
| Units man days per $m^3$ | | | | | |
| All operations combined | a) 40 metres | 1.30 | 0.76 | 0.38 | 0.36 |
| | b) 100 metres | 1.51 | 0.97 | 0.59 | 0.57 |
| **Tropical countries, untrained manpower** | | | | | |
| Operation | | Units $m^3$ per 8 hour day per person | | | |
| Felling, snedding and cross-cutting | | 0.78 | 1.39 | 6.56 | 7.74 |
| Debarking | | 0.78 | 1.73 | 4.10 | 4.62 |
| Extraction | a) 40 metres | 3.22 | 3.22 | 3.22 | 3.22 |
| | b) 100 metres | 1.61 | 1.61 | 1.61 | 1.61 |
| All operations combined | a) 40 metres | 0.35 | 0.62 | 1.41 | 1.51 |
| | b) 100 metres | 0.31 | 0.52 | 0.98 | 1.03 |
| Units man days per $m^3$ | | | | | |
| All operations combined | a) 40 metres | 2.87 | 1.61 | 0.71 | 0.66 |
| | b) 100 metres | 3.19 | 1.92 | 1.02 | 0.97 |

Source "Harvesting in man-made forests in developing countries." FAO Rome 1976

(1) The 3cm diameter tree was not shown on the graphs but a line was extrapolated on each to arrive at a figure.

With trained manpower under temperate conditions, trees of average diameter 18cms. could be felled, snedded, cross-cut, debarked and extracted from 40 metres up to 100 metres manually at a rate of between 2.6m$^3$ to 1.7m$^3$ per day whereas in tropical countries with unskilled labour the estimated volume for all the above combined operations is 1.41m$^3$ to 0.98m$^3$ per day. Assuming that the direct labour cost is Kshs.20 per day, this would give a cost of Kshs.7.7 to 11.8 per m$^3$ for trained workers under temperate conditions and Kshs.14.2 to 20.4 for unskilled workers under tropical conditions. It can be observed that for 3cms. diameter the estimated cost per m$^3$ is between Kshs.58 and 64 for unskilled workers in tropical countries or three to four times as much, but these latter figures were derived from extrapolating the various graphs and no actual measurements have been undertaken on small diameter trees. What is certain however is the smaller the diameter the more expensive it will be per m$^3$ to fell and extract. However, accepting these figures, if the trees were grown on farm for household use and omitting the debarking which isn't necessary for household use, then one and a quarter days per month would be required to cut and collect the fuelwood for a household of six for wood of average bhd of 3cms., and one day every two months for trees of a bhd of 18cms. Commercially, small diameter trees do not appear to be worth while and ten centimetres diameter seems to be about the lower economic limit for felling and extraction, but studies need to be done in this area.

## Chapter V The Woodfuel Route: financial cost and labour budget to satisfy demand for wood energy.

### 1. The cost of not ensuring an adequated supply of woodfuel.

The main report forecasts that there will be serious shortfalls in supply of wood energy by the year 2000. Of course in reality, supply and demand will be in equilibrium even if no action is taken to increase the tree planting, but such inaction will have serious economic and ecological consequences for Kenya. The rural population will turn to substitute biomass fuels, agricultural residues and dung after they have virtually destroyed all the tree and shrub vegetation. This will have serious effects on the soil structure and fercility. Their eating habits will change and their food intake will decline. For those people who can afford commercial fuels, paraffin, L.P. gas and electricity will be substituted for wood and charcoal. The estimated annual demand for wood energy by the year 2000 (policy case) is of the order of 30.7 million tonnes of wood of which 22.2 million tonnes will be burnt directly and 8.5 million tonnes will be converted into about 1.4 million tonnes of charcoal. The estimated shortfall of woodfuel is 10.5 million tonnes of which 7.6 million tonnes is fuelwood and 2.9 million tonnes is wood for charcoal, giving about 0.25 million tonnes of charcoal. At today's



prices in Nairobi, this shortfall is worth about Kshs.1770 million of which Kshs. 315 million would be foreign exchange. The shortfall of 10.5 million tonnes of woodfuel is equivalent to approximately 816 million litres of paraffin which in Kenya is worth about Kshs.3100 million of which Kshs. 2325 million is foreign exchange. Therefore by not ensuring an adequate supply of fuelwood the people will have to pay annually an extra Kshs.1330 million by the year 2000 for the next cheapest alternative and the country will have to find an additional US $ 188 million per year (Kshs.2010 million). Between the present day (1982) and the turn of the century, an extra US $ 1260 million (Kshs.13500 million) will have to be found to import paraffin if nothing is done to meet the demand for wood energy. This is equivalent to one year's total imports, and one and a half times Kenya's yearly exports. Also the people will have to find an extra Kshs.8930 million. As will be seen, even the lower of these two figures namely Kshs.8.9 x $10^9$ is much more that adequate to pay for the investment in forestry and tree planting to ensure that there will be adequate supplies of woodfuel by the year 2000. What is more, investing in tree planting will provide far more employment, especially rural employment, than by following the next cheapest practical alternative, namely, paraffin. So from a financial, foreign exchange, employment and ecological point of view, the cheapest and the best way is to ensure that the forecasted demand for wood energy will be met.

## 2. The wood resource policy potential and the target programme

### i total potential

Table 6.1 in the main report gives the wood resource policy potential to the year 2000 whereas table 7.3 gives the proposed national targets in order to achieve the forecasted demand for wood energy by the year 2000. A summary of these two tables is given in table 14 below and in table 16

Table 14 Potential area that could be incorporated into the energy plan

| Strategy | Potential area by year 2000 1000 ha. | Average Yield yield tonnes/ha. | Annual Yield Steady State Millions of tonnes | Annual Yield by year 2000 |
|---|---|---|---|---|
| 1. Agroforestry high potential (H.P) | 6000(1) (930)(2) | 40(25.8)(2) | 24.0 | 24.0 |
| medium " (M.P) | 1565(1) (300)(2) | 2.5(13.0)(2) | 3.9 | 3.9 |
| 2. Replanted natural forest | 400 | 21.5 | 8.6 | 7.1 |
| 3. Peri-urban plantations (H.P) | 100 | 21.5 | 2.2 | 1.8 |
| (M.P) | 100 | 10.7 | 1.1 | 0.9 |
| 4. Managed natural forests Near (3) | 500 | 2.7-7.1(5.5) | 2.8 | 2.2 |
| Far (3) | 350 | 2.7-7.1(5.5) | 1.9 | 1.5 |
| 5. Industrial fuelwood plantations | 50 | 21.5 | 1.1 | 0.9 |
| Total (forestry equivalent) | 2730 | 16.7 | 45.6 | 42.3 |

(1) This is all the area under agriculture at present for it is considered to be all potential agro-forestry land. The recommended tree cover is of the order of 20% crown cover so as a rough guide the equivalent area in forestry terms is 1.2 million hectares. Already there is the equivalent of about half this area under trees (0.6 mill. ha.) on agricultural land.

(2) This is an estimate of the forestry equivalent area of trees planted on agricultural land. All the other areas are given in forestry terms and therefore for consistency and comparison this has been done for the agro-forestry area. However, it must be stressed from a farming point of view it is the stem area not the crown area that is important : The stem area only occupies about 50 square metres per hectare at a maximum which is 0.5% of the area, a negligible amount of surface land taken up by the tree. Also, if the tree roots are deep rooting they will not interfere with the surface agricultural crops.

(3) This is the total remaining natural forest area, excluding national parks, assuming 140000 hectares are converted to fuelwood plantations and a possible 40000 hectares to industrial wood plantations for sawmwood and pulp etc. It is assumed that 260000 ha of the fuelwood plantations area (total 400000 ha) is from gazetted forest land which at present is not forested. If the [illegible]ie of the potential 400000 ha was not converted to fuelwood plantations then the po[illegible]al area for managed natural forest could increase up to a maximum of about 1 mi[illegible] hectares.

### ii agro-forestry potential

In forestry equivalent terms the potential area that could be planted or managed for fuelwood (and other wood) production is estimated to be some 2.7 million hectares. However, it must be stressed that only 250000 hectares is land that requires change of use, namely, the land for peri-urban plantations and the industrial fuelwood plantations. All the remaining area is land already under forestry or farming land where intensive agro-forestry practices are recommended. Planting the right kind of tree species at the correct spacing on agricultural land will not interfere with the agricultural crops, rather they should enhance them by protecting the microclimate, stabilising the soil, green mulching and pumping up mineral elements, via the leaves, from lower soil horizons that have been lost to the surface (agricultural) crops. The whole point of agro-forestry is to increase the total output on a given piece of land by tapping all the soil and water horizons and taking advantage of the year round favourable growth conditions which trees and shrubs are able to do. Of course the potential area for agro-forestry is by definition all the land presently under agriculture plus new land which may be brought into agriculture which includes some of the existing land classified as forest.

### iii present forest area in Kenya

The area of closed or high forest in Kenya today is about 1.39 million hectares of which 0.16 million hectares are plantations. Most of this forest area is owned by the government and controlled by the forestry department but 0.20 million ha. is outside the control of the forestry department. A total of 1.64 million hectares of land is gazetted as forest area but 0.45 million hectares of this total is in other use or carries very little tree cover on it. Table 15 gives a breakdown of ownership and use of the forest land in Kenya.

Table 15 Forest land in Kenya - ownership and use (1980)[1]

Units: million hectare

| Land type/ownership | State forest service (Gazetted land) | National parks | Private land Trust land City Council land | Total by type |
|---|---|---|---|---|
| Natural Forest[2] (closed forest) | 1.04 | 0.06 | 0.13 | 1.23 |
| Plantation Forest | 0.15 | — | 0.01[4] | 0.16 |
| Sub Total | 1.19 | 0.06 | 0.14 | 1.39 |
| Land in other use or[3] Land with little tree cover | 0.45 | — | — | 0.45 |
| Total by ownership | 1.64 | 0.06 | 0.14 | 1.84 |

(1) Forest areas of 10 hectares and upwards.
(2) This does not include open woodlands (miombo woodland) and trees on savanna areas.
(3) Gazetted forest land only
(4) Mainly eucalyptus for tea drying and wattle for tannin production.

Source: R.Doute et al. A forest inventory of Kenya using remote sensing techniques Kenya Rangeland Ecological Monitoring Unit( KREMU ). Technical Report N°30 March 1981 Box 47416 Nairobi Kenya

iv) Managed natural forest potential

Most of the natural forests are not managed. Valuable commercial trees are cut legally or otherwise within these areas and are either hand-sawn or taken to the sawmills or plywood factories. The rural people are also permitted to collect fuelwood from dead branches and trees, but in some areas young saplings and bamboos are illegally cut for fuels and poles. The estimated annual yield from these areas varies between $3m^3$ and $5m^3$ per ha. However, if these areas were brought under management, this yield could at least be doubled by felling over mature trees, fertilising all species and by reducing the rotation age. The data given in the appendix to the main report, entitled "An inventory of biomass in Kenya", limited the volume estimation to trees greater than 15cms. in diameter (dbh). There are many young trees with diameters less than the minimum 'inventory diameter' and therefore the total volume given in the report is most likely an under-estimation. Also, many of these small diameter trees should be thinned out and would make excellent fuelwood and poles. However, all these measures require management practices to be introduced into the natural forests and for this there must be



trained manpower, but the potential for management by the year 2000 is all the area still remaining under natural forests. It is proposed to convert some of the natural forest to plantations, both for fuelwood and industrial wood. Of course by the year 2000 some natural forest will have been converted to other land uses especially for agricultural production, it may be of the order of 120000 hectares or 10% of the natural forest area, outside the national parks. However, there should be remaining, about 850000 hectares of natural forest which could be managed intensively.

v. replanted natural forest potential

Table 14 gives the potential for replanted high forest to be 400000 hectares. In addition, about another 40,000 hectares will be needed for industrial wood products such as sawnwood and pulp. The reason for proposing the conversion of natural forest to plantations is that a plantation will yield about six times the volume and on a shorter rotation, than the unmanaged natural forest it replaced, or three times the volume if the forest were managed. By converting the natural forest to plantations some of the pressure that is at present being put on these forests will be taken off, for the plantations will supply the products most in demand, namely, fuelwood and poles. Also, plantations act as an encroachment barrier, discouraging squatting and illegal felling. Because they are more productive, plantations will generate more employment and lead to the establishment of energy industries such as charcoal and densified wood production. Therefore, by converting about 17% of the natural forest into plantation forest(200,000 ha) it should be possible to preserve the remaining 850,000 ha of natural forest albeit under proper management. The remaining area to satisfy the potential plantation area of 440,000 ha,-240,000 ha could come from the 450,000 hectares of gazetted forest area that has little tree cover on it or is at present in other use. Some of this land may be illegally farmed at present and it may be impossible to remove the people. Therefore these people should be given permission to stay provided they plant and maintain a certain number of trees per hectare (say 240) in various agro-forestry systems. These farms could then be turned into demonstration plots for other farmers to learn from. Likewise if 120,000 hectares of natural forest is to be converted to agricultural use, a condition could be laid down that a certain number of trees have to be left, or a certain number planted. Such measures should ensure the self sufficiency of the farms and thus relieve the pressure on the forest. Also it is an excellent method of winning the people over to protecting the forests and co-operating with the foresters.

vi. peri-urban potential

The schemes mentioned so far to satisfy the demand for wood energy, do not envisage a change of land use, however the proposals for peri-urban plantations and industrial fuelwood plantations do require such a change. Table 14 envisages a potential of 200,000 hectares of peri-urban plantations which would be situated

around towns and cities in order to meet some of their wood energy requirements. These plantations would at the same time act as a green belt to prevent a continuous spread of urban development and give cities a 'lung' where the urban people can go and relax and breathe unpolluted air. The government may have to pass laws to enable city authorities to equire land for such plantations and there may be opposition by the landowners, for an area of land for forestry commands a much lower price than if the land was to be developed for housing or industry. But this is one positive way the government could improve the quality of life for the urban dweller. Also, even if land was designated for development but this development was not proposed for about ten years, then the area could be planted with trees, most of which would be felled when the land was required but some trees could be left so that the site would have mature trees on it, say one or two in each garden and avenues of trees along roads. The bulk of the peri-urban plantations would be around Nairobi and this area has much land that could benefit from tree planting - the Ngong hills, round part of the Nairobi National Park and on the Athi plains. As mentioned previously, these are areas either important for water catchment/wildlife preservation or of low agricultural value, and because of the black cotton soil may be expensive to develop as building land. There are areas near many of the other major towns where the soil is very fragile and needs protection, for example in the hills on leaving Mombasa, near the Menengai crater at Nakuru to supplement the existing plantations, and on the escarpment just outside Kisumu. Each town and city council could identify areas near to or within their boundaries that could be planted with trees. They could encourage individuals and organisations to plant in small gardens and on small plots as well as themselves planting along roads and in public places. However, they should receive encouragement and guidance plus help from the various involved ministries. Therefore, although the suggestion to plant peri-urban forests may be contentious, it could improve the quality of life for the urban dweller, provide employment and reduce the demand for wood energy because wood/densified wood burnt directly is more economical on the demand for trees than is charcoal. This important arguemant should not be overlooked.

vii industrial plantation potential

The case for wood energy plantations to supply some of the requirements for industry should not be as problematic as peri-urban plantations. Already several industries are using wood fuel such as the lime, pottery, tea, tobacco, wood processing and even the sugar industry, although bagasse,(cane waste), is the main boiler fuel for this latter industry. Other industries have shown interest in using woodfuel, namely, the pulp/paper mill at Webuye and the cement factory at Athi river. It may also be one cheap form of rural electrification by having small wood-fired power stations supplied from industrial fuelwood plantations on the doorstep. A number of studies have been undertaken to show that woodfuel can more



than compete with fueloil and coal except perhaps at the coast near the refinery or port of delivery for coal. The further one moves inland the greater the advantage woodfuel has,provided it is grown in close proximity to the user and in areas of reasonable rainfall. Therefore the existing woodfuel-using industries should be encouraged to become self sufficient in their demands for wood energy and studies should be undertaken, say around Athi river, to determine what kind of yields can be expected from this medium-low rainfall area, what establishment methods are required to grow trees and most importantly,the worth of it. Table 14 estimates the potential area for industrial fuelwood plantations is 50,000 ha of land in high rainfall areas. Of course, the equivalent in medium rainfall areas would be approximately twice as much, but even so there should not be all that much difficulty in finding such areas of land because all the industries mentioned above are rural based, hence the competition between the various land uses are less.

viii target programme

The potential annual yield,from table 14, is of the order of 46 million tonnes and by the year 2000, if the planting was undertaken at a fairly uniform rate, it would reach over 90% of this potential, namely, 42 million tonnes. However, if all the policy proposals, as outlined in the main report, are undertaken to conserve energy both on the supply and demand sides, then the estimated requirements for woodfuel to fill the demand gap is approximately 22 million tonnes, or about half the quantity that it is felt could be achieved if the potential is fully realised. Therefore, there are an unlimited number of combinations that could be applied to achieve the target and table 16 is one such combination which brings in an element of each of the five strategies.

Table 16 Wood project policy case national targets.

| Strategy | Proposed area by year 2000 1000 ha | % of potential Table 14 % | Annual Yield Steady State Millions of tonnes | Annual Yield by 2000 |
|---|---|---|---|---|
| 1. Agro-forestry | | | | |
| 'high potential' (H.P.) | 2661(410)(1) | 44 | 10.6) 11.5 | 8.2) 8.9 |
| medium potential (M.P) | 360( 70)(1) | 23 | 0.9) | 0.7) |
| 2. Replanted natural forest | 306 | 76 | 6.8 | 4.4 |
| 3. Peri-urban plantation-H.P. | 80 | 80 | 1.7) 2.7 | 0.8) 1.2 |
| -M.P. | 85 | 85 | 1.0) | 0.4) |
| 4. Managed natural forest Near(2) | 260 | 52 | 1.6 ) 2.7 | 1.6) 2.7 |
| Far(2) | 180 | 51 | 1.1 ) | 1.1) |
| 5. Industrial fuelwood plantation | 39 | 78 | 0.9 | 0.8 |
| Total (forestry equivalent) | 1430 | 52 | 24.6 (3) | 18.0 (3) |

(1) Forestry equivalent areas but planted in such a way as not to interfere but rather enhance the agricultural and pastural crops.

(2) The most productive parts of the natural forests are managed in preference to the least productive parts, hence the average sustainable yield of 6.1t/ha per year is higher than the average shown in table 14. There are no yield differences between 'near' and 'far' natural forests. This distinction relates the distance to the consumer.

(3) These figures differ somewhat from the figures given in the main report because slightly different conversion factors have been used and the rate of planting per year may differ although the total by 2000 is the same.



In the proposed targets for achieving an adequate supply of woodfuels from sustainable yield, more emphasis has been placed on schemes that have already been tried, than schemes that are in the developmental stage, hence the relatively low targets as compared to potential for agro-forestry and natural forest management. It is known how to establish and manage fuelwood plantations, but even though farmers do plant trees on their land the most effective agro-forestry systems have yet to be developed. Also, management of natural forests is more difficult than plantation management and very little emphasis has been given to their management in the past. Nevertheless, although in percentage terms, agro-forestry and natural forest management receives less emphasis than plantation schemes, in absolute terms they will supply most of the fuelwood and so the greatest effort has to be put into these two strategies, especially seeing that they will supply the bulk of the rural energy, either where the demand is or within a short walking distance, thus relieving the women and children of a considerable burden.

There is nothing sacrosanct about the targets given in table 16, the different strategies can be varied, but in order to achieve a balance of sustainable yield(supply) and demand by the turn of the century, a target of 22 million tonnes of woodfuel from the various strategies must be aimed at.(1) The various costs per hectare and the anticipated returns have already been given in section 3. These costs can now be used to give a total cost and manpower budgets.

## Chapter VI.

## Cost and manpower budget of the woodfuel project policy case

### 1. Introduction-

When building up the cost and manpower budgets for the various components of the woodfuel project policy case the models described in chapter 3 and Appendices 5-9 have been used. These models give anticipated costs and returns by year on a per hectare basis. Also, usually more than one option is given for each model, for example, whether tree seeds or seedlings are planted. Using this information, total costs and returns have been worked out using each option. It is assumed that the planting targets, as given in table 16, are achieved by the year 2000 and the initial planting, or in the case of the shamba system, tree clearing, starts in 1983. While all the target planting programme is completed by the turn of the century, the model has been continued until the 25th or 26th year, that is, 2007 or 2008 to illustrate how costs, returns and employment build up. In all cases, the anticipated cumulative returns are greater than cumulative costs by 2008, although for the short rotation crops returns usually exceed the costs before the year 2000. Before giving a summary of the total cost of the policy case the individual

(1) In fact with the strategy as outlined in table 16 it will be 2003 before this target is achieved.

components will be described separately.

2. Agro-forestry budget - high potential area

It is proposed to bring under intensive agro-forestry over 2.5 million hectares by the year 2000. That is not to say that the remaining area of high potential land, just under 3.5 million hectares, will be neglected. On the contrary, it is assumed that a sufficient effort will be made by the farmers on these latter areas to at least maintain the existing tree capital, but it is assumed that a substantially increased wood yield will be confined to the former area. In order to achieve the production target set out in table 16, the farmers have to be motivated through the provision of the most suitable tree species and the introduction of appropriate agro-forestry systems for each farm type. This will mean that an agro-forestry extension service has to built up and most importantly, provided with means of transport to visit the farmer. It is assumed that the farmer will provide labour free and of course obtain the wood products free of charge. However, because the use of wood energy saves the country a considerable amount of foreign exchange, a case can be made out to give a planting grant and a management grant to the farmer who successfully plants and maintains the appropriate tree species in the described agro-forestry system. Such grants may be open to abuse, but it is the cheapest way to rapidly increase the tree population on farm land, bringing about soil stabilisation, better water retention and improved micro-climate. What is more, the firewood collecting burden for the women and children should be eased considerably once sufficient fuelwood is grown on farm and this could lead to improved welfare. A planting grant in the order of Kshs.20 per hectare of agricultural land may act as sufficient inducement for farmers to plant and maintain 240 tree seedlings per hectare. If the planting was successful then a further Kshs.20 per hectare could be given when the trees were two years old, just before the first yield is obtained. If farmers also plant woodlots on areas that are of not much use for agriculture then a planting grant of Kshs.100 per forest hectare could be given, followed by a maintenance grant of Kshs.100 when the trees are two years old. This would require a competent and mobile extension service but it would act as a catalyst to provide better agricultural and agro-forestry practices. The suggested tree species for such agro-forestry systems are ones that do not interfere very much with the agricultural crops and these are described fully in the appendix on agro-forestry. Most of them will provide nitrogen, phosphorus and potassium fertiliser (NPK) for the agricultural crops, essential elements for healthy and productive crop growth. Appendix 7c estimates that at least 15Kgs. of available nitrogen, 3Kgs. of phosphorus and 14 Kgs. of potassium could be added to every hectare each year if branch mulching was practiced with such species as Leucaena leucocephala. So the farmer and the country has much to gain by encouraging tree planting on farm, for there should be enhanced crop production [illegible] to foreign exchange saving on fertiliser inputs. In the model it is assumed that such inputs are worth Kshs.20 per hectare per year to the farmer, but this is a very conservative estimate of the true worth of the fertiliser. In fact the fertiliser value may be as high as Kshs.200 per hectare.

Appendix 11b & c gives the costs and returns of the proposed agro forestry scheme in high rainfall areas assuming tree seeds and tree seedlings are planted respectively and assuming assuming the farm labour is costed at Kshs.20 per 8 hour day, the supervisory labour is costed at the appropriate government rate, depending on qualification and experience. It is further assumed that the trees have a standing value of between Kshs.15 and 20 per $m^3$ and that the fertiliser input is worth Kshs.10 per hectare/year (1)(2). Given the above assumptions and taking the area planted to agro-forestry/woodlots as per Appendix 11b, then all costs would be covered by 1990 or 1991 and of course this would be one or two years earlier if it is assumed that the government covers such costs as seed provision and extension work. If seedlings rather than seeds were planted this would increase the costs both to the farmer and the government, and the returns would also be increased but only marginally. In this case costs and returns would be recovered between 1993 and 1995, and by 1990 if the cost of seedlings and extension work are excluded. By the year 2000, the estimated total cost from planting 2661,000 hectares would be in the order of Kshs.54 million if tree seeds were planted and Kshs.957 million if seedlings were used. The respective yield per year this date would be 13.0 and 13.2 million $m^3$ (8.1 and 8.2 mill. tonnes air dry), which should be sufficient fuel (and poles) for about 8 million people. Once the scheme has achieved a steady state, the annual cost will be in the order of between 51 and 64 million shillings for the 2661,000 hectares under agro-forestry/woodlot management depending on whether seeds or seedlings are planted but the returns will be in the region of Kshs.270 million to Kshs.360 million, assuming the value of the wood is between Kshs.15 and 20 per standing $m^3$. The steady state annual yield is estimated to be 16.4 to 17.0 million $m^3$ (10.2 to 10.6 mill. tonnes). However, if the farmers costs and returns are neglected, then by the year 2000 the cost to the government will be between Kshs.million 332 and 555 and the returns will be the savings through soil stabilisation and the saving of foreign exchange cost for substitute fuel for the 8 million tonnes of wood plus 201,000 t of N, 40,000 t of P and 188,000 t of K. The foreign exchange saving of this quantity of fertiliser could be in the region of Kshs.1900 million. (see Appendix 7c) So, on the fertiliser saving alone, the returns far out weigh the cost to government, another strong argument in favour of giving a subsidy to farmers to encourage intensive agro-forestry systems.

1) This may be underestimated by as much as a factor of 10 (see app 7c.)
2) The model assumes that for every 2 ha of farm, one ha. is planted under an agro-forestry system and on the ha. 2 ha of woodlots are planted. There are also [illegible] on each ha. The tree species in the woodlot may not be nitrogen fixers here [illegible] for dividing the estimated income from fertiliser on farm land by two - see app [illegible]

What is the labour budget of such a system? Appendix IId gives the labour requirements each year from 1983 to 2007 plus the labour requirement when the system is in a steady state. For convenience, the labour rquirements have been divided between farm and tree nursery/extension work. The extension labour requirements have been sub-divided into different grades of people, namely, university graduates, college agro-forestry graduates and office staff. In a steady state, about 130,000 man years (1) are required to fell, cross-cut, carry and stack the 10½ million tonnes of woodfuel (and poles), and some 3,000 to 4,000 man years are required to plant and maintain the 2661,000 hectares, depending on whether seeds or seedlings are planted. This means on average for each hectare of agricultural land 3 hours per year will berequired to look after the 340 trees and 106 hours per year needed to fell, cross-cut, extract and stack the four tonnes of wood. If the average family size is six, and assuming present use conditions, then each family would require about 1½ hectares of land under intense agro-forestry/woodlot systems to be self sufficient in woodfuel (and poles) and on average, 4½ hours would be required per year to tend the trees and 159 hours to fell and collect the fuelwood. This is the equivalent of just over 3 hours per week( or just under ½ an hour per day) and should result in a considerable saving of time and effort compared to the norm for firewood collection today. Thus, even though over 130,000 man years will be required to obtained the 10½ million tonnes of firewood, this is probably half of what is needed today and therefore the farmer and his family will gain tremendously from such a system.

If tree seedlings as opposed to seeds are provided for the agro-forestry scheme on high potential land to supply the 2661,000 hectares, assuming that the trees are raised in nurseries off farm, then about 850 people will be employed on average each year to raise these seedlings. Of course, it only takes about 3 months to raise the seedlings and therefore 3,440 people will find temporary employment each year for quarter of a year. However the extension people could work all the year round and about 70 university graduates, 700 college graduates and 630 office staff would be required to maintain such an area of agro-forestry. This means that each college graduate would cover an area of just under 4.000 ha of farm land, or in the order of 2,000 farms. Of course to back up the extension worker there would be demonstration units, short courses for farmers, literature and radio broadcasts. Also it would be of great use if agriculture, forestry and agro-forestry could be taught in schools and this would mean that such subjects be introduced into the teacher training courses. Perhaps every rural school should

(1) It is assumed that there are 270 working days per year.



have a shamba (vegetable plot) and be encouraged to plant trees around the school and raise seedlings in the school nursery.

To reach a goal of 2661.000 hectares of agro-forestry/woodlot systems by the year 2000 in high potential agricultural areas, particularly Central, Nyanza and Western provinces could go a long way to meet the requirements for wood energy at the place where it is consumed, namely, on farm. Such a target will require government or aid agencies to invest a considerable amount of money into the extension services, somewhere in the region of 38 - 46 million shillings per year (1982 constant price), however the benefits to the rural population in time saved, soil stability and increased farm production and to government in saving of foreign exchange are immense and far outweigh the costs.

## 3 Agro-forestry budget - medium potential area

The project policy case calls for 360,000 hectares in medium potential agricultural areas to be brought under intense agro-forestry/woodlot management by the year two thousand. Appendices IIe & f give costs and returns for the above scheme to the year 2007, while Appendix IIg gives the manpower requirements over the same period. The total cumulative costs by 2000 comes to some Kshs.68 or Kshs.127 million, depending on whether seeds or seedlings are planted, of which Kshs.43 or Kshs.77 million will be for extension work and nursery costs. It is most likely that a combination of seeds and seedlings will be used, therefore the above represent the cost boundaries. The anticipated yield by 2000 is approximately 10½ $m^3$ py( 7 million tonnes) and by this year, cumulative returns will exceed cumulative costs. In a steady state the yearly cost, where seeds are planted, is estimated to be some Kshs.5.1 million for the 360,000 ha of which extension service costs will be Kshs.3.6 million. If seedlings are planted, then the yearly cost will be Kshs.7.1 million of which, Kshs.4.5 million are for extension and nursery work.

The labour requirements ( Appendix IIg ) for the farmer, when the scheme has reached a steady state, amount to between 10,400 and 10.900 man years depending on whether seeds or seedlings are planted and the anticipated steady state volume production is about 13.5 million $m^3$ py( 9 million tonnes). 2.4 hectares are required to meet the family requirements for fuelwood (and poles) and this will require about 149 man hours per year to fell and extract the wood and a further 7 hours to tend the trees, or in total 3 hours per week or in productive labour value terms, Kshs.7.50 per week. The number of nursery workers amounts to 114 and extension staff to 190, of which an estimated 10 are university graduates, 95 college graduates and 85 office staff with the college graduates in charge of

just under 4000 hectares.

The policy case envisages that together the agro-forestry schemes will meet about 60% of the proposed target and of course this will not require a change of land use,only a more rational and intensification of it's use.

## 4. Replanted forest budget

After agro-forestry,the replanted forest option is the most important proposal in terms of the provision of woodfuel.There is also the most certainty about the costs and yields for they are based on well-tried practices,unlike agro-forestry where very little recorded cost and yield data are available.The output from these woodfuel plantations will,in the main,meet the demands of the urban populations and industry although some will be for rural household and cottage industry use.The woodfuel project policy case proposes to plant 306,000 hectares principally from gazetted forest lands,of which 1 million hectares can be classified as closed natural forest and and half a million hectares as land with little tree cover or land in other use (table 15). Therefore,it is theoretically possible to obtain all the proposed area from gazetted forest land that does not have closed natural forest on it.However it is uncertain what the current use of this land is and so it has been assumed that when compiling the budgets,half of the proposed area would come from closed natural forest and half from gazetted forest land with little or no tree cover.It is also assumed that the closed forest has a standing stock of 150 $m^3$/ha and therefore on average each hectare,when being prepared for replanting will yield 75 $m^3$,most of which could be used as wood fuel;thus there will be production( and income) right from the start of this option.Appendix 12 gives the cost/return and labour budgets for the full cost replanted forest option and Appendix 13 gives a similar budget,but assuming that the 'shamba'system is employed to replant the forest.

By the year 2000 the cumulative total cost for replanting 306,000 hectares ( full cost option) is some Kshs.858 million and the anticipated annual volume production in 2000 is 4.2 million $m^3$ ( 3.0 million tonnes) from the new plantation and 1.9 million $m^3$( 1.4 million tonnes) from clearing the forest. Of course from 2001 onwards,no more volume will come from clearing but the plantation volume will build up rapidly to 10.6 million $m^3$ by 2007 and then decline to a steady state volume of 9.5 million $m^3$ ( 6.8 million tonnes).If the wood is sold standing at Kshs.20 per $m^3$ and excluding the income from the sale of wood from the clearing operation,then cumulative costs will be covered by cumulative revenue by 2005.At Kshs.15 per $m^3$ cumulative revenue will cover costs by 2008, and in a steady state condition the costs will be Kshs.50 million per year and



the revenue Kshs.143 to 191 million,depending on whether the standing value is Kshs.15 or 20 per $m^3$.

Turning to employment,(Appendix 12 b) the planting of 306,000 hectares will create employment for nearly 40,000 people directly working the forest, of which 38,000 people will be in thinning and felling and 2000 raising seedlings, planting and tending.In addition,a further 3300 people will be required for supervision,so total employment is in the region of 43,300 when the plantations reach a steady state.An estimated 165 university graduates will be required to run such a proposal together with 1650 college graduates,foremen and maintenance staff,plus 1490 office staff,so apart from helping to solve Kenya's energy crisis,the proposed planting programme generates a considerable amount of new employment.Other jobs will be created in woodfuel manufacture for example, charcoal and densified wood production as well as in distribution and trading of the woodfuel products.

The Shamba system (Appendix 13) is a variation of the replanted forest proposal,but instead of planting the forest immediately after the land has been prepared,farmers are allowed to plant agricultural crops for four years,provided they undertake the land preparation themselves excluding of course,the felling of the existing natural forest.In the fifth year trees are planted together with their crops and a final agricultural crop is planted in the sixth year,with the farmers undertaking the weeding of the tree crop free of charge. Thus the establishment costs are cheaper than in the 'full cost' method. By the year 2000 the total cumulative costs( Appendix 13a) amount to Kshs.639 million and the anticipated volume production is 4.8 million $m^3$ ( 3.3 million tonnes). There will be no volume production from clearing as all the area would have been cleared by 1996,but the steady state volume production will be the same as in the previous case namely,9.5 million $m^3$ ( 6.8 million tonnes). The steady state expenditure for the 306,000 hectares will be Kshs.40 million per year and the income Kshs.143 to 191 million plus Kshs.350,000 from farmers rent for the use of the land.

The same amount of people will be employed in thinning,felling and supervision but slightly fewer people will be employed in the establishment and tending operations (Appendix 13b) as the farmers will be undertaking clearing and weeding.When the steady state is reached 42,600 people will find full time employment,some 700 less than in the full cost operation.But it will give employment and food production to farmers who will be able to farm 306,000 ha.for a total of six years.

5. Peri-urban budget -ihigh potential low elevation area

As stated previously, the reasons for having fuelwood plantations near to the urban consumer is to try to persuade people to burn wood directly instead of charcoal, to provide some employment to the urban people, to have a green belt around towns which can be used as a recreation area, and to prevent erosion on fragile soils near towns.

If people are going to burn wood directly for cooking then efficient and acceptable stoves will have to be introduced and also the fuelwood will have to be marketed in convenient sizes ready for use. With regard to employment, two of the peri-urban schemes have an animal feed component incorporated in them and this not only improves the economics of the proposal but nearly triples the employment. It also means that animal feed factories will have to be established, and perhaps densified wood factories to prepare the wood in a convenient and presentable form. The combined fuel/animal feed proposals need not necessarily be confined to peri-urban area. In fact it may be advisable to introduce them into some of the replanted forest schemes. However, a study should be made into the demand for animal feed, and the forest gate price of protein rich fodder to confirm if the assumption made about prices and markets in this report are correct. The peri-urban proposal has been divided into three schemes, namely, high potential areas at both low and high elevations and medium potential area principally on the Athi plains around Nairobi. All these schemes require a change of land use.

The low elevation high potential proposal covers an area of 5000 hectares and is suggested for land around Mombasa and perhaps around Kisumu (Appendix 9). This is a combined fuelwood/fodder project on a five year rotation. It is envisaged that the ground would have to be ploughed and fertilised with phosphate fertilisers and fenced to keep out cattle, sheep and goats. By the year 2000 the anticipated cumulated cost is Kshs.18 million and the annual yield of wood is 94,000 $m^3$ ( 59,000 tonnes) and fodder is 15,000 tonnes( air dry). If the leaves can be sold at an 'on tree' price of Kshs.150 per tonne then the cumulative returns should be between Kshs.23 and 25 million, depending whether the stumpage price for the wood is Kshs.15 or 20. Also, returns would be covered by 1998 assuming that the first planting of 1000 hectares starts in 1990. In a steady state the annual cost will be Kshs.1.2 million and the returns between Kshs.3.3 and 3.7 million from 70,000 $m^3$ ( 44,000 tonnes) of wood and 15,000 tonnes of fodder.

The above scheme will employ nearly two thousand people of which 1200 will be required for fodder collection, 600 for thinning and felling, 40 for plantation establishment and maintenance and 55 for supervision. By introducing a fodder component into the fuelwood scheme the employment possibilities have been enhanced considerably giving full time employment to one person for every three hectares as compared to one person per seven hectares for a fuelwood only scheme.

5. Peri-urban budget -ihigh potential high elevation area

This scheme is a conventional fuelwood plantation project without any fodder component for there is some uncertainty about fodder tree species suitable for high elevations. Several have been proposed in the agro-forestry appendix report but little information is available on yields. It is proposed to plant 75,000 hectares by the year 2000 and the cumulative cost by that year will be Kshs.116 million ( Appendix 14c). The anticipated annual volume production by 2000 is 1.0 million $m^3$ (0.7 million tonnes). Cumulative returns are estimated to cover cumulative costs by between 2005 and 2007 and in a steady state the annual cost will be Kshs15 million per year and the returns between Kshs.35 and 47 million for the two stumpage prices (Kshs.15 and 20)

It is estimated that just less than 10,200 jobs will be created, 8,800 in thinning and felling operations, 500 in establishment and tending and 800 supervisory. This works out at one person being employed for every seven hectares.

5 Peri-urban budget-iimedium potential area

Like the low elevation project, this scheme is a combined fuelwood/fodder project but in addition the production of honey is also envisaged because the species suggested Prosopis spp is an excellent one for honey production. It has been proposed to plant 85,000 hectares by the year 2000 and the estimated cumulative cost in that year ranges from Kshs.334 to 385 million depending whether seeds or seedlings are planted( Appendix 14 e and 14g). The anticipated yield by 2000 is 0.6 million $m^3$ ( 0.4 million tonnes) and this will reach a steady state of 1.3 million $m^3$ ( 1.0 million tonnes). The cumulative costs will be covered by cumulative returns between the years 2001 and 2003 and in a steady state the annual costs will be between Kshs.21 and 22 million depending on whether seeds or seedlings are planted. The coresponding income is, for wood Kshs.20 to 24 million(Kshs.15 or 20 stumpage price), for fodder Kshs.43 million(142,000 tonnes of pods) and for honey Kshs.5 million( 1530 tonnes).

The estimated employment for the 85,000 hectares in a steady state is between 18,500 and 18,700 of which 11,500 are for pod collection, 400 for honey

collection,5,000 for thinning and felling,between 300 and 400 for planting and tending and 1300 for supervision. Again,when fuel and fodder production is combined,the employment possibilities are increased.In this particular scheme one person is employed per 4½ hectares.

## 6. Managed natural forest budget

There are about 1.2 million hectares of natural forests remaining inKenya out of which 1.0 million ha.is gazetted (protected) forest.However,as explained previously there are another 0.5 million hectares of land that is gazetted but which now carries little or no tree cover on it or is in other use.Formerly, most of this land must have been forested and one reason why the trees have been cleared away is that very little,if any,management was practised and so the rural population treated the trees as expendable commodities.Also,with an ever increasing pressure for more food production it is understandable that under-utilised resources come under attack.In order to increase farm and forestry production it is necessary for Kenya to increase it's unit production rather than expand into marginal farming areas and the few remaining areas of forest land.Agro-forestry is a means of increasing tree production on farm land without reducing the agricultural output.Indeed,if green mulching is practised,and the inputs of fertiliser are as predicted,then the agricultural output should increase.It has also been suggested growing tree species that produce food and fodder as well as wood thereby helping to solve more than one problem at once.. But it is expedient and most likely necessary to start managing the natural forests if they are to be saved from further destruction.Such management will also ensure that they fulfill their primary functions of water catchment,soil conservation and a store of genetic material.As a further insurance,a man-made barrier in the form of plantations around the lower boundaries of the forests, acts as a physical ,if not a psychological barrier to the rural population,who wish to clear the fringes of the forests for agricultural production;the replanted forest area,as suggested previously,could form this barrier.

Nevertheless,the demand for wood products,especially fuelwood,is going to put increasing pressure on all tree resources and therefore,instead of waiting for the trees to be cut randomly and usually to an excessive degree,it is far better and more productive to practice controlled thinning and felling by removing the dead and dying trees and thinning excessive regeneration,especially of so-called non-commercial trees,in order to give the remaining trees room for growth.Given good management,the volume removed from natural forests,both of trees and bamboo, may be at least double,while maintaining if not increasing the growing stock, especially the growing stock of more valuable trees.

While all the remaining natural forest is potentially manageable,management systems have to be developed and ,as in the case of agro-forestry,people have to be trained to manage these areas with very little practical experience to rely on.Therefore the policy programme suggests that about half of the natural forest -440,00 hectares be brought under management by the year 2000.Such a programme may cost in the region of Kshs.417 million by 2000 but the cumulative income should be between Kshs.533 and 710 million if it is assumed that the stumpage price ranges from Kshs.15 to 20 per $m^3$.However,it is anticipated that about 20% of of the wood will be commercially valuable timber which should command a much higher stumpage price.In a steady state the annual cost would be Kshs.44 million and the returns 56 to 75 million ( Appendix 15a) based on fuelwood stumpage prices.Management of the natural forest would not only entail taking out more thinnings and fellings,but just as importantly,practicing whole tree utilisation.At the present,the timber merchants only pay for what they remove from the forest and many of the merchants leave over half of the felled volume behind.Therefore by better utilisation,a much larger off-take can be achieved.This could happen if the people cutting the tree had to pay for what they felled rather than what they removed.Equally this statement applies to the plantation as well as the natural forests.There are also many plantation forests that are under thinned and therefore the age of reaching commercial exploitability is prolonged and also early yields from thinning are forfeited.

The key to better utilisation and larger off-takes is good management and it is estimated that in order to manage the 440,000 hectares,about 2,700 people will be required,of which 130 will be university graduates,1340 college graduates and 1200 office staff.This means that one college graduate would be in charge of approximately 330 ha. and a university graduate,ten times that area. (Appendix 15b) In addition,13,900 people would be required to annually fell and extract 4.6 million $m^3$ of timber of which an estimated 3.7 million $m^3$ (2.7 million tonnes) may be fuelwood.It is also possible to exploit the natural forests for other forest products for example,honey,herbs,medicine,fibre,food and natural extracts from trees such as gum and resin.Only by undertaking research into what products the forests can yield will the forest service discover if it is worthwhile to utilise these so-called minor forest products.In several countries pines are tapped to give rosin and resins.Rosin is a necessary additive for paper making and instead of Kenya importing rosin for the pulp and paper mill,it may be commercially viable to tap the pine plantations.Again,resin can be used as a torch to provide light,so there is potential to use the so-called minor forest

products to a much larger extent.

## 7. Industrial fuelwood plantation budget

The suggested industrial fuelwood plantations cover the last part of the policy proposals. To establish these plantations will usually involve a change of land use and together with the peri-urban areas it will mean the policy proposals call for just over 200,000 hectares to be afforested rather than be reforested or brought under intensive agro-forestry. This is a relatively small area of land to change use, especially when it is considered how much land has been taken out of forestry in the past. Even so, it is estimated that an additional 120,000 hectares of forest land will be turned over to agriculture by the turn of the century and therefore the net change in favour of forestry may only be in the region of 80,000 hectares if the policy proposals are acceptted in full.

The industrial fuelwood plantations are to provide fuelwood, densified wood and charcoal for specific industries. It is proposed to plant 39,000 hectares in close proximity to the consumer industries and by the year 2000 this will cost in total Kshs.127 million and the annual yield would be 1.1 million $m^3$ ( 0.8 million tonnes). In a steady state the annual cost would amount to some Kshs.6 million and the returns from a volume production of 1.2 million $m^3$ (0.9 mill.t) ranges from Kshs.18 to 24 million depending on the stumpage price (App.16a). The actual model used to calculate the cost is the straight fuelwood plantation but of course, multi-purpose tree species could be substituted for the above.

It is estimated that (App.16b) 4,900 people will be involved in forestry operations of which 4,600 will be undertaking thinning and felling. A further 413 people will be needed for supervision of which an estimated 21 will be university graduates, 206 college graduates and 186 office staff, giving a total labour requirement of about 5300 full time people.

## 8. Policy proposals total budget at the national level

### i financial costs and returns

The individual components of the fuelwood project proposal have been described above. Table 17 combines all these components to give a financial estimate of the total programme by the year 2000. Table 17a describes the lowest cost option - that is planting seeds or establishing plantations by the Shamba system where a choice is available. Alternatively, table 17b looks at the costs of the programme if seedlings are used and if the replanted forest is established by paying all labour costs. In the case of the agro-forestry proposals neither the



Table 17 Kenya woodfuel energy plan. Financial budget of the national policy proposals

Table 17a Cumulative costs and returns by the year 2000, using seeds and the Shamba system where appropriate

Units million shillings

| Policy Option | Area to be est. | Cumulative Costs | | | Annual Vol.Prod. by 2000 | Cumulative Revenue | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Direct | Overhead | Total | | Fuelwood at 15/-m3 | Fuelwood at 20/-m3 | Cleared natural 15/-m3 | Forest 20/-m3 | Total revenue 15/-m3 | Total revenue 20/-m3 |
| | 000ha. | | | | Mill m3 | | | | | | |
| Agro-forestry(1) | | | | | | | | | | | |
| High pot. | 2661 | 8 | 328 | 336 | 12.95 | - | - | - | - | - | - |
| Med pot. | 360 | 1 | 42 | 43 | 1.04 | - | - | - | - | - | - |
| Replanted forest | 306 | 298 | 341 | 639 | 4.79 | 314 | 419 | 344 | 459 | 658 | 878 |
| | | | | | | | | Leaves/pods/Honey (5) | | | |
| Peri-urban | | | | | | | | | | | |
| High pot. coast | 5 | 16 | 2 | 18 | 0.09 | 6 | 8 | 17 | 17 | 23 | 25 |
| High " elsewhere | 75 | 104 | 116 | 220 | 1.04 | 96 | 127 | | | 96 | 127 |
| Med pot. | 85 | 196 | 138 | 334 | 0.57 | 31 | 41 | 278 | 278 | 309 | 319 |
| Managed forest | 440 | - | 417 | 417 | 3.74 | 533 | 710 | | | 533 | 710 |
| Industrial ptn. | 39 | 55 | 72 | 127 | 1.11 | 55 | 73 | | | 55 | 73 |
| Total | 3971(2) | 678 | 1456 | 2134 | 25.33(3) | 1035 | 1378 | 639 | 754 | 1674 | 2132 |

Table 17b Cumulative costs and returns by the year 2000 using seedlings and fully paid labour

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A/F High P (1) | 2661 | 228 | 328 | 556 | 13.16 | - | - | - | - | - | - |
| A/F Med P | 360 | 31 | 42 | 73 | 1.07 | - | - | - | - | - | - |
| Replanted forest | 306 | 419 | 439 | 858 | 6.07 | 322 | 429 | 344 | 459 | 666 | 888 |
| P/U H.P. coast | 5 | 16 | 2 | 18 | 0.09 | 6 | 8 | 17 | 17 | 23 | 25 |
| P/U H.P. other | 75 | 104 | 116 | 220 | 1.04 | 96 | 127 | | | 96 | 127 |
| P/U M.P. | 85 | 247 | 138 | 385 | 0.57 | 31 | 41 | 278 | 278 | 309 | 319 |
| Managed forest | 410 | - | 417 | 417 | 3.74 | 533 | 710 | | | 533 | 710 |
| Industrial ptn | 39 | 55 | 72 | 127 | 1.11 | 55 | 73 | | | 55 | 73 |
| Total | 3971(2) | 1100 | 1554 | 2654 | 26.85(4) | 1043 | 1388 | 639 | 754 | 1682 | 2142 |

(1) Excludes the farmers costs and returns. If government were to give a planting and maintenance grant of Kshs.40 per hectare then this would increase the cost component by Kshs.100 million in each table.

(2) Forest equivalent area 1430,000 hectares (3) Equivalent to 16.9 million air dry tonnes (4) Equiv. to 18.0 mill. air dry t.

(5) Returns from leaves 17; pods 24.9; honey 241 million Kshs.

farmers costs nor his returns from fuelwood and fertilisers have been included in the budget as it is assumed that these inputs are provided free of charge and the outputs are obtained without any monetary payments.However,these costs and returns are tabulated inAppendix 11,assuming the farmer is paid for his inputs and conversely he pays for the outputs.

The cumulative costs by the year 2000 of planting the equivalent of 1.43 million hectares of land under various fuelwood option is estimated to be between Kshs.2134 and Kshs.2654 million in 1982 constant value terms.If government agrees to pay a grant to the farmers for initially planting and maintaining trees in agroforestry systems then this would increase the costs by Kshs.105 million over the period if the total grant came to Kshs.40 per hectare of farm land. The estimated annual production by the year 2000 is between 17 and 18 million tonnes of wood and this will meet about 35% of the projected 'policy case" demand for energy by 2000 and nearly 60% of the woodfuel demand.The anticipated money returns range from Kshs.1680 to 2135 million with stumpage prices of Kshs.15 and 20 per $m^3$.So if the financial estimates are more or less correct then returns nearly cover costs by the turn of the century.Of course.there is no establishment and tending cost charged for the cleared natural forest and so it could be argued that the income from the sale of this wood should be excluded. In that case the anticipated revenue is reduced to between Kshs.1330 and 1680 million.By the year 2007 when the cumulative returns from practically every option is greater than the cumulative cost the total financial cost is Kshs. 3900 million and the total financial returns range from Kshs.3400 million(1)to 4300 million for an output of 26.9 million tonnes of fuelwood plus 151,000 tonnes of fodder and 1500 tonnes of honey.In a steady state the annual cost for all the components will be about Kshs.190 million and the returns range from Kshs.320 to 410 million for an output of 24.6 million tonnes of woodfuel or about 50% of the estimated demand for wood energy by the year 2000.

All the above costs are based on a set of assumed per hectare costs that could be achieved by good management. These have been described previously and set out in detail in Appendix 5.However,average costs in Kenya today are about 50% greater than the above costs,ranging from 75% more for direct costs and 45% more for overhead costs.If these costs were applied to the various proposals then the cumulative cost by the year 2000 would be Kshs.3200 million (table 17a) while the returns would remain the same.In nearly every case,the financial

(1) The reason why this total income is less than the total cost is because there is no money income from the agro-forestry option.



yield would be less than 10% although in a steady state, income would exceed cost by at least Kshs.40 million per year instead of the estimated Kshs.130 million under the assumed cost structure. Thus,unless labour efficiency is increased,which should be well within the bounds of good management,the government will have much less surplus to invest in the economy of the country.

ii employment possibilities

What kind of employment would the woodfuel proposal generate?Table 18 gives an estimate of the total employment possibilities when the steady state is reached and Appendices 11 - 16 give the build up from year to year.It is estimated that the wood energy proposals will create employment for between 97,000 and 99,000 people in the forest or supervising the agro-forestry proposals.Between 87,000 and 89,000 will be employed on direct operations whereas 10,000 will be required for management and supervision. If more food/fodder/woodfuel schemes are introduced into the policy options then employment could be boosted well beyond the 100,000 mark at very little extra cost. However,as previously stated,the economics of fodder production and markets must be thoroughly investigated.

Most of the employment will be in thinning and felling and it would be advisable to organise training courses for the workers in the various operations of felling,cross-cutting,debarking,extraction and piling. This can be exhausting work,especially if hand tools are used as is recommended.Therefore the design and introduction of the correct tools is most important for efficient and energy saving work as is the sharpening and maintenance of these tools. About 500 university graduates will be required to manage the various options in plantation forestry,agro-forestry and management of natural forests.This means that on average twenty graduates will be needed each year to the year 2007 to manage such a programme.This is in addition to the graduates turned out today, therefore,the university intake into the forestry school - assuming most of the graduates are foresters- will have to be more than doubled and emphasis will have to be placed on agro-forestry,extension work,management of natural forests. short rotation plantation management and harvesting of small diameter trees.

While the intake into the university forest school will have to be about doubled,the intake into the agricultural and forestry colleges needs to be increased about five-fold.Every year approximately 200 new college graduates will be required for agro-forestry extension work,plantation and natural forest management and supervision of harvesting.Perhaps a new college is required to cope with such an increase in numbers and the change of emphasis in training from the traditional forestry subjects to agro-forestry and extension work. Table 18 only gives the employment possibilities in the forest or on the farm,

Table 18 Kenya woodfuel energy plan. Manpower budget of the national policy proposals

Table 18a Manpower budget-steady state- when seeds are planted and the Shamba system is used

Units man years (270 man days/yr)

| Policy Option | Direct Employment | | | | Supervisory Labour | | | | All Labour |
|---|---|---|---|---|---|---|---|---|---|
| | Forest | Thin.& Fell. | Collecting fodder etc. | Total | Graduates Univ. | Graduates College | Office staff | Total | |
| Agro-forestry High P. | - | - | | | 70 | 705 | 634 | 1409 | 1409 |
| " " Medium P. | - | - | | | 10 | 95 | 95 | 190 | 190 |
| Replanting Forest | 1727 | 37762 | | 39489 | 155 | 1552 | 1396 | 3103 | 42592 |
| Peri-urban HighP.coast | 43 | 577 | 1243 | 1863 | 3 | 33 | 29 | 65 | 1928 |
| " " " " other | 534 | 8839 | | 9373 | 40 | 398 | 357 | 795 | 10168 |
| " " Medium P. | 301 | 5001 | 11968 | 17270 | 64 | 644 | 579 | 1287 | 18557 |
| Managing nat.forest | - | 13866 | | 13866 | 134 | 1336 | 1203 | 2673 | 16539 |
| Industrial ptn. | 278 | 4596 | | 4974 | 21 | 206 | 186 | 413 | 5287 |
| Total | 2883 | 70641 | 13211 | 86735 | 497 | 4969 | 4469 | 9935 | 96670 |

Table 18b Manpower budget - steady state - when seedlings are planted and labour fully paid

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A/F High P. | 1175 | - | | 1175 | 70 | 705 | 634 | 1409 | 2584 |
| A/F Medium P. | 158 | - | | 158 | 10 | 95 | 85 | 190 | 348 |
| Replanting forest | 2181 | 37762 | | 39943 | 165 | 1654 | 1490 | 3309 | 43252 |
| P.U. H.P.coast | 43 | 577 | 1243 | 1863 | 3 | 33 | 29 | 65 | 1928 |
| P.U. H.P.other | 534 | 8839 | | 9373 | 40 | 398 | 357 | 795 | 10168 |
| P.U. Medium P. | 427 | 5001 | 11968 | 17396 | 64 | 644 | 579 | 1287 | 18683 |
| Managing nat.forest | - | 13866 | | 13866 | 134 | 1336 | 1203 | 2673 | 16539 |
| Industrial ptn. | 278 | 4596 | | 4874 | 21 | 206 | 186 | 413 | 5287 |
| Total | 4796 | 70641 | 13211 | 88648 | 507 | 5071 | 4563 | 10141 | 98789 |



but of course,more jobs will be created in the production of densified wood and charcoal and in the distribution and marketing of woodfuel products.

The labour inputs by the farmer and his family have been excluded from table 18 but have been discussed previously. Rather than being a burden to the farmer,growing trees on farm will save the farmer and his family a considerable amount of time and therefore while the total proposals on the one hand create a substantial amount of employment they also save labour inputs where they are most needed.

9. Policy potential : financial and manpower budget

Tables 17 and 18 give a summary of the financial and labour implications of the policy proposal.Of course,the different parts of the proposal need not be adhered to.It is possible to increase the agro-forestry component and decrease the replanting programme,but the policy options were drawn up bearing in mind the requirements of the different sectors of the economy.Table 14 sets out the maximum area of land for each option under a woodfuel programme.Table 19 illustrates the costs,revenues and labour requirements if the maximum area for each option was incorporated into the programme.

If all farmers accepted and practiced optional agro-forestry then it is possible that they could produce 21.6 million tonnes or 70% of all the anticipated demand for wood energy by the year 2000.However,there would be areas where surpluses occur such as in the Rift Valley and Eastern Provinces and there would be problems marketing small quantities of wood from each farm to where the demand is namely,in urban areas and for industry.Agro-forestry in combination with the proper management of the entire area of natural forest could supply at least 85% of the fuelwood requirements,so it may seem plausible that by just concentrating on these two parts of the policy proposals the fuelwood crisis could be solved.But as explained previously,it is in these two areas that the least expertise occurs and there remains more uncertainty about the forecasted yields,costs and returns than in conventional plantation forestry,hence the spreading of the risks and uncertainties.Also,part of the strategy is to grow the fuelwood near to the consumer centres and this is why peri-urban and industrial plantations have been suggested as well as agro-forestry schemes. Also,the reason for replanted forest areas,apart from acting as an encroachment barrier,is to offer scope for industrial production of densified wood,and efficient manufacture of charcoal and otherwood energy products.These industries must be guaranteed sufficient raw material within a small transport radius of the factory in order to make production economic.

Table 17 Kenya woodfuel energy plan - natural resources policy potential

Table 17a Cumulative costs and returns by the year 2000 assuming all the potential land is used, conditions and fully paid labour used

Units million shillings

| Policy Potential | Area ('000 ha) | Cumulative Costs: Direct | Cumulative Costs: Over Head | Cumulative Costs: Total | Ann. vol. prod. '000 mill.³ | Cumulative Revenue: Fuelwood at 15/-m³ | Cumulative Revenue: Fuelwood at 20/-m³ | Cumulative Revenue: Cleared material forest. 15/-m³ | Cumulative Revenue: Cleared material forest. 20/-m³ | Leaves pods Fert. | Honey | Total Revenue 15/-m³ | Total Revenue 20/-m³ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A/F High P.(2) | 5000(4) | [illegible] | 733 | (2153)1232 | 29.7 | (1221) | (4294) | | | (355) | | (3576) | (4633) |
| A/F Med P.(2) | 1555(4) | ( 257) | 135 | ( 552) 319 | 4.5 | ( 130) | ( 646) | | | ( 30) | | ( 570) | ( 520) |
| Replanted forest | 500 | 553 | 573 | 1131 | 3.3 | 420 | 551 | 450 | 500 | | | 870 | 1161 |
| P.U. H.P.coast | 6 | 19 | 2 | 21 | 0.1 | 7 | 10 | - | | 20 | | 27 | 30 |
| P.U. H.P.other | 94 | 1301 | 126 | 276 | 1.3 | 120 | 160 | | | | | 120 | 160 |
| P.U. Med.nat. | 100 | 290 | 162 | 453 | 0.7 | 35 | 48 | | | 233 | 35 | 303 | 375 |
| Managed nat.forest | 350 | - | 306 | 306 | 6.2(5) | 347 | 1151 | | | | | 287 | 1151 |
| Industrial plm. | 50 | 75 | 142 | 213 | 2.3 | 224 | 249 | | | | | 224 | 299 |
| Total(3) | 9065 | 17231 | 2753 | 4375 | 52.3 | 1594 | 2159 | 450 | 500 | 313 | 35 | 2431 | 3206 |

Table 17b Manpower budget - steady state - for policy potential - settlings and fully paid labour used

Units man years (270 man days/yr)

| Policy Option | Area '000 ha | Direct Employment: Forest | Direct Employment: Thin.& Fell. | Direct Employment: Collecting fodder etc. | Total | Supervisory/Labour: Graduates Univ. | Supervisory/Labour: Graduates Colleges | Supervisory/Labour: Office staff | Total | All Labour |
|---|---|---|---|---|---|---|---|---|---|---|
| A/F High P. | 5000 | 2649 | | | 2649 | 158 | 1590 | 1429 | 3177 | 5825 |
| A/F Med P. | 1555 | 687 | | | 687 | 43 | 413 | 370 | 825 | 1513 |
| Replanted forest | 500 | 2451 | 49382 | | 52213 | 216 | 2152 | 1947 | 4325 | 56538 |
| P.U. H.P.coast | 6 | 52 | 692 | 1492 | 2236 | 1 | 49 | 24 | 73 | 2314 |
| P.U. H.P.other | 94 | 659 | 11073 | | 11747 | 53 | 499 | 447 | 996 | 12743 |
| P.U. Med.nat. | 100 | 502 | 5821 | 14000 | 20065 | 75 | 758 | 681 | 1514 | 21579 |
| Managed nat.forest | 350 | - | 25737 | | 25737 | 293 | 2531 | 2324 | 5154 | 31151 |
| Industrial plm. | 50 | 336 | 5872 | | 6208 | 27 | 254 | 238 | 529 | 6737 |
| Total | 9065 | 7356 | 99635 | + 15572 | 123033 | 832 | 3107 | 7470 | 16509 | 139642 |

(1) Forestry equivalent = 2639,999 m³.
(2) Figures in brackets are the estimated shadow costs and returns to the farmers.
(3) Air dry weight equivalent = 35.0 million tonnes.
(4) The average production for all the managed natural forests is less than the average for the 100,000 ha. degraded bushy and scrub are included as well.
(5) Estimated subsidy to farmers at Kshs 40 per agricultural ha. Kshs.203 million.



If the entire policy potential was undertaken then there would be more than sufficient production (about 15% more) to meet the "policy case" wood energy demand by 2000 and 75% of the "base case" demand. The cost of such a programme is in the region of 4,500 million shillings and it would create job opportunities for 140,000 people. While it is not anticipated that the policy potential will be fulfilled it can be seen that there is scope for expansion, particularly in agro-forestry and managed natural forests beyond the year 2000 especially when agro-forestry and natural forest management systems have been developed and proved.

## Chapter VII

## Woodfuel policy option compared to other options

Table 17b estimated that by the year 2000 the total costs of the various components of the woodfuel policy option is in the region of Kshs.2700 million or on average Kshs.150 million per year. However it is anticipated that there will be at least an income of Kshs.1700 million during the same period and so, the net cost will be in the region of Kshs.1000 million. By the turn of the century the anticipate yield will be 18 million tonnes of wood energy and this is about 35% of the forecasted demand for all energy. Therefore a direct investment of Kshs.2700 million will cover about 35% of Kenya's energy requirement. This cost should be compared and contrasted to Kenya's next hydro-electricity scheme - The Kiambere power station. The capital cost of this project is estimated to be Kshs.4,300 million and it's rated capacity is 140MW. When it is fully working it will generate about 430 million KWh. which is equivalent to 1.54 million Giga Joules or 0.1 million tonnes of wood. Of course, because of efficiency differences in the burning of wood energy and electricity the above quantity of electricity may be in the region of 0.25 million tonnes of wood energy in wood equivalent terms, but even so this represents 0.5% of the forecasted requirement forenergy by the year 2000. Therefore an investment of Kshs. 4,300 million in hydro electricity will provide 0.5% of Kenya's energy requirements and to match the 35% that the wood energy will provide, would require Kshs. 0.30 billion( $10^{12}$) or 111 times as much investment What is more, 60% of this latter investment would be in the form of foreign exchange whereas, this not more than 10% of capital investment in the woodfuel policy option. Kiambere Hydro scheme may be an extreme example for comparison purposes for it is remote and has some engineering problems. A relatively cheap hydro scheme was the Gitaru scheme which was built a few years ago at the cost of Kshs.960 million and with a rated capacity of 145 MV. But even taking this cost figure the capital require-

ment to produce the equivalent of 35% of Kenya's energy requirement from the hydro electricity are in the order of 65,000 million shillings or 24 times the cost of the wood energy proposals.Of course electrical energy is a much more versatile energy form than wood,but the capital cost of providing this energy to the population,especially when taking into consideration the distribution costs to the rural areas highlights how cheap the wood energy policy option is. It is also very doubtful whether such an investment,even if there was sufficient water,would provide anything like the sustained employment of the forestry option.

Perhaps a more realistic comparison is that between woodfuel and paraffin, paraffin being the cheapest alternative to woodfuel.Assuming a relative increase in the efficiencies of wood stoves as compared to other stoves,as has been done in the policy option forecast,then,approximately 4.4 million tonnes of paraffin (5040 million litres) are equivalent to 18 million tonnes of wood.At present the Mombasa refinery is producing about 2.9 million tonnes of all products but it's design capacity is 4.2 million tonnes.However,without a cracking unit only 15% of the output is paraffin/jet fuel.Therefore to cope with 4.4 million tonnes a 30 million tonne refinery would be required.Even with a cracking plant the capacity of the refinery would be about 20 million tonnes .The capital investment for a 20 million tonne refinery plus cracking plant would be in the region of Ksh.14,000 million,but of course the share of the refinery attributed to paraffin would be approximately Kshs.3,000 million (1)Therefore the capital investment of the "paraffin component" of a refinery may be slightly more expensive than the capital investment of the woodfuel policy option and more importantly the total refinery investment will be five times as much.In must also be borne in mind that most of the capital cost (about 80%) is foreign exchange and the cost of the crude is all foreign exchange.This can be illustrated by the fact that if 4.4 million tonnes of already refined paraffin were to be imported then at today's prices it would cost in the region of Kshs. 18,000 million of foreign exchange per year which is more than six times the capital cost of the entire woodfuel programme proposals.Also the employment possibilities at a refinery would be in the 100's rather than in the 1,000's. So the woodfuel option in absolute terms is the cheapest, costs by far the least foreign exchange and provides the most employment.

(1) There is the problem of finding markets for the other products produced and of course a cracking plant could produce diesel as well as paraffin. Therefore there may be some competition as what to produce.



There are other costs attached to the woodfuel proposals that have not been dealt with but should be mentioned in order to give a complete picture.No price has been put on the value of the land for most of it will remain in current use. However,it is proposed that for peri-urban and industrial plantations 204,000 ha. will involve a change of land use.Farm land in high potential areas is worth about Kshs.17,000 per ha. and in medium potential areas about Kshs.10,000 per ha.If it is assumed that these prices reflect the value of the land then the cost for purchasing the land for peri-urban and industrial plantations will be in the region of Kshs.2870 million which is more than the estimated capital cost of the entire programme.If houses have to be built for all the work force of nearly 100,000 then this would cost approximately Kshs.2700 million.Also to train the graduates both at the university and college level as well as running training centres and estsblishing a centre for stove improvement may cost somewhere in the region of Kshs.500 million over a 25 year period,so the entire programme may entail a cost of Kshs. 8300 million to the year 2000,or on average,Kshs.460 million per year.For this investment Kenya will produce at least 35% of it's own energy requirement.This energy source is based on indigenous resources and skills which are cheaper than alternative energy options and requires a minimum amount of foreign exchange. By taking the sustained wood energy route,water catchment areas will be protected,soil will be stabilised and it's fertility increased,the quality of life of the rural population should be enhanced and a significant number of jobs will be created.Finally,by choosing a fuel that requires very little capital input, and an investment that will pay for itself relatively quickly.Money will be released,especially foreign exchange,to buy capital equipment that should assist in the rapid economic development of the nation.

COSTS AND BENEFITS OF PROPOSED TREE PLANTING PROGRAMME FOR SATISFYING KENYA'S WOOD ENERGY REQUIREMENTS

PART II

APPENDICIES

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Appendix 1. Capital and running costs of a two cubic metre/day biogas plant.

1982 prices assumed.

| Capital Cost | Indian rupees | Kshs | |
|---|---|---|---|
| Gas holder | 2481 | 3328 | |
| Pipeline | 668 | 896 | |
| Construction | 3054 | 4096 | |
| Total Cost | 6203 | 8320 | of which Foreign Exchange Kshs. |
| **Annual Cost** | | | |
| Depreciation Gas holder(10yrs) | 243 | 333 | 300 |
| " Pipeline (30yrs) | 22 | 30 | 28 |
| " Civil work(40yrs) | 76 | 102 | 52 |
| Paint and painting | 266 | 357 | 150 |
| Annual maintinance | 266 | 357 | 50 |
| Dung collection(4.93tonnes) | 92 | 123 | 0 |
| Water 4,930 litres | 12 | 16 | 0 |
| TOTAL | 982 | 1318 | 580 |
| Cost per cubic metre of gas | 1.35 | 1.80 | 0.79 |

Assume the dung is put on the land. No charge made for purchase of dung, and no benefit attributed to dung as a fertiliser. To supply dung, 2-3 cattle are required.
No interest costs charged on capital.
Prices given in 1975 terms: 15% inflation assumed, therefore multiply by 2.66 to obtain 1982 prices.
$1m^3$ biogas contains 60% methane and 40% carbon dioxide: energy value 22M Joules per $m^3$

Source: Methane generation from human, animal and agricultural wastes. National Academy of Sciences, Washington D.C. 1977. P.120.

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Appendix 2a Moisture content and weight of one cubic metre of Eucalyptus saligna at different ages and at different stages of drying (1)

| Age (yrs) | 5 | | | 10 | | | 15 | | |
|---|---|---|---|---|---|---|---|---|---|
| Specific gravity | 0.61 | | | 0.66 | | | 0.70 | | |
| Time from felling | M.C. (dry basis)% | Weight per $m^3$ (t) | Volume per t ($m^3$) | MC(db) % | Wt/$m^3$ (t) | V/t ($m^3$) | MC(db) % | Wt/$m^3$ (t) | V/t ($m^3$) |
| When felled | 160 | 1.59 | 0.63 | 140 | 1.59 | 0.63 | 116 | 1.52 | 0.66 |
| After 6 weeks | 80 | 1.10 | 0.91 | 70 | 1.12 | 0.89 | 58 | 1.11 | 0.90 |
| After 12 weeks | 40 | 0.85 | 1.18 | 35 | 0.90 | 1.11 | 29 | 0.91 | 1.10 |
| After 18 weeks | 20 | 0.73 | 1.37 | 17½ | 0.78 | 1.28 | 14½ | 0.81 | 1.24 |
| After 18-24 weeks | 15 | 0.70 | 1.43 | 15 | 0.76 | 1.31 | 15 | 0.81 | 1.24 |

(1) Wood is felled, debarked, cross-cut into metre lengths and stacked.



Appendix 2b Energy available for cooking/heating at different moisture contents (1)

Units: Giga Joules

| Age (yrs) | 5 | | | 10 | | | 15 | | |
|---|---|---|---|---|---|---|---|---|---|
| Time from felling | MC % | GJ/$t_9$ $10^9$ Joules | GJ/$m^3$ | MC % | GJ/$t_9$ $10^9$ Joules | GJ/$m^3$ | MC % | GJ/$t_9$ $10^9$ Joules | GJ/$m^3$ |
| When felled | 160 | 5.72 | 9.09 | 140 | 6.53 | 10.38 | 116 | 7.37 | 11.20 |
| After 6 weeks | 80 | 9.32 | 10.27 | 70 | 10.01 | 11.21 | 58 | 10.96 | 12.17 |
| After 12 weeks | 40 | 12.67 | 10.77 | 35 | 13.23 | 11.91 | 29 | 13.96 | 12.70 |
| After 18 weeks | 20 | 15.19 | 11.09 | 17½ | 15.64 | 12.12 | 14½ | 16.03 | 12.98 |
| At 15% MC | 15 | 15.95 | 11.19 | 15 | 15.95 | 12.19 | 15 | 15.95 | 12.98 |
| At bone dry weight | 0 | 18.70 | 11.41 | 0 | 18.70 | 12.42 | 0 | 18.70 | 13.15 |



(1) The low heat value(equivalent to the heat practically available) has been calculated using the formulae: $100x-2.4(54+m)/100 + m$ Where x = The high heat value for wood - 20.0 MJ/Kg
m = Moisture content of the wood (dry basis)
The factor 2.4 MJ/kg of water is the amount of heat required to drive off 1Kg of water.

Appendix 3a Economic transport radius for fuelwood at different moisture contents assuming the wood is sold at a fixed cost per Joule (1)

(i) Market price Kshs 200 per tonne at 15% MC(Kshs.12.50 per G.Joule)

| Moisture content(dry basis) % | 160 | 80 | 40 | 20 | 15 | 10 |
|---|---|---|---|---|---|---|
| Effective energy value GJ/tonne | 5.7 | 9.3 | 12.7 | 15.2 | 16.0 | 16.8 |
| Weight of $1m^3$(2) (tonnes) | 1.59 | 1.10 | 0.85 | 0.70 | 0.67 | |
| Roadside price per tonne (2) (Kshs) | 28 | 41 | 53 | 62 | 64 | 67 |
| Market price(200/-t)(Kshs/t) | 72 | 117 | 159 | 190 | 200 | 211 |
| Difference between market and roadside price (Kshs/t) | 44 | 76 | 106 | 128 | 136 | 144 |
| Retail/wholesale profit margin (15%) (Kshs/t) | 11 | 18 | 24 | 28 | 30 | 32 |
| Cost for transport (Kshs/t) | 33 | 58 | 82 | 100 | 106 | 112 |
| Road transport cost (Kshs/Km/tonne) (4) | 1.00 | 1.00 | 1.18 | 1.37 | 1.43 | 1.49 |
| Maximum profitable road transport radius (Kms) | 33 | 58 | 69 | 73 | 74 | 75 |
| Road transport cost (Kshs/Km/tonne) | 0.40 | 0.40 | 0.47 | 0.45 | 0.57 | 0.60 |
| Maximum profitable rail transport radius (Kms) | 82 | 145 | 174 | 182 | 186 | 187 |

(ii) Market price Kshs.100 per tonne at 15% MC (Kshs.6.25 per G.Joule

| | | | | | | |
|---|---|---|---|---|---|---|
| Market price(100/-t)(Kshs/t) | 36 | 58 | 79 | 95 | 100 | 105 |
| Price difference-market-Roadside )Kshs/t) | 8 | 17 | 26 | 33 | 36 | 38 |
| Profit margin (15%) (Kshs/t) | 5 | 9 | 12 | 14 | 15 | 16 |
| Cost for transport (Kshs/t) | 3 | 8 | 14 | 19 | 21 | 22 |
| Maximum road transport radius (4) | 3 | 8 | 12 | 14 | 15 | 15 |
| Maximum rail transport radius (4) | 8 | 20 | 30 | 35 | 37 | 37 |

Appendix 3a FOOTNOTES

(1) When wood is sold at a fixed price per Joule the cosr per tonne will vary according to it's moisture content. The higher the moisture content, the lower the price.

(2) When wood dries there is very little shrinkage, therefore the volume can be taken as constant, irrespective of weight.

(3) This is assuming the purchase price of the wood, plus felling, cross-cutting, debarking and extraction is Kshs.45 per $m^3$

(4) It is assumed that a lorry or railcar can carry one $m^3$ or less per tonne weight. The standard price for road transport is Kshs.1 per tonne per kilometre and for rail Kshs.0.40 t/Km. If $1m^3$ weighs less than one tonne then the price per tonne increases to take account of the bulkiness of the product and the appropriate rates are given under road and rail costs.

Appendix 3b Economic transport radius for fuelwood at a fixed price per tonne irrespective of moisture content (5)

Market price Kshs.200 per tonne

| Moisture content | 160 | 80 | 40 | 20 | 15 | 10 |
|---|---|---|---|---|---|---|
| Effective energy value(GJ/tonne) | 5.7 | 9.3 | 12.7 | 15.2 | 16.0 | 16.3 |
| Weight of $1m^3$ (tonnes) (2) | 1.59 | 1.10 | 0.85 | 0.73 | 0.70 | 0.67 |
| Roadside price per tonne(Kshs)(4) | 28 | 41 | 53 | 62 | 64 | 67 |
| Market Price (Kshs) | 200 | | | | | |
| Difference Market-Roadside(Kshs) | 172 | 159 | 147 | 138 | 136 | 133 |
| Profit Margin(15%) | 30 | | | | | |
| Cost for transport (Kshs/t) | 142 | 129 | 117 | 108 | 106 | 103 |
| Maximum profitable road transport radius (Kms)(4) | 142 | 129 | 99 | 79 | 74 | 69 |
| Maximum profitable rail radius (Kms)(4) | 355 | 322 | 249 | 196 | 186 | 172 |
| Cost per Giga Joule (Kshs)(5) | 35.1 | 21.5 | 15.8 | 13.2 | 12.5 | 11.9 |

(5) When wood is sold at a fixed price irrespective of moisture content, then the cost per Giga Joule increases with moisture (see last line).

(2)(3)(4)
See footnotes under Appendix 3a

Appendix 4a Cost of production of densified wood and charcoal made in various kilns and retorts.

| Output tonnes | Densified wood plant: Quantity | Densified wood plant: Cost Total (Kshs. million) | Densified wood plant: Cost Per tonne Kshs. Local | Retort 10,000 kcal/kg charcoal: Quantity | Retort: Cost Total (Kshs. million) | Retort: Cost F.E. | Retort: Cost Local | Small Brick Kiln 3200 charcoal: Quantity | Small Brick Kiln: Cost Total | Small Brick Kiln: Cost F.E. | Small Brick Kiln: Cost Local | Efficient earth kiln 30 charcoal: Quantity | Efficient earth kiln: Cost Total | Efficient earth kiln: Cost F.E. | Efficient earth kiln: Cost Local | Inefficient earth kiln 30 charcoal: Quantity | Inefficient earth kiln: Cost Total | Inefficient earth kiln: Cost F.E. | Inefficient earth kiln: Cost Local |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | |
| **Capital investment** | | | | | | | | | | | | | | | | | | | |
| **Running Cost** | | | | | | | | | | | | | | | | | | | |
| wood (standing) 1000m³ | 118.7 | 1.78 | 0.18 | 45.0 | 0.48 | 0.07 | 0.41 | 19.2 | 0.29 | 0.03 | 0.26 | 0.22 | 10.00 | 1.00 | 9.00 | 0.26 (labour) | 5.40 | 0.20 | 5.20 |
| wood (harvesting) | 118.7 | 2.56 | 0.36 | 45.0 | 1.35 | 0.13 | 1.22 | 19.2 | 0.58 | 0.06 | 0.52 | | 2.40 | 0.00 | 2.40 | | 2.40 | 0.20 | 2.20 |
| wood (delivery) 10Km | 356.1 | 4.57 | 2.04 | 27.0 | 0.99 | 0.45 | 0.54 | 192.0 | 0.25 | 0.11 | 0.14 | | | | | | | | |
| water | 2.5 | 0.01 | 0.00 | 7.2 | 0.02 | 0.00 | 0.02 | | | | | | | | | | | | |
| electricity, oil, fuel | 2.0 | 0.56 | 0.28 | 1.2 | 0.32 | 0.26 | 0.06 | | | | | | | | | | | | |
| other labour | 26.1 | 2.17 | 0.57 | | | | | | | | | | | | | | | | |
| processing | | 2.40 | 1.60 | | | | | | | | | | | | | | | | |
| packaging, other | | | 1.45 | | | | | | | | | | | | | | | | |
| | | HIL | 0.95 | | 0.48 | 0.19 | 0.29 | | Supplied from wood 0.17 | 0.07 | 0.10 | | Supplied from wood 2.10 | 1.20 | 1.00 | | Supplied from wood 1.50 | 0.60 | 0.90 |
| insurance | | 2.00 | 0.20 | 1.00 | 0.27 | 0.11 | 0.16 | | HIL | | | | HIL | | | | HIL | | |
| | | 1.00 | 0.10 | 0.90 | 0.20 | 0.02 | 0.18 | | 0.05 | 0.01 | 0.04 | | Included as capital 0.12 | 0.10 | 0.02 | | Included as capital 0.16 | 0.10 | 0.06 |
| **Total running cost** | | 14.45 | 5.20 | 12.25 | 4.43 | 1.24 | 3.19 | | 1.37 | 0.28 | 1.09 | | 16.20 | 2.40 | 14.00 | | 9.40 | 0.90 | 8.50 |
| labour direct (10⁶) | 140 | 1.29 | 0.00 | 1.29 | 0.42 | 0.00 | 0.42 | 24 | 0.08 | 0.00 | 0.08 | 2 | 9.60 | 0.00 | 9.60 | 2 | 9.60 | 0.00 | 9.60 |
| office staff, chemists etc | | 0.07 | 0.02 | 0.05 | 0.05 | 0.02 | 0.03 | | HIL | | | | HIL | | | | HIL | | |
| **Total labour** | | 1.36 | 0.02 | 1.34 | 0.47 | 0.02 | 0.45 | | 0.08 | 0.00 | 0.08 | variable costs | 9.60 | 0.00 | 9.60 | variable costs | 9.60 | 0.00 | 9.60 |
| **depreciation** (Yrs) | | | | | | | | | | | | | | | | | | | |
| machinery (10) | | 7.06 | 6.26 | 0.80 | 2.09 | 1.85 | 0.24 | | 0.09 | 0.01 | 0.08 | tools | 0.20 | 0.20 | 0.00 | tools | 0.20 | 0.20 | 0.00 |
| building (20) | | 0.75 | 0.30 | 0.45 | 0.37 | 0.15 | 0.22 | | 0.03 | 0.00 | 0.03 | | HIL | | | | HIL | | |
| transportation (10) | | 1.27 | 0.43 | 0.84 | 0.61 | 0.26 | 0.35 | | 0.05 | 0.01 | 0.04 | | HIL | | | | HIL | | |
| other equipment (10) | | 0.68 | 0.41 | 0.27 | 0.01 | 0.00 | 0.01 | | | | | | 0.40 | 0.00 | 0.40 | | 0.40 | 0.00 | 0.40 |
| **Total depreciation** | | 9.76 | 7.40 | 2.36 | 3.18 | 2.25 | 0.81 | | 0.17 | 0.02 | 0.15 | | 0.60 | 0.20 | 0.40 | | 0.60 | 0.20 | 0.40 |
| **Total production cost** | | 29.57 | 12.82 | 16.75 | 8.26 | 3.61 | 4.65 | | 1.62 | 0.30 | 1.32 | | 26.20 | 2.52 | 23.00 | | 19.40 | 1.10 | 18.30 |
| **Total production cost (Kshs)** | | 282 | 122 | 160 | 826 | 361 | 465 | | 504 | 94 | 412 | | 442(1) | 42 | 400 | | 647(1) | 42 | 605 |
| **Selling price (2)** | | 71 | 22 | | 76 | 29 | | | 51 | 1 | | | 13 | | | | 6 | | |
| **Ex factory unit price (Kshs)** | | 325 | | | 950 | | | | 580 | | | | 510 | | | | 745 | | |

Notes to Appendix 4a

(1) 25% of the charcoal in the retort is briquetted. These are the fines and charcoal dust. It is only for the brick kilns to produce briquettes but this has not been considered.

(2) The retort produces in addition to 10,000 tonnes of charcoal 2,500 tonnes of wood tar and 1.8 million m³ of gas. The production costs are after deducting wood gas Kshs.177 per 1000m³ and wood tar Kshs.877 per tonne. It is assumed that these products are sold at factory for Kshs.1000 for tar and Kshs.87 per 1000m³ wood gas. The costs of the retort depend on these by-products being sold. If there is no market for them or they cannot fetch the prices assumed then the viability of the retort is questionable.

(3) Production efficiency by earth kiln is somewhat uncertain. The lower figure is based on the own production of 30 tonnes per year whereas the upper figure is based on the own production of 60 tonnes per year. The lower figure was obtained from a student project in Tanzania but it is thought to be on the low side.

(4) Ex factory price arrived at by assuming an approximate 15% mark up.

(5) Note: If not all earth kiln operators do not pay for the wood, the unit production price without wood is Kshs.262 per tonne; for a kiln Kshs.300 per tonne, Kshs.540 per tonne.

(6) The unit production price excluding wood is Kshs.467 per tonne; for a kiln

(7) Break even point calculated by assuming the running costs are variable and the labour plus depreciation costs are fixed, except for the earth kiln where the labour is also variable. Therefore:

B.E.P. output = Fixed cost/ unit selling price - unit variable cost

B.E.P. as a % = BEP output/ rated capacity

For the brick kiln BEP output = 250,000/580 - 1210,000/3200 = 1646 t.

B.E.P. % = 1646/ 3200 = 51%



Appendix 4b Economic transport for densified wood and charcoal produced in different kilns/retorts

| | | Densified Wood | Retort | Brick Kiln | Earth Kiln Efficient | Earth Kiln Inefficient |
|---|---|---|---|---|---|---|
| Production Costs | Kshs/t | 282 | 504 | 506 | 442 | 647 |
| Selling Price(15% mark-up) | Kshs/t | 325 | 580 | 580 | 510 | 745 |
| Market Price | Kshs/t | 500 | 1000 | | | |
| Wholesale & retail profit | Kshs/t | 75 | 150 | | | |
| Price to wholesaler | | 425 | 850 | | | |
| Price difference Market-Ex factory | Kshs/t | 100 | 270 | 270 | 340 | 105 |
| Weight per m³ (tonnes) | | 0.80 | 0.40(1) | 0.30 | 0.30 | 0.30 |
| Cost per tonne by road(2) | Kshs/Km | 1.25 | 1.88 | 2.50 | 2.50 | 2.50 |
| Maximum profitable road transport radius | Kms | 80 | 144 | 108 | 136 | 42 |
| Cost per tonne by rail(2) | Kshs/Km | 0.50 | 0.75 | 1.00 | 1.00 | 1.00 |
| Maximum profitable rail transport radius | Kms | 200 | 360 | 270 | 340 | 105 |

(1) 25% of the charcoal briquetted, density 0.67 t/m³.

(2) For charcoal, because of it's low density, a vehicle or rail waggon cannot carry it's full load, however, this means less wear and tear for the vehicle. Also it can be piled high so it is assumed that the cost per tonne based on volume alone can be reduced in practice by 25%. The costs based on volume are as follows:- Kshs/t/Km

Road: densified wood 1.25 Retort charcoal 2.50 other charcoal 3.33

Rail: " " 0.50 " " 1.00 " " 1.33

Appendix 5 Costs, returns and labour budget of a one hectare fuelwood plantation over plantation's lifetime. All labour paid for-'Full cost'

Appendix 5a Cost in man days of various establishment operations (direct costs)per hectare

Assumed rotation - 10 years

| Year | Operation | Country: Tanzania(1) Low | Tanzania(1) High | Kenya Average | Kenya Assumed(2) | Operation | Country: U.K. (3) |
|---|---|---|---|---|---|---|---|
| 0 | Nursery-raising plants 1600 plants (including O/H) | 5.0 | 9.6 | 32.9 | 12.0 | Nursery 1600 plants | 4.5 |
| | Forestry establishment (1500 plants) | | | | | Forestry estab.(1500 plants) | |
| 0 | Clearing | 7.0 | 11.6 | 21.0 | 12.0 | Fencing | 4.[illegible] |
| 0 | Staking | 3.7 | 5.0 | 10.0 | 5.0 | Clearing | 3.0 |
| 0 | Pitting | 2.2 | 4.2 | 22.0 | 10.0 | Draining | 3.6 |
| 0 | Planting | 5.0 | 9.2 | 16.0 | 12.0 | Ploughing | 2.7 |
| 0 | Weeding 1st.year | 2.0 | 4.0 | 9.0 | 4.0 | Planting | 2.0 |
| | | | | | | Weeding 1st. year | 0.1 |
| Initial establishment plus weeding | | 19.9 | 34.0 | 78.0 | 44.0 | I.E. plus weeding | 13.5 |
| 1&2 | Weeding 2nd and 3rd year | 0.8 | 2.9 | 19.0 | 7.0 | Weeding 2nd to 5th year | 1.0 |
| 1&2 | Beating up 2nd and 3rd year | 1.9 | 2.3 | 5.0 | 4.0 | B.U. 2nd to 5th year | 0.3 |
| | Weeding and B.U. total | 2.7 | 5.2 | 24.0 | 11.0 | Weeding and B.U. total | 1.3 |
| | Plant cost for planting | 5.0 | 9.2 | 32.0 | 12.0 | Plant cost for planting | 4.5 |
| | " " for B.U. | 0.5 | 1.0 | 3.2 | 1.2 | " " for B.U. | 0.4 |
| Total direct establishment cost(3yrs) | | 28.1 | 50.0 | 137.2 | 58.2 | Establishment cost (3yrs) | 19.7 |
| Overhead costs as a % of direct costs(4) | | 119 | 144 | 150 | 150 | O/H costs % direct costs | 55 |
| Daily pay for labour Kshs. (5) | | 25 | | | | Daily pay Kshs. (6) | 200 |
| Estimated establishment cost including overhead (Kshs) | | 1397 | 2038 | 6910 | 3410 | | 6107 |

(1) The Tanzanian costs are three year averages, the low costs are from West Kilimanjaro and the high costs from Mount Meru.

(2) The assumed costs are the costs that the author thinks can be achieved. They are about half the Kenya average costs but 40% more than the Tanzania high costs.

(3) The U.K. costs are average costs for medium and large private estates in Scotland. The fencing, clearing and ploughing includes the machine or material costs in labour equivalent terms.

(4) Overhead costs include supervision, office staff, machines, materials not directly used in establishment operations, road construction, fire patrol, office rent etc., and a proportion of regional, H.Q. and research costs.

(5) The pay of casual labour is between Kshs.10 and 12 per day but the rate of Kshs 20 assumes that the employees are permanent and includes employers share of pension contribution etc.

(6) 1980 Weekly wage in U.K. for foresters £57.50 = Kshs.1094: 1980 stumpage price £2.30 = Kshs.44/m³



Appendix 5b Direct and overhead costs per hectare for a fuelwood plantation on a ten year rotation plus four, ten year rotations (15 years) from suckers.

Units Kshs.

| Year | Operation | Tanzania Low | Tanzania High | Kenya Average | Kenya Assumed | Kenya 15yr rotation Year | Kenya 15yr rotation Assumed |
|---|---|---|---|---|---|---|---|
| 0 | Initial establishment plus weeding | 497 | 875 | 2200 | 1120 | 0 | 112[illegible] |
| 1 | Beating up & weeding | 44 | 84 | 424 | 144 | 1 | 144 |
| 2 | Weeding | 20 | 40 | 120 | 100 | 2 | 100 |
| 0-10 | Overhead costs per year (average) | 76 | 131 | 400 | 200 | 0-15 | 150 |
| 10,20,30,40) | Weeding and (1) | 28 | 48 | 100 | 80 | 15,30,45,60) | 80 |
| 11,21,31,41) | Coppice reduction | 20 | 40 | 60 | 60 | 16,31,46,61) | 60 |
| 11-50 | Overhead costs per yr. (average) | 35 | 63 | 115 | 100 | 16-75 | 75 |
| 0-50 | Direct costs | 753 | 1351 | 3384 | 1924 | 0-75 | 1924 |
| 0-50 | Overhead costs | 2236 | 3961 | 9000 | 6200 | 0-75 | 6900 |
| 0-50 | Total costs | 2989 | 5312 | 12384 | 8124 | 0-75 | 8824 |

(1) No income attributed to small volume from coppice reduction.

Appendix 5c Anticipated volume production, and income per hectare over the life of the crop

| Ten Year Cycle | | | | | Fifteen Year Cycle | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Operation | volume production m³ | Income per standing m³: Kshs15 per m³ | Kshs20 per m³ | Year | Volume prod.m³ (2) | Income per standing m³: Kshs15 per m³ | Kshs20 per m³ |
| 7 | Thinning | 50 | 750 | 1000 | 10 | 45 | 675 | 900 |
| 10 | Felling | 250 | 3750 | 5000 | 15 | 180 | 2700 | 3600 |
| 17,27,37,47 | Thinning | 65 | 975 | 1300 | 27-32 57-72 | 55 | 825 | 1100 |
| 20,30,40,50 | Felling | 250 | 3750 | 5000 | 30 45 60 75 | 180 | 2700 | 1600 |
| | Thinning income | 310 | 4650 | 6200 | 0-75 | 265 | 3975 | 5300 |
| 0-50 | Felling income | 1250 | 18750 | 25000 | 0.75 | 900 | 13500 | 18000 |
| 0-50 | Total income | 1560 | 23400 | 31200 | 0-75 | 1165 | 17475 | 23300 |

Labour costed at Kshs.20 per day:Overhead costs include material costs,depreciation as well as supervision and maintenance costs.

(1) This is an average volume production(incuding branchwood) over the life of the crop.In reality the average yields in the five rotations may be as follows:m³/ha/yr 1st rotation 23,2nd R,42,3rd R.37,4th R.30,5th R.24

(2) This is an average volume production(including branchwood)over the life of the crop. Average yields in 5 rotations may be:m³/ha/yr 1stR.12.2ndR.21,3rdR.18,4thR.15,5thR.12

Appendix 5d Labour budget per hectare per year establishment and maintenance.

Units man days

| Year | Operation | Tanzania Low | Tanzania High | Kenya Average | Kenya Assumed | Kenya 15yr R. Year | Kenya 15yr R. Assumed |
|---|---|---|---|---|---|---|---|
| 0 | Initial establishment and weeding | 24.9 | 43.8 | 110.0 | 56.0 | 0 | 56.0 |
| 1 | Beating up and weeding | 2.2 | 4.2 | 21.2 | 7.2 | 1 | 7.2 |
| 2 | Weeding | 1.0 | 2.0 | 6.0 | 5.0 | 2 | 5.0 |
| 0-10 | Overhead per yr(average) | 1.0 | 1.7 | 5.8 | 2.6 | 0.15 | 2.0 |
| 10,20,30,40) | Weeding and | 1.4 | 2.4 | 5.0 | 4.0 | 15,30,45,60 | 4.0 |
| 11,21,31,41) | Coppice reduction | 1.0 | 2.0 | 3.0 | 3.0 | 16,31,46,61 | 3.0 |
| 11-50 | Overhead per yr(average) | 0.5 | 0.8 | 1.4 | 1.3 | 16-75 | 1.0 |
| 0-50 | Direct labour | 37.7 | 67.6 | 169.2 | 96.2 | | 96.2 |
| 0-50 | Supervisory and maintenance labour | 31.0 | 50.7 | 119.8 | 80.6 | | 92.0 |
| 0-50 | Total labour | 68.7 | 118.3 | 289.0 | 176.8 | | 188.2 |
| | Man years(270 man days/yr) | 0.3 | 0.4 | 1.1 | 0.7 | | 0.7 |

Appendix 5e Thinning and felling labour budget per cubic metre

Units man days

| Year | Operation | Tanzania Low | Tanzania High | Kenya Average | Kenya Assumed | Kenya 15yr R. Year | Kenya 15yr R. Assumed |
|---|---|---|---|---|---|---|---|
| 7,17,27,37,47 | Thinning | 0.55 | 0.82 | 1.38 | 1.10 | All thinnings | 1.10 |
| 10,20,30,40,50 | Felling | 0.50 | 0.75 | 1.25 | 1.00 | All fellings | 1.00 |
| | Thinning overhead | 0.02 | 0.03 | 0.05 | 0.04 | All thinnings | 0.04 |
| | Felling overhead | 0.02 | 0.03 | 0.05 | 0.04 | All fellings | 0.04 |

Appendix 5f Thinning and felling labour budget per hectare

Units man days

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7 | Thinning | 27.5 | 41.2 | 68.8 | 55.0 | 10 | 49.5 |
| 17,27,37.47 | Thinning | 35.8 | 53.6 | 89.4 | 71.5 | 25 40<br>55 70 | 60.5 |
| 10.20,30,40,50 | Felling | 125.0 | 187.5 | 312.5 | 250.0 | 15,30,45,60,75 | 180.0 |
| 7 | Thinning overhead | 1.0 | 1.5 | 2.5 | 2.0 | 10 | 1.8 |
| 17,27,37,47 | Thinning overhead | 1.31 | 2.0 | 3.2 | 2.6 | 25 40 | 2.2 |
| 10,20,30,40,50 | Felling overhead | 5.0 | 7.5 | 12.5 | 10.0 | 15,30,45,60,75 | 7.2 |
| 0-50 | Direct labour | 795.7 | 1193.1 | 1988.9 | 1591.0 | 0-75 D | 1191.5 |
| 0-50 | Supervisory labour | 31.2 | 47.0 | 77.8 | 62.4 | 0-75 S | 46.6 |
| 0-50 | Total labour | 826.9 | 1241.1 | 2066.7 | 1653.4 | 0-75 T | 1238.1 |
| | Man years (270 man days/yr) | 3.1 | 4.6 | 7.7 | 6.1 | | 4.6 |
| Area to give full employ. to 1 person in est. thinn. and felling | Direct | 16.2 | 10.7 | 6.3 | 8.0 | | 15.7 |
| | Sup. | 217.0 | 138.2 | 68.3 | 94.4 | | 146.1 |
| | Hectares Total | 15.1 | 9.9 | 5.7 | 7.4 | | 14.2 |



Appendix 6 Costs, returns and labour budget of a one hectare fuelwood plantation over the plantation's lifetime. Part of labour provided free. 'Shamba system'(1)

Appendix 6a Cost in man days of various establishment operations (direct costs) per ha.

Assumed rotation 10 years

| Year | Operation | Country Tanzania Low | Tanzania High | Kenya Average | Kenya Assumed |
|---|---|---|---|---|---|
| 0 | Nursery-Raising plants 1600 plants(including O/H) | 5.0 | 9.8 | 32.0 | 12.0 |
| | Forestry establishment(1600 plants) | | | | |
| 0 | Clearing | Done by farmers | | | |
| 0 | Staking | 3.7 | 5.0 | 10.0 | 8.0 |
| 0 | Pitting | 2.2 | 4.2 | 16.0 | 8.0 |
| 0 | Planting | 5.0 | 9.2 | 16.0 | 12.0 |
| 0 | Weeding | Done by farmers | | | |
| Initial establishment plus weeding | | 10.9 | 18.4 | 42.0 | 26.0 |
| 1 | Weeding 2nd year | Done by farmers | | | |
| 2 | Weeding 3rd year | 1.0 | 2.0 | 6.0 | 5.0 |
| 1&2 | Beating up 2nd&3rd year | 1.9 | 2.3 | 5.0 | 4.0 |
| | Weeding and B.U. total | 2.9 | 4.3 | 11.0 | 9.0 |
| | Plant costs for planting | 5.0 | .9.8 | 32.0 | 12.0 |
| | " " for B.U. | 0.5 | 1.0 | 3.2 | 1.2 |
| Total direct establishment costs(3 yrs) | | 19.3 | 33.5 | 88.2 | 48.2 |
| Overhead costs as a % of direct costs(2) | | 149 | 144 | 150 | 150 |
| | Daily pay for labour | 20 | | | |
| | Estimated establishment costs including overheads | 959 | 1632 | 4410 | 2410 |
| Saving compared to full cost models | | 438 | 806 | 2400 | 1000 |

(1) The costs from the full cost model(appendix 5a) have been used as a basis. Clearing and weeding in the first and second years is done by the farmers. Also, it is assumed that the pitting costs are reduced in the Kenyan examples because the land is already worked over by the farmers and these costs are high.

(2) Overhead costs included, local supervision, office staff, office rent, machines, material not directly used in establishment operations, road construction, fire patrol, etc., and a proportion of region, H.Q. and research costs.

Appendix 6b Direct and overhead costs per hectare for a fuelwood plantation on a ten year rotation plus four, ten year rotations (15 yrs.) for suckers. - Shamba system

| Year | Operation | Tanzania Low | Tanzania High | Kenya Average | Kenya Assumed | Kenya 15yr R. Year | Kenya 15yr R. Assumed |
|---|---|---|---|---|---|---|---|
| 0 | Initial establishment | 317 | 563 | 1480 | 760 | 0 | 760 |
| 1 | Beating up | 48 | 66 | 164 | 104 | 1 | 104 |
| 2 | Weeding | 20 | 40 | 120 | 100 | 2 | 100 |
| -4 to 10 (1) | Overhead costs per yr. (average) | 38 | 65 | 170 | 100 | -4 to -15 | 80 |
| 10,20,30,40) | Weeding and | 28 | 48 | 100 | 80 | 15,30,45,60) | 80 |
| 11,21,31,41) | Coppice reduction (2) | 20 | 40 | 60 | 60 | 16,31,46,61) | 60 |
| 11-50 | Overhead costs per yr. (average) | 35 | 63 | 115 | 100 | 16-75 | 75 |
| -4 to 50 | Direct costs | 577 | 1021 | 2404 | 1524 | -4 to 75 | 1524 |
| -4 to 50 | Overhead costs | 1970 | 3494 | 7150 | 5500 | -4 to 75 | 6100 |
| -4 to 50 | Total costs | 2547 | 4516 | 9554 | 7024 | -4 to 75 | 7624 |

(1) Overhead costs start when the farmers move in, that is four years before planting starts.

(2) No income attributed to small volume from coppice reduction.

Appendix 6c Anticipated volume production and income per hectare over the lifetime of the crop.

The volume production and the income from the volume is the same as in Appendix 5c. However, in addition there is an anticipated rent from the farmers of Kshs 15 per ha. for four years. Total Kshs.60

Appendix 6d Labour budget per hectare per year - establishment and maintenance.

| Year | Operation | Tanzania Low | Tanzania High | Kenya Average | Kenya Assumed | Kenya 15yr.R. Year | Kenya 15yr.R. Assumed |
|---|---|---|---|---|---|---|---|
| 0 | Initial establishment | 15.9 | 28.2 | 74.0 | 38.0 | 0 | 38.0 |
| 1 | Beating up | 2.4 | 3.3 | 8.2 | 5.2 | 1 | 5.2 |
| 2 | Weeding | 1.0 | 2.0 | 6.0 | 5.0 | 2 | 5.0 |
| -4-10 | Overhead per yr. (average) | 0.5 | 0.9 | 2.2 | 1.3 | -4-15 | 1.0 |
| 10,20,30,40) | Weeding and | 1.4 | 2.4 | 5.0 | 4.0 | 15,30,45,60 | 4.0 |
| 11,21,31,41) | Coppice reduction | 1.0 | 2.0 | 3.0 | 3.0 | 16,31,46,61 | 3.0 |
| 11-50 | Overhead per yr. (average) | 0.5 | 0.8 | 1.4 | 1.3 | 16-75 | 1.0 |
| 0-50 | Direct labour | 28.9 | 51.1 | 120.2 | 76.2 | | 76.2 |
| 0-50 | Supervisory and maintenance labour | 27.5 | 45.5 | 89.0 | 71.5 | | 80.0 |
| 0-50 | Total labour | 56.4 | 96.6 | 209.2 | 147.7 | | 156.2 |
| | Man Years (270 man days/yr) | 0.2 | 0.4 | 0.8 | 0.5 | | 0.6 |



Appendix 6e Thinning and felling labour budget per cubic metre.

This labour budget is the same as Appendix 5e.

Appendix 6f Thinning and felling labour budget per hectare.

This labour budget is the same as Appendix 5f except the area to give full employment to one person is marginally more.

Appendix 7 Costs, returns and labour budget of a one hectare agro-forestry system (tree cost/returns only) over the lifetime of the trees.

Appendix 7a Cost in man days of various establishment operations (direct costs) for a) planting seeds b) planting seedlings per hectare of agricultural land and per hectare equivalent of forest land.

Plant seeds or seedlings to secure 240 trees per hectare (15% of 1600) anticipated rotation 6 years plus another 4 rotations of 6 years from suckers.
Kenya assumed model costs used.

| Yr. | Operation | Kenya Assumed Costs: Seeds Planted: Hectare of agricultural land | Seeds Planted: Equivalent hectare of ForestLand | Seedlings Planted: Hectare of agic. land | Seedlings Planted: Equivalent hectare of ForestLand |
|---|---|---|---|---|---|
| 0 | Nursery-providing seeds | (0.1) | (0.7)(1) | | |
| 0 | " " seedlings | | | 1.8 | 12.0 |
| 0 | Transporting seedlings | (included in above) | | ( 1.2 ) | (8.0)(1) |
| | Establishment of trees | | | | |
| 0 | Clearing | Done for the farming system | | | |
| 0 | Staking | ) | | 0.2 | 1.4 |
| 0 | Pitting | ) 0.2 | 1.4 | 1.2 | 8.0 |
| 0 | Planting | ) | | 1.8 | 12.0 |
| 0 | Weeding (extra) | 0.8 | 5.3 | 0.8 | 5.3 |
| | Initial establishment & weeding | 1.0 | 6.7 | 4.0 | 26.7 |
| 1 | Weeding (extra) 2nd year | 0.5 | 3.3 | 0.5 | 3.3 |
| 2 | Weeding (extra) 3rd year | 0.5 | 3.3 | -NIL- | |
| | Weeding (extra) total | 1.0 | 6.6 | 0.5 | 3.3 |
| | Plant/seed cost & transport | (0.1) | (0.7) | 1.8 (3.0) | 12.0 (20.0) |
| | Total direct establishment cost | 2.0 | 13.3 | 6.3 | 42.0 |
| | Overhead cost (mainly extension advice) | 0.5 | 3.3 | 0.5 | 3.3 |
| | Estimated estab. costs incl. o/heads | 92 | 613 | 200 | 1333 |

(1) Figures in brackets are labour equivalent costs not direct labour costs.
(2) Overhead costs included a small amount for the farmers time protecting the trees plus a large amount for th cost of extension work given freely to the farmers.

Appendix 7b Direct and overhead costs per farm hectare and per forestry equivalent hectare for farm trees in agro-forestry systems on a six year rotation plus four six year rotations from suckers.

| Yr. | Operation | Kenya Assumed Costs: Seeds Planted: Agricultural land | Seeds Planted: Equivalent ForestLand | Seedlings Planted: Agric. land | Seedlings Planted: Equivalent ForestLand |
|---|---|---|---|---|---|
| 1 | Initial establishment and weeding | 22 | 147 | 140 | 933 |
| 1 | Extra weeding | 10 | 67 | 10 | 67 |
| 2 | Extra weeding | 10 | 66 | - | - |
| 0-6 | Overhead cost per yr (extension advice) | 10 | 67 | 10 | 67 |
| 6.12.18,24) | Extra weeding | 10 | 66 | 10 | 66 |
| 7,13,19,25) | Coppice reduction(1) | 10 | 67 | 10 | 67 |
| 7-30 | Overhead cost per yr(average) | 10 | 66 | 10 | 66 |
| 0-30 | Direct costs | 122 | 813 | 230 | 1533 |
| 0-30 | Overhead costs | 310 | 2067 | 310 | 2067 |
| 0-30 | Total costs | 432 | 2880 | 540 | 3600- |

(1)

(2) No income attributed to small volume obtained from coppice reduction.

In a controlled experiment with the Giant Hawaii strain of Leucaena leucocephala, one hectare of bushes mowed to a height of 1m every 3 months provided foliage containing 500-600Kgs. of nitrogen per year of which about 40% is available for enhancing crop growth, that is, 200-240Kgs/ha/yr. in addition the foliage contains 44% phosphorus, 187Kgs potassium as well as calcium and micro-nutrients per hectare.

On an agro-forestry system where wood production is as important as fertiliser production the anticipated yield of fertiliser would only be about half of a crop grown solely for fertiliser. Also the tree density on an agro-forestry system will only be about 15% of a pure forestry system so the anticipated available nitrogen from an agro-forestry Leucaena spp. system grown for fuel and fertiliser would be in the order of 15Kg/ha/yr of nitrogen(N), 3Kgs phosphorus(P), and 14Kg of potassium(K) but this should be worth more than the Kshs.20 as assumed in the model.

Note.

N:P:K:(15:15:15) cost 137/- per 50Kg bag which on average works out at about Kshs.6 per Kg. of N., P. or K. Therefore the above inputs from mulching is worth nearly ten times the above assumed figure or Kshs.190 of which the foreign exchange cost may be of Kshs.140 if mineral fertiliser was used instead.



Appendix 7c (i) Anticipated volume production and income per farm hectare and per forest equivalent hectare plus an estimate of the 'green manure' value of the tree leaves over the life of the croo

a) In high rainfall areas (seed)

| Yr | Operation | per ha Farm Land: Volume production $m^3$(1) | Income per standing $m^3$: at Kshs15 per $m^3$ | Income per standing $m^3$: at Kshs20 per $m^3$ | Fertiliser income | per ha equivalent Forest Land: Vol. prod. $m^3$(1) | Income per standing $m^3$: at Kshs15 per $m^3$ | Income per standing $m^3$: at Kshs20 per $m^3$ | Fertiliser income |
|---|---|---|---|---|---|---|---|---|---|
| 3 | Thinning/Branch mulching | 1.0 | 15 | 20 | ) | 6.7 | 100 | 133 | ) |
| 4 | " " | 2.0 | 30 | 40 | ) | 13.3 | 200 | 167 | ) |
| 5 | " " | 2.0 | 30 | 40 | ) | 13.3 | 200 | 166 | ) |
| 6 | Felling/Branch mulching | 21.0 | 315 | 420 | ) | 14.0 | 2100 | 2800 | ) |
| 8,14,20,26) | | 2.0 | 30 | 40 | ) 20 | 13.3 | 200 | 167 | ) 133 |
| 9,15,21,27) | Thinning and | 2.0 | 30 | 40 | ) | 13.3 | 200 | 166 | ) |
| 10,16,22,28) | Branch mulching | 2.0 | 30 | 40 | ) | 13.3 | 200 | 167 | ) |
| 11,17,23,29) | | 2.0 | 30 | 40 | ) | 13.3 | 200 | 167 | ) |
| 12,18,24,30 | Fell. and Br. Mulching | 19.0 | 285 | 380 | ) | 126.6 | 1900 | 2534 | ) |
| 0-30 | Thinning income/Mulching | 37.0 | 555 | 740 | 380 | 246.7 | 3700 | 4933 | 2533 |
| 0-30 | Felling income/Mulching | 97.0 | 1455 | 1940 | 100 | 646.6 | 9700 | 12934 | 667 |
| 0-30 | Total income | 134.0 | 2010 | 2680 | 480 | 893.3 | 13400 | 17867 | 3200 |

(1) This is average volume production over the 5 rotations. The average yields per rotation may be as follows : $m^3$/ha/yr 1st rotation 1.7(11.5), 2nd.R.3.0(20.0), 3rdR.2.6(17.2), 4thR.2.1(14.3), 5thR.1.7(11.5)

Forestry equivalent yields in brackets.

Appendix 7c (i) b) in high rainfall areas (seedlings)

| Yr | Operation | per ha Farm Land: Volume production $m^3$ (1) | Income per standing $m^3$: at Kshs15 per $m^3$ | Income per standing $m^3$: at Kshs20 per $m^3$ | Fertiliser income | per ha equivalent Forest Land: Vol. prod. $m^3$ (1) | Income per standing $m^3$: at Kshs15 per $m^3$ | Income per standing $m^3$: at Kshs20 per $m^3$ | Fertiliser income |
|---|---|---|---|---|---|---|---|---|---|
| 2,8,14,20,26 ) | | ) | ) | ) | ) | ) | ) | ) | ) |
| 3,9,15,21,27 ) | Thinnings and | ) | ) | ) | ) | ) | ) | ) | ) |
| 4,10,16,22,28) | branch | ) 2.0 | ) 30 | ) 40 | ) 20 | ) 13.3 | ) 200 | ) 167 | ) 133 |
| 5,11,17,23,29) | Mulching | ) | ) | ) | ) | ) | ) | ) | ) |
| 6,12,18,24,30) | Fell. & Br.Mulch. | 19.0 | 285 | 380 | | 126.6 | 1900 | 2533 | |
| 0-30 | Thinning & mulch. income | 40.0 | 600 | 800 | 400 | 266.7 | 4000 | 5333 | 2667 |
| 0-30 | Felling & mulch. income | 95.0 | 1425 | 1900 | 100 | 633.3 | 9500 | 12667 | 666 |
| 0-30 | Total income | 1350 | 2025 | 2700 | 500 | 900.1 | 13500 | 18000 | 333 |

(1) This is average volume production over the five rotations. The average yield per rotation may be as per footnote (1) table Appendix 7c(i) a).

Appendix 7c (ii) a) in medium rainfall areas (seeds)

| Yr | Operation | per ha Farm Land: Volume production $m^3$ (1) | Income per standing $m^3$: at Kshs15 per $m^3$ | Income per standing $m^3$: at Kshs20 per $m^3$ | Fertiliser income | per ha equivalent Forest Land: Vol. prod. $m^3$ (1) | Income per standing $m^3$: at Kshs15 per $m^3$ | Income per standing $m^3$: at Kshs20 per $m^3$ | Fertiliser income |
|---|---|---|---|---|---|---|---|---|---|
| 3) | Thinning and | 0.6 | 9 | 12 | ) | 4.0 | 60 | 80 | ) |
| 4) | branch | 1.2 | 18 | 24 | ) | 8.0 | 120 | 160 | ) |
| 5) | mulching | 1.2 | 18 | 24 | ) | 8.0 | 120 | 160 | ) |
| 6 | Felling & branch mulching | 12.1 | 182 | 242 | ) | 80.7 | 1210 | 1613 | ) |
| 8,14,20,26) | | 1.2 | 18 | 24 | ) 12 | 8.0 | 120 | 160 | ) 12 |
| 9,15,21,27) | Thinning and | 1.2 | 18 | 24 | ) | 8.0 | 120 | 160 | ) |
| 10,16,22,28) | branch mulching | 1.2 | 18 | 24 | ) | 8.0 | 120 | 160 | ) |
| 11,17,23,29) | | 1.2 | 18 | 24 | ) | 8.0 | 120 | 160 | ) |
| 12,18,24,30 | Fell. and Br. mulch. | 11.0 | 165 | 220 | ) | 73.3 | 1100 | 1467 | ) |
| 0-30 | Thinning & mulch. income | 22.2 | 333 | 444 | 240 | 148.0 | 2220 | 2960 | 1600 |
| 0-30 | Felling & mulch. income | 56.1 | 842 | 1122 | 48 | 374.0 | 5610 | 7480 | 320 |
| 0-30 | Total income | 78.3 | 1175 | 1566 | 288 | 522.0 | 7830 | 10440 | 1920 |

(1) See footnote (1) table Appendix 7c(ii) b)

Appendix 7c (ii) b) in medium rainfall areas (seedlings)

| Yr | Operation | per ha Farm Land: Volume production $m^3$ (1) | Income per standing $m^3$ at Kshs15 per $m^3$ | Income per standing $m^3$ at Kshs20 per $m^3$ | Fertiliser income | per ha equivalent Forest Land: Vol. prod. $m^3$ (1) | Income per standing $m^3$ at Kshs15 per $m^3$ | Income per standing $m^3$ at Kshs20 per $m^3$ | Fertiliser income |
|---|---|---|---|---|---|---|---|---|---|
| 2,8,14,20,26 ) 3,9,15,21,27 ) 4,10,16,22,28) 5,11,17,23,29) | Thinning and branch mulching | 1.2 | 18 | 24 | 12 | 8.0 | 120 | 160 | 12 |
| 6,12,18,24,30 | Fell.& Br.mulch. | 11.0 | 165 | 220 | | 73.3 | 1100 | 1467 | |
| 0-30 | Thinning & mulch.income | 24.0 | 360 | 480 | 240 | 1600 | 2400 | 3200 | 1600 |
| 0-30 | Felling & mulch.income | 55.0 | 825 | 1100 | 60 | 366.7 | 5500 | 7333 | 400 |
| 0-30 | Total income | 79.0 | 1185 | 1580 | 300 | 526.7 | 7900 | 10533 | 2000 |

(1) This is average volume production over the five rotations. The average yield per rotation may be as follows: $m^3$/ha/yr 1stR.1.0(6.8),2ndR.1.8(11.8),3rdR.1.5(10.1),4thR.1.3(8.4),5thR.1.0(6.8)
Forestry equivalent yields in brackets.

Appendix 7d Labour budget per hectare per year establishment and maintenance

Kenya Assumed Costs

| Year | Operation | Seeds Planted: per ha. Farm land | per ha. equivalent forest land | Seedlings Planted: per ha. Farm land | per ha. equivalent forest land |
|---|---|---|---|---|---|
| 0 | Initial establishment & weeding | 1.0 | 6.7 | 5.8 | 38.7 |
| 1 | Weeding | 0.5 | 3.3 | 0.5 | 3.3 |
| 1 | Weeding | 0.5 | 3.3 | - | - |
| 0-6 | Overhead per year | 0.1 | 0.7 | 0.1 | 0.7 |
| 6,12,18,24 ) | Weeding and coppice | 0.5 | 3.3 | 0.5 | 3.3 |
| 7,13,19,25 ) | reduction | 0.5 | 3.3 | 0.5 | 3.3 |
| 7-30 | Overhead per year | 0.1 | 0.7 | 0.1 | 0.7 |
| 0-30 | Direct labour | 6.0 | 40.0 | 10.3 | 68.7 |
| 0-30 | Supervisory & maintenance | 3.1 | 20.7 | 3.1 | 20.7 |
| 0-30 | Total labour | 9.1 | 60.7 | 13.4 | 89.4 |
| Man years (270 man days/year) | | | 0.2 | | 0.3 |

Appendix 7e Thinning,felling and mulching labour budget per $m^3$ (1)

| Year | Operation | Kenya Assumed Costs: per ha Farm Land | per ha Forest Land |
|---|---|---|---|
| 2,8,14,20,26 ) 3,9,15,21,27 ) 4,10,16,22,28) 5,11,17,23,29) | Thinning and mulching | 3.1 2.9 2.6 2.2 | 3.1 2.9 2.5 2.2 |
| 6,12,18,24,30 | Felling & mulching | 1.8 | 1.8- |
| | Thinning overhead | ) included in establishment | |
| | Felling overhead | ) overheads table Appendix 7d | |

(1) See Appendix 10

Appendix 7f

Thinning, felling and mulching labour budget per hectare

| Year | Operation | Kenya Assumed Costs: per ha farm land (High rainfall areas) | per ha forest land (High rainfall areas) | per ha farm land (Medium rainfall areas) | per ha forest land (Medium rainfall areas) |
|---|---|---|---|---|---|
| 2,8,14,20,26 ) 3,9,15,21,27 ) 4,10,16,22,28) 5,11,17,23,29) | Thinning and mulching | 6.2<br>5.8(2.9yr3)<br>5.2<br>4.4 | 41.3<br>38.7(19.3yr3)<br>34.7<br>29.3 | 3.7<br>3.5(1.7yr3)<br>3.1<br>2.6 | 24.7<br>23.3(11.6yr3)<br>20.8<br>17.6 |
| 6,12,18,24,30 | Felling & mulching | 34.2(37.8yr6) | 228.0(252yr6) | 19.8(21.8yr6) | 131.9(145.3yr6) |
| 0-30 | Total labour | 279.7 | 1864.7 | 163.7 | 1093.3 |
| Man years (270 man days/year ) | | 1.0 | 6.9 | 0.6 | 4.0 |
| Weight of wood felled etc.(tonnes) | | 84.4 | | 52.7 | |
| Man days per tonne (average consumption per capita) | | 3.3 | | 3.1 | |

Appendix 8 Cost,return and labour budget of a one hectare fuelwood/fodder plantation over the plantation's lifetime.'Athi plain model'

Appendix 8a Cost in man dats of various establishment operations(direct costs)per hecta

Plant seeds or seedlings to secure 1600 trees per hectare;anticipated rotation 15 years(medium rainfall area)plus a further foure rotations of 15 years from suckers.Assumed species Prosopis spp(1)
Kenya assumed model costs used.

| Year | Operation | Wood/fodder/honey: Plant Seeds | Wood/fodder/honey: Plant Seedlings | Wood only sold: Plant Seeds | Wood only sold: Plant Seedlings |
|---|---|---|---|---|---|
| 0 | Nursery - provide seeds | 1.0 | | 1.0 | |
| 0 | " " seedlings | | 12.0 | | 12.0 |
| | Establishment of trees | | | | |
| 0 | Fencing (materials Kshs 260) (2) | 2.5 | 2.5 | 2.5 | 2.5 |
| 0 | Ploughing(machine Kshs 600) (2) | 3.0 | 3.0 | NIL | NIL |
| 0 | Fertiliser(fertiliser Kshs 600)(2) | 1.0 | 1.0 | NIL | NIL |
| 0 | Clearing | 12.0 | 12.0 | 12.0 | 12.0 |
| 0 | Staking | ) | 5.0 | ) | 5.0 |
| 0 | Pitting | ) 1.4 | 5.0 | ) 2.0 | 10 |
| 0 | Planting | ) | 12.0 | ) | 12.0 |
| 0 | Weeding | 6.6 | 4.0 | 7.0 | 4.0 |
| 0 | Initial establishment plus weeding | 26.5 | 45.5 | 23.5 | 46.5 |
| 1 | Weeding | 7.0 | 4.5 | 7.0 | 4.5 |
| 1 | Beating up | 0.1 | 1.5 | 0.1 | 1.5 |
| 2 | Weeding | 5.0 | 5.0 | 5.0 | 5.0 |
| | Weeding and B.U. total | 12.1 | 11.0 | 12.1 | 11.0 |
| 0 | Plant/seed cost for planting | 1.0 | 12.0 | 1.0 | 12.0 |
| 1 | Plant/seed cost for B.U. | 0.1 | 1.2 | 0.1 | 1.2 |
| 0-2 | Total direct establishment cost | 39.7 | 69.7 | 36.7 | 70.7 |
| Overhead costs as% of direct costs excluding fencing,ploughing,fertilising(3)(4) | | 150 | 150 | 150 | 150 |
| Estimated establishment costs including overheads (Kshs) | | 3250 | 4750 | 2120 | 3720 |

(1) Prosopis pods contain 34-39% protein,and 7-8% oil.However seeds must be ground to obtain full food value,if not,most of the seeds which contain half the food value will be undigested.Prosopis flowers also have a sweet nectar which makes a fine hone

(2) The fencing material,fertiliser and ploughing machine costs are not included in the labour costs,these costs Kshs.1460 have to be added to the labour costs for the fuel-wood/fodder plantation,and just the fencing costs for the fuelwood plantation.

(3) Overhead costs include local supervision,office staff,office rent,machines,materials not directly used in establishment operations,road construction,fire patrol etc.and a proportion of regional,H.Q.and research costs.

(4) The overhead costs for fencing,ploughing and fertilising have already been included in the material/machine costs.

**Appendix 8b** Direct and overhead costs per hectare for a fuelwood/fodder plantation(and a fuelwood plantation alone) on a fifteen year rotation plus four fifteen year rotations from suckers. (Assumed species Prosopis spp.)

Kenyan assumed model costs used.

Units Kshs.

| Year | Operation | Wood/fodder/honey sold | | Wood only sold | |
|---|---|---|---|---|---|
| | | Plant Seeds | Seedlings | Plant Seeds | Seedlings |
| 0 | Initial establishment & weeding | 2010 | 2510 | 750 | 1430 |
| 1 | Beating up plus weeding | 144 | 144 | 144 | 144 |
| 2 | Weeding | 100 | 100 | 100 | 100 |
| 0-15 | Overhead costs per yr (average) | 200 | 200 | 150 | 150 |
| 15,30,45,60 | Fertiliser application | 620 | 620 | - | - |
| 15,30,45,60) 16,31,46,61) | Weeding and coppice reduction(1) | 60 | 60 | 60 | 60 |
| 16-75 | Overhead costs per yr (average) | 80 | 80 | 80 | 80 |
| 0-75 | Direct cost including materials and machines | 200 | 200 | 150 | 150 |
| 0-75 | Overhead costs | 5294 | 5894 | 1554 | 2234 |
| 0-75 | Total costs | 15200 | 15200 | 11400 | 11400 |
| | | 20494 | 21094 | 12954 | 13634 |

(1) No income to small volume of coppice reduction.

**Appendix 8c** Anticipated volume, fodder and honey production and income per hectare over the life of the crop. (Assumed species Prosopis spp)

| Year | Operation | Volume production $m^3$(1) | Pods production t | Honey production Kg | Income per standing $m^3$ at Kshs15 | Income per standing $m^3$ at Kshs20 | Uncollected pods worth Kshs300/t | Uncollected honey worth Kshs 1/Kg |
|---|---|---|---|---|---|---|---|---|
| 2 | Collecting pods and honey | | 0.5 | 10 | | | 150 | 10 |
| 3 | | | 1.0 | 20 | | | 300 | 20 |
| 4 | | | 1.5 | 20 | | | 450 | 20 |
| 5-15 | | | 2.0 | 20 | | | 600 | 20 |
| 10 | Thinning | 45 | | | 675 | 900 | | |
| 15 | Felling | 180 | | | 2700 | 3600 | | |
| 17,32,47,62, | Collecting pods and honey | | 0.5 | 10 | | | 150 | 10 |
| 18,33,48,63 | | | 1.0 | 20 | | | 300 | 20 |
| 19,34,49,64 | | | 1.5 | 20 | | | 450 | 20 |
| 20,30,35,45,50,60,65,75 | | | 2.0 | 20 | | | 600 | 20 |
| 25,40,55,70 | Thinning | 55 | | | 825 | 1100 | | |
| 30,45,60,75 | Felling | 180 | | | 2700 | 3600 | | |
| 0-75 | Pods/honey income | | 125.0 | 1350 | | | 37500 | 1350 |
| 0-75 | Thinning income | 265 | | | 3975 | 5300 | | |
| 0-75 | Felling income | 900 | | | 13500 | 18000 | | |
| 0-75 | Total income | 1165 | | | 17475 | 23300 | 37500 | 13500 |

(1) This is an average volume production over the lifetime of the crop. The average yield per rotation may be as follows:

$m^3$/ha/yr 1stR.11.5,2ndR20.9,3rdR.18.4,4: 4.9,5thR.11.9

## Appendix 8d Labour budget per hectare per year establishment and maintenance

| Kenya Assumed Costs | | | | | |
|---|---|---|---|---|---|
| Year | Operation | Wood/Fodder/honey | | Wood only sold | |
| | | Seeds | Seedlings | Seeds | Seedlings |
| 0 | Initial establishment | 27.5 | 57.5 | 24.5 | 58.5 |
| 1 | Weeding and beating up | 7.2 | 7.2 | 7.2 | 7.2 |
| 2 | Weeding | 5.0 | 5.0 | 5.0 | 5.0 |
| 0-15 | Overhead per year | 2.6 | 2.6 | 2.0 | 2.0 |
| 15,30,45,50 ) | Fertiliser application | 1.0 | 1.0 | - | - |
| 15,30,45,60 ) | Weeding and | 3.0 | 3.0 | 3.0 | 3.0 |
| 16,31,46,61 ) | Coppice reduction | 4.0 | 4.0 | 4.0 | 4.0 |
| 16-75 | Overhead per year | 2.6 | 2.6 | 2.0 | 2.0 |
| 0-75 | Direct labour | 71.7 | 71.7 | 67.7 | 67.7 |
| 0-75 | Supervisory and maintenance | 197.6 | 197.6 | 152.0 | 152.0 |
| 0-75 | Total labour | 269.3 | 269.3 | 219.7 | 219.7 |
| | Man years (270 man days/year) | 1.0 | 1.0 | 0.8 | 0.8 |

## Appendix 8e Thinning,felling,pod and honey labour budget per $m^3$ and tonne

| Year | Operation | | Wood/fodder/honey | | Wood only sold | |
|---|---|---|---|---|---|---|
| | | | Seeds | Seedlings | Seeds | Seedlings |
| 0-75 | All thinnings | per $m^3$ | 1.10 | 1.10 | 1.10 | 1.10 |
| 0-75 | All fellings | per $m^3$ | 1.00 | 1.00 | 1.00 | 1.00 |
| | Thinning overhead | per $m^3$ | 0.04 | 0.04 | 0.04 | 0.04 |
| | Felling overhead | per $m^3$ | 0.04 | 0.04 | 0.04 | 0.04 |
| 0-75 | All pod collection | per tonne (1) | 22.20 | 22.20 | - | - |
| 0-75 | All honey collection | per tonne (1) | 75.00 | 75.00 | - | - |
| P | Pod collection overhead | " " (1) | 0.50 | 0.50 | - | - |
| | Honey collection overhead | " " (1) | 2.0 | 2.0 | - | - |

(1) The labour inputs for collecting the pods and honey plus the supervision of the same are guesses, as these kinds of operations,especially the pod collecting has not been undertaken in Kenya to a large extent. Therefore these figures must be taken as provisional.
Pod collection includes carrying the pods(in sacks)to the nearest road for transport to the mill,and honey includes taking the honey and/or wax to the refinery or collecting point. It is assumed that the hive cannot produce both honey and wax at any one time.

## Appendix 8f Thinning,felling,pod and honey collection labour budget per hectare

| Year | Operation | | Wood/fodder/honey Seeds | Wood/fodder/honey Seedlings | Wood only Seeds | Wood only Seedlings |
|---|---|---|---|---|---|---|
| 10 | Thinning | | 49.5 | 49.5 | 49.5 | 49.5 |
| 25,40,55,70 | Thinning | | 60.5 | 60.5 | 60.5 | 60.5 |
| 15,30,45,60,75 | Felling | | 180 | 180 | 180 | 180 |
| 10 | Thinning overhead | | 1.8 | 1.8 | 1.8 | 1.8 |
| 25,40,55,70 | Thinning overhead | | 2.2 | 2.2 | 2.2 | 2.2 |
| 15,30,45,60,75 | Felling overhead | | 7.2 | 7.2 | 7.2 | 7.2 |
| 0-75 | Direct thinning & felling labour | | 1191.5 | | | |
| 0-75 | Supervisory " " " | | 46.6 | | | |
| 0-75 | Total fuelwood labour | | 1238.1 | | | |
| | Man years(270 man days/year) | | 4.6 | | | |
| Area to give full employment to one person in establishment,thinning and felling- hectares | | Direct | 16.0 | | 16.1 | |
| | | Sup. | 82.9 | | 102.0 | |
| | | Total | 13.4 | | 13.9 | |
| 2, 17,32,47,62 ) | | | Direct(O/H) | | | |
| 3, 18,33,48,63 ) | | | 11.0(0.25) | | | |
| 4, 19,34,49,64 ) | Collecting pods | | 22.0(0.50) | | | |
| 5, 20,35,50,65 ) | (supervision) | | 33.0(0.75) | | | |
| | | Total | 44.0(1.00) | | | |
| | | | 2750.9(62.50) | | | |
| 2, 17,32,47,62 ) | | | Direct(O/H). | | | |
| 3, 18,33,48,63 ) | Collecting honey | | 0.75( 0.10) | | | |
| 15,30,45,60,75 ) | (supervision) | | 1.50( 0.20) | | | |
| | | Total | 101.25( 2.70) | | | |
| 0-75 | Direct labour collecting pods & honey | | 2851.2 | | | |
| 0-75 | Supervisory labour " " " | | 65.2 | | | |
| 0-75 | Total Labour | | 2916.4 | | | |
| | Man years (270 man days /year | | 10.8 | | | |
| Area to give full employment to one person in pod and honey collection Hectares | | Direct | 7.1 | | | |
| | | Sup. | 310.6 | | | |
| | | Total | 6.9 | | | |
| Area to give full employment to one person- all operations combined Hectares | | Direct | 4.9 | | 16.1 | |
| | | Sup. | 65.4 | | 102.0 | |
| | | Total | 4.6 | | 13.9 | |
| Total man years (270 man days/year) | | | 16.4 | | 5.4 | |
| Average man years (270 d/yr) | | | 0.22 | | 0.07 | |

Appendix 9 Cost returns and labour budget of a one hectare fuelwood/fodder plantation over the plantation's lifetime!Low elevation model'

Appendix 9a Cost in man days of various establishment operations(direct costs)per ha.

Plant seeds or seedlings to secure 1600 trees per hectare:anticipated rotation 5 years plus a further 4 rotations of 5 years from suckers. Assumed species Leucaena spp.(1) (high rainfall areas)Prosopis sop.(2) (medium rainfall areas)

Kenya assumed model costs used.

| Year | Operation | High Rainfall Areas Plant seeds | High Rainfall Areas Plant seedlings | Medium Rainfall Areas Plant seeds | Medium Rainfall Areas Plant seedlings |
|---|---|---|---|---|---|
| 0 | Nursery- provide seeds | 1.0 | | 1.0 | |
| 0 | Nursery- provide seedlings | | 12.0 | | 12.0 |
| 0 | Establishment of trees :. same costs as per 'Athi plain'model App.8a | | | | |
| 0 | Initial establishment | 26.5 | 45.5 | 26.5 | 45.5 |
| 1-2 | Weeding & beating up | 7.1 | 6.0 | 12.1 | 11.0 |
| 0-1 | Plants for planting & beating up | 1.1 | 13.2 | 1.1 | 13.2 |
| 0-2 | Total direct establishment costs | 34.7 | 64.7 | 39.7 | 69.7 |
| Overhead costs as % of direct costs (3)(4) | | 150 | 150 | 150 | 150 |
| Estimated establishment costs including(O/H) Kshs. | | 3000 | 4500 | 3250 | 4750 |

(1) Leucaena leaves,if grown for fodder alone,will yield about 8 tonnes of edible dry matter per ha.per year. This is equivalent to about 1000kgs of protein per ha/yr. However,when grown for fuel and fodder the production of fodder will drop. It has been assumed that in order to obtain 14m$^3$ wood per ha.per year the annual yield of fodder will be 4 tonnes per ha. at a maximum and average 3.0t/ha/a

(2) Prosopis will yield 2 tonnes of dry matter(pods)at a maximum and on average 1¼ t/ha/yr.In addition the average honey yield will be 14Kg/ha/a. The average annual yield of wood is estimated to be 9.6m$^3$/ha.

(3) Overhead costs include local supervision,office staff,office rent,machines,materials not directly used in establishment operations,road construction,fire patrol etc. and a proportion of regional,H.Q. and research costs. If the forest service does not undertake such plantations then these latter O/H costs are not applicable.

(4) The overhead costs for fencing,ploughing and fertilising have already been included in the material/machine costs.

Appendix 9b Direct and overhead costs per hectare for a fuelwood/fodder plantation on a 5 year rotation plus 4 five year rotations from suckers. a) In a high rainfall area b)in a medium rainfall area both at low elevations (below 1,500 m )

Kenya assumed costs used Units Kshs.

| Year | Operation | High Rainfall Areas Seeds | High Rainfall Areas Seedlings | Medium Rainfall Areas Seeds | Medium Rainfall Areas Seedlings |
|---|---|---|---|---|---|
| 0 | Initial establishment & weeding | 2010 | 2610 | 2010 | 2610 |
| 1 | Beating up plus weeding | 144 | 144 | 144 | 144 |
| 2 | Weeding | - | - | 100 | 100 |
| 0-5 | Overhead costs per yr.(average) | 200 | 200 | 200 | 200 |
| 5,10,15,20 | Fertiliser application | 620 | 620 | 620 | 620 |
| 5,10,15,20) | Weeding and | 100 | 100 | 100 | 100 |
| 6,11,16,21) | reduction (1) | - | - | 60 | 60 |
| 6-25 | Overhead costs per yr.(average) | 100 | 100 | 100 | 100 |
| 0-25 | Direct cost incl.mat.& mchs. | 5134 | 5634 | 5374 | 5374 |
| 0-25 | Overhead costs | 2700 | 2700 | 2700 | 2700 |
| 0-25 | Total costs | 7834 | 8334 | 8074 | 8574 |

(1) No income attributed to small volume coppice reduction.

Appendix 9c (i) Anticipated volume and fodder production and income per hectare over the lifetime of the crop.- high rainfall area(Leucaena spp.)

| Year | Operation | Volume production m$^3$(1) | Weight production leaves t(2) | Income Fuelwood Kshs15 m$^3$ | Income Fuelwood Kshs20 m$^3$ | Uncollected leaves Kshs. 150t |
|---|---|---|---|---|---|---|
| 1,6 ,11,16,21) | Thinning | 1 | 0.75 | 15 | 20 | 112.5 |
| 2,7 ,12,17.22) | Collecting | 2 | 2.50 | 30 | 40 | 375.0 |
| 3,8 ,13,18,23) | leaves | 6 | 4.0 | 90 | 120 | 600.0 |
| 4,9 ,14,19,24) | | 16 | 4.0 | 240 | 320 | 600.0 |
| 5,10,15,20,25 | Felling & collecting lvs. | 45 | 4.0 | 675 | 900 | 600.0 |
| 0-25 | Leaves income | | 76.25 | | | 11437.5 |
| 0-25 | Thinning income | 125 | | 1875 | 2500 | |
| 0-25 | Felling income | 225 | | 3375 | 4500 | |
| 0-25 | Total income | 350 | 76.25 | 5250 | 7000 | 11437.5 |

(1) This is an average volume production over the life of the crop.The average per rotation may be as follows: m$^3$/ha/yr 1stR.10.3,2ndR.18.8,3rdR.16.6,4thR.13.5, 5thR.10.8. Average- 14.

(2) Air dry tonnes of leaves average production 3.05 t/ha/a

**Appendix 9c(ii)** Anticipated volume, fodder and honey production and income per hectare over the lifetime of the crop- medium rainfall area. (Prosopis spp.)

| Year | Operation | Volume production $m^3$ (1) | Pods production t (2) | Huney production Kg | Income per standing $m^3$ at Kshs15 | Income per standing $m^3$ at Ksns20 | Uncollected pods worth Ksns 300/t | Uncollected honey worth Kshs 1/Kg |
|---|---|---|---|---|---|---|---|---|
| 2,7,12,17,22, 3,8,13,18,23 4,9,14,19,24 50,10,15,20,25 | Thinning, collecting pods and honey Felling,pods,honey | 1<br>3<br>12<br>32 | 0.75<br>1.50<br>2.00<br>2.0 | 10<br>20<br>20<br>20 | 15<br>45<br>180<br>480 | 20<br>60<br>240<br>640 | 225<br>450<br>600<br>600 | 10<br>20<br>20<br>20 |
| 0-25 | Pods/honey income | 80 | 21.25 | 350 | 1200 | 1600 | 6375 | 350 |
| 0-25 | Thinning income | 160 | | | 2400 | 3200 | | |
| 0-25 | Felling income | 240 | 21.25 | 350 | 3600 | 4800 | 6375 | 350 |
| 0-25 | Total income | | | | | | | |

(1) This is an average volume production over the lifetime of the crop. The average yield per rotation may be as follows: 1stR.7.1,2ndR.12.9,3rdR.11.4,4thR.9.2,5thR.7.4, Average 9.6

(2) Air dry tonnes, average yield 4.25t/ha/a

**Appendix 9d** Labour budget per hectare per year establishment and maintenance

Kenya Assumed Costs

| | | High Rainfall Seeds | High Rainfall Seedlings | Medium Rainfall Seeds | Medium Rainfall Seedlings |
|---|---|---|---|---|---|
| 0 | Initial establishment | 27.5 | 57.5 | 27.5 | 57.5 |
| 1 | Weeding and beating up | 7.2 | 7.2 | 7.2 | 7.2 |
| 2 | Weeding | - | - | 5.0 | 5.0 |
| 0-5 | Overheads per year(average) | 2.6 | 2.6 | 2.6 | 2.6 |
| 5,10,15,20 | Fertiliser application | 1.0 | 1.0 | 1.0 | 1.0 |
| 5,10,15,20) | Weeding & coppice | 5.0 | 5.0 | 5.0 | 5.0 |
| 6,11,16,21) | reduction | - | - | 3.0 | 3.0 |
| 6-25 | Overheads per year(average) | 1.3 | 1.3 | 1.3 | 1.3 |
| 0-25 | Direct labour | 58.7 | 88.7 | 75.7 | 105.7 |
| 0-25 | Supervisory & maintenance | 41.6 | 41.6 | 41.6 | 41.6 |
| 0-25 | Total labour | 100.3 | 130.3 | 117.3 | 147.3 |
| | Man years(270 man days/yr) | 0.4 | 0.5 | 0.4 | 0.5 |

**Appendix 9e** Thinning, felling, leaves, pod and honey collection labour budget per $m^3$ and tonne

| Year | Operation | High Rainfall Seed | High Rainfall Seedling | Medium Rainfall Seed | Medium Rainfall Seedling |
|---|---|---|---|---|---|
| 1,6 ,11,16,21 ) | Thinning per $m^3$ | 3.10 | | | |
| 2,7 ,12,17,22 ) | | 3.00 | | | |
| 3,8 ,13,18,23 ) | | 2.80 | | | |
| 4,9 ,14,19,24 ) | | 2.50 | | | |
| 5,10,15,20,25 | Felling per $m^3$ | 2.00 | | | |
| 0-25 | Thinning & felling overhead/$m^3$ | 0.04 | | | |
| 0-25 | All leaves/pod collection per tonne(1) | 22.00 | | | |
| 0-25 | All honey collection per tonne(1) | 75.00 | | | |
| 0-25 | Leaves/pod overhead per tonne (1) | 0.50 | | | |
| 0-25 | Honey overhead per tonne (1) | 2.00 | | | |

(1) The labour inputs for collecting the leaves, pods and honey, plus the supervision of the same, are guesses as these kinds of operations, especially the leaves and pod collecting, have not been undertaken in Kenya to a large extent. Therefore these figures must be taken as provisional. Pod collection includes carrying the pods in sacks, sun-drying the leaves and then carrying the sacks to the nearest road for transporting to the mill, and honey includes taking the honey and/or wax to the refinery or collecting point. It is assumed that the hive cannot produce both honey and wax at any one time.

Appendix 9f Thinning, felling, pod, leaf and honey collection labour budget per ha.

| Year | Operation | High Rainfall Seeds (Leucaena) | High Rainfall Seedling (Leucaena) | Medium Rainfall Seeds (Prosopis) | Medium Rainfall Seedling (Prosopis) |
|---|---|---|---|---|---|
| 1,6 ,11,16,21) | Direct labour(Supervision) | 3.1(0.04) | | ------ | |
| 2,7 ,12,17,22) | | 6.0(0.08) | | 3.0(0.04) | |
| 3,8 ,13,18,23) | Thinning (overhead ) | 16.8(0.24) | | 8.4(0.12) | |
| 4,9 ,14,19,24) | | 40.0(0.54) | | 30.0(0.48) | |
| 5,10,15,20,25 | Felling (overhead ) | 90.0(1.80) | | 64.0(1.28) | |
| 0-25 | Direct thinning & felling labour | 779.5 | | 527.0 | |
| 0-25 | Supervisory " " " | 14.0 | | 9.6 | |
| 0-25 | Total fuelwood labour | 793.5 | | 536.6 | |
| | Man years(270 man days/yr.) | 2.9 | | 2.0 | |
| Area to give full employment to one person in establishment, thinning and felling.- Hectares | Direct | 8.1 | 7.8 | 11.2 | 10.7 |
| | Sup. | 121.4 | 121.4 | 131.8 | 131.8 |
| | Total | 7.6 | 7.3 | 10.3 | 9.9 |
| | | Direct(O/H) | | Direct(O/H) | |
| 1,6 ,11,16,21) | | 16.5(0.38) | | - - | |
| 2,7 ,12,17,22) | Collecting leaves | 55.0(1.25) | | 16.5(0.38) | |
| 3,8 ,13,18,23) | and pods | 88.0(2.00) | | 33.0(0.75) | |
| 4,9 ,14,19.24) | (Supervision) | 88.0(2.00) | | 44.0(1.00) | |
| 5,10,15,20,25) | | 88.0(2.00) | | 44.0(1.00) | |
| | Total | 1677.5(38.12) | | 687.5(15.62) | |
| | | | | Direct (O/H) | |
| 2,7 ,12,17,22) | Collecting honey | | | 0.75 0.10 | |
| 3,8 ,13,18,23) | (Supervision) | | | 1.50 0.20 | |
| 5,10,15,20,25) | | | Total | 26.25 3.50 | |
| 0-25 | Direct labour collecting leaves, pods and honey | 1677.5 | | 713.8 | |
| 0-25 | Supervisory labour collecting leaves, pods and honey | 38.1 | | 19.1 | |
| 0-25 | Total labour | 1715.6 | | 732.9 | |
| | Man years (270 man days per yr.) | 6.4 | | 2.7 | |
| Area to give full employment to one person in fodder and honey collection - Hectares | Direct | 4.0 | | 9.5 | |
| | Sup. | 177.2 | | 353.4 | |
| | Total | 3.9 | | 9.2 | |
| Area to give full employment to one person- all operations combined Hectares | Direct | 2.7 | 2.7 | 5.0 | 5.0 |
| | Sup. | 72.0 | 72.0 | 96.0 | 96.0 |
| | Total | 2.6 | 2.6 | 4.9 | 4.8 |
| Man years all operations (270 d/y) | | 9.7 | 9.8 | 5.1 | 5.2 |
| Average man years(270 d/y) | | 0.39 | 0.39 | 0.21 | 0.21 |



Appendix 10 Felling and extraction of Eucalyptus- direct labour budget according to diameter and distance extracted

Appendix 10a Crop Specifications (1)

| Diameter at breast height | (cms) | 3 | 10 | 18 | 20 |
|---|---|---|---|---|---|
| Age of crop | (yrs) | 1.5 | 4 | 10 | 13 |
| Total height | ( m ) | 3.3 | 9.3 | 15.0 | 16.0 |
| Mid-diameter | (cms) | 2.5 | 5.5 | 12.8 | 13.5 |
| Stem volume to tip 1000 trees | ($m^3$ ) | 1.6 | 22.0 | 192.0 | 229.0 |
| Stem & branch volume " " | ($m^3$ ) | 1.9 | 26.5 | 203.0 | 275.0 |
| Plants per hectare | | 10000 | 1600 | 1600 | 1600 |
| Cumulative volume | ($m^3$ ) | 19.4 | 42.4 | 326 | 444 |
| Average annual yield per ha. | ($m^3$ ) | 12.9 | 10.6 | 32.6 | 34.2 |

(1) It is assumed that fuelwood will not be grown to diameter greater than 20cms.

Appendix 10b Productivity of trained workers in temperate country (1)(6)

Unit $m^3$ per 8 hour day per person

| Diameter | | 3(5) | 10 | 18 | 20 |
|---|---|---|---|---|---|
| Felling, snedding, cross-cutting(2) | ($m^3$) | 2.05 | 3.65 | 17.17 | 20.30 |
| Debarking (2) | ($m^3$) | 1.66 | 3.67 | 8.87 | 9.56 |
| Extraction a) 40 metres (3) | ($m^3$) | 4.76 | 4.76 | 4.76 | 4.76 |
| b) 100 metres | ($m^3$) | 2.38 | 2.38 | 2.38 | 2.38 |
| All operations combined a) 40 metres | $m^3$ per man day | 0.77 | 1.32 | 2.61 | 2.75 |
| b) 100 metres | $m^3$ per man day | 0.66 | 1.03 | 1.68 | 1.74 |
| All operations combined a) 40 metres | MAN DAYS PER $M^3$ | 1.30 | 0.76 | 0.38 | 0.36 |
| b) 100 metres | MAN DAYS PER $M^3$ | 1.51 | 0.97 | 0.59 | 0.57 |

Source : Harvesting in man-made forests in developing countries. FAO Rome 1976.

(1) All hand labour used.

(2) Felling with hand saw and axe, snedding(removing branches) with an axe and cross-cutting to metre lengths with a saw.

(3) Removing bark by hand with a barking tool to facilitate drying.

(4) Extraction by headload and stacking piles im x 1.5m x 2m

(5) The source book did not give figures for 3cm DBH, these have been extrapolated from graphs which started at 10cms DBH

(6) Normal allowances have been made for rest time etc.

Appendix 10c Reduction applied to temperate countries productivity figures to arrive at figures for tropical countries

Units Trees felled & extracted per 8 hour day per person ( $m^3$/day )

| Diameter (cms) | 3 | 10 | 18 | 20 |
|---|---|---|---|---|
| **Operation** | | | | |
| Felling, Snedding & Cross-cutting | | | | |
| Cutting shortwood with power saw (temperate rate) | 1200(2.28) | 153(4.05) | 94(19.08) | 82(22.55) |
| Using saw and axe: reduce production by 10% | 1080(2.05) | 137.7(3.65) | 84.6(17.17) | 73.8(20.30) |
| Cross-cut into lengths shorter than 2.5m reduce 15% | 918 | 117 | 72 | 63 |
| Undulating terrain, reduce 5% | 872 | 111 | 68 | 60 |
| Lack of experience reduce 30% | 610 | 78 | 48 | 42 |
| Body weight (1) reduce 15% | 523 | 67 | 41 | 36 |
| Nutritional factor (2) reduce 12½% | 458 | 58 | 36 | 31 |
| Heat stress reduce 10% | 412(0.78) | 52.5(1.39) | 32.3(6.55) | 28.2(7.74) |
| **Debarking** | Units $m^3$ per 8 hour day per person | | | |
| Debarking in temperate countries | 1.66 | 3.67 | 8.67 | 9.56 |
| Lack of experience reduce 30% | 1.16 | 2.56 | 6.07 | 6.67 |
| Body weight (1) " 15% | 1.00 | 2.20 | 5.20 | 5.74 |
| Nutritional factor (2) " 12½% | 0.87 | 1.93 | 4.55 | 5.02 |
| Heat stress " 10% | 0.78 | 1.73 | 4.10 | 4.52 |
| Extraction distance (metre) | 40 | 60 | 80 | 100 |
| **Extraction (3)** | Units $m^3$ per 8 hour day per person | | | |
| Extraction in temperate climate | 1.76 | 4.50 | 2.74 | 2.38 |
| Body weight (1) reduce 15% | 4.08 | 3.75 | 2.35 | 2.04 |
| Nutritional factor (2) " 12½% | 3.57 | 3.28 | 2.06 | 1.78 |
| Heat stress " 10% | 2.22 | 2.96 | 1.85 | 1.61 |

(1) Normal body weight for workers in temperate climates is about 70Kgs. Assumed average body weight for workers in tropical climates is about 60Kgs. Therefore apply reduction factor 60/70 or reduce by 14.3%

(2) Food intake per day for manual workers should be 4000 calories. Assume worker in tropical climate consumes 3,500 calories, reduction fraction is 3500/4000 = 12.5%

(3) Figures taken from a two man crew. Productivity could be increased substantially by using a wheeled U-frame (sulky) for extraction.

Appendix 10d Productivity estimates of partially trained workers in tropical countries felling and extracting by hand

Units $m^3$ per 8 hour day per person

| Diameter | 3 | 10 | 18 | 20 |
|---|---|---|---|---|
| **Operation** | | | | |
| Felling, snedding cross-cutting (1) ($m^3$) | 0.78 | 1.39 | 6.55 | 7.74 |
| Debarking (2) ($m^3$) | 0.78 | 1.73 | 4.10 | 4.52 |
| Extraction a) 40m (3) ($m^3$) | 3.22 | 3.22 | 3.22 | 3.22 |
| b) 100m ($m^3$) | 1.61 | 1.61 | 1.61 | 1.61 |
| All operations combined a) 40 metres | 0.35 | 0.62 | 1.41 | 1.51 |
| $m^3$/man day b) 100 metres | 0.31 | 0.52 | 0.98 | 1.03 |
| All operations combined a) 40 metres | 2.87 | 1.61 | 0.71 | 0.56 |
| b) 100 metres | 3.19 | 1.12 | 1.02 | 0.97 |

Source : Harvesting in man-made forests in developing countries FAO Rome 1976

(1) Felling with hand saw and axe, snedding (removing branches) with axe and cross-cutting into metre lengths with hand saw.

(2) Removing bark by hand with barking tool to facilitate drying

(3) Extraction by headload and stacking at roadside in piles 1m x 1.5m x 2m The productivity for 60m and 80m is also given in table Appendix 10c

(4) Normal allowance has been made for rest time etc.

## Appendix 11: Costs, returns and labour budget of proposed agro-forestry programme

### Appendix 11a. Volume and cost multipliers for the agroforestry models

Appendix 7 gives the anticipated yield for high potential areas as 2.8 t/ha/yr where as the assumed average yield from agricultural land with agro-forestry, woodlots and hedges is 4.0 t/ha/yr. Therefore the costs and volume figures as given in appendix 7 have to be increased by 4.0/2.8 = 1.43 to give average cost and yield figures for the high potential areas. Similarly the multiplier for the medium potential areas is $2.5/1.755^2 = 1.424$. The adjusted yields for high and medium potential areas is as follows:-

| Yield: | High rainfall | | | | medium rainfall | | | |
|---|---|---|---|---|---|---|---|---|
| | Anticipated | | Adjusted | | Anticipated | | Adjusted | |
| Establish: | Seed | Seedling | S | SL | S | SL | S | SL |
| Year | | | | | | | | |
| 2 | - | 1.52 | - | 2.17 | - | 0.91 | - | 1.30 |
| 3 | 0.76 | 1.52 | 1.09 | 2.17 | 0.45 | 0.91 | 0.64 | 1.30 |
| 4 | 1.52 | | 2.17 | | 0.91 | | 1.30 | |
| 5 | " | | " | | " | | " | |
| 6 | 14.54 | 15.99 | 20.79 | 22.87 | 8.30 | 9.14 | 11.83 | 13.02 |
| 7 | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| 8 | 2.67 | | 3.82 | | 1.59 | | 2.26 | |
| 9 | " | | " | | " | | " | |
| 10 | " | | " | | " | | " | |
| 11 | " | | " | | " | | " | |
| 12 | 25.33 | | 36.22 | | 14.62 | | 20.82 | |
| 13 | NIL | | NIL | | NIL | | NIL | |
| 14 | 2.36 | | 3.37 | | 1.41 | | 2.01 | |
| 15 | " | | " | | " | | " | |
| 16 | " | | " | | " | | " | |
| 17 | " | | " | | " | | " | |
| 18 | 22.38 | | 32.00 | | 12.95 | | 18.44 | |
| 19 | NIL | | NIL | | NIL | | NIL | |
| 20 | 1.91 | | 2.73 | | 1.41 | | 1.62 | |
| 21 | " | | " | | " | | " | |
| 22 | " | | " | | " | | " | |
| 23 | " | | " | | " | | " | |
| 24 | 18.16 | | 25.97 | | 10.44 | | 14.87 | |



### Appendix 11b. Costs and returns of proposed agroforestry schemes in high rainfall areas: Pressure planted

| Year | Farm area planted ha | Direct costs: Seeds | Direct costs: Farm per year | Direct costs: Total | Cumulative total | Overhead costs: Per year | Overhead costs: Cumulative total | Total costs: Per year | Total costs: Cumulative total | Volume production t/ha | Revenue: Stumpage per m³ per yr | Revenue: Stumpage cumulative | Stumpage costs per m³ per yr | Stumpage costs cumulative | Fertilizer, insecticide per yr | Fertilizer, insecticide cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Units | | | | | |
| 1982 0 | 54 | 0.15 | 1.54 | 1.69 | 1.69 | 0.77 | 0.77 | 3.46 | 3.46 | | | | | | | |
| 1 | 120 | 0.34 | 4.20 | 4.54 | 6.23 | 2.45 | 3.22 | 4.99 | 8.45 | | | | | | | |
| 85 2 | " | " | 5.92 | 6.26 | 12.49 | 4.72 | 7.94 | 10.98 | 19.43 | | | | | | | |
| 3 | " | " | 6.87 | 7.21 | 19.70 | 5.85 | 13.79 | 13.06 | 32.49 | | | | | | | |
| 4 | " | " | " | " | 26.91 | 7.61 | 20.85 | 14.82 | 47.31 | 59 | 0.88 | 0.88 | 1.18 | 1.18 | 0.54 | 0.54 |
| 5 | " | " | " | " | 34.12 | 9.23 | 30.18 | 16.54 | 63.85 | 248 | 3.72 | 4.60 | 4.96 | 6.14 | 1.74 | 2.28 |
| 6 | 165 | 0.47 | 8.93 | 9.40 | 43.52 | 11.65 | 41.83 | 21.05 | 84.90 | 508 | 7.62 | 12.22 | 10.16 | 16.30 | 2.94 | 5.22 |
| 90 7 | " | " | 11.29 | 11.76 | 55.28 | 14.05 | 55.88 | 25.81 | 110.71 | 1886 | 28.29 | 40.51 | 37.72 | 54.02 | 4.14 | 9.36 |
| 8 | " | " | 12.88 | 13.35 | 68.63 | 16.41 | 72.29 | 29.76 | 140.47 | 3345 | 50.92 | 91.43 | 67.10 | 121.12 | 4.80 | 14.16 |
| 9 | " | " | " | " | 81.98 | 18.77 | 91.06 | 32.12 | 172.59 | 3601 | 54.02 | 145.45 | 72.02 | 193.14 | 5.34 | 19.50 |
| 10 | " | " | " | " | 95.33 | 21.12 | 112.19 | 34.48 | 207.52 | 4108 | 61.62 | 207.07 | 82.16 | 275.10 | 6.49 | 26.49 |
| 11 | " | " | " | " | 108.68 | 23.49 | 135.68 | 36.64 | 244.36 | 4644 | 69.96 | 277.03 | 93.28 | 368.38 | 8.64 | 35.13 |
| 95 12 | 167 | 0.48 | 14.35 | 14.83 | 123.51 | 25.86 | 161.54 | 40.11 | 285.07 | 5220 | 78.30 | 355.33 | 104.44 | 472.78 | 10.24 | 45.42 |
| 13 | 170 | 0.49 | 17.31 | 17.81 | 140.82 | 28.31 | 189.87 | 45.62 | 330.69 | 8458 | 126.87 | 482.20 | 169.16 | 642.94 | 11.94 | 57.36 |
| 14 | " | " | 18.33 | 18.82 | 159.15 | 30.74 | 220.61 | 49.97 | 379.76 | 10848 | 162.72 | 644.92 | 216.96 | 859.90 | 12.66 | 69.96 |
| 15 | " | " | " | " | 177.48 | 33.17 | 253.78 | 51.50 | 431.26 | 11292 | 169.39 | 814.31 | 226.04 | 1083.94 | 13.59 | 83.55 |
| 16 | " | " | " | " | 195.81 | 35.60 | 289.38 | 53.43 | 484.69 | 11780 | 176.70 | 989.65 | 235.60 | 1319.54 | 15.26 | 98.81 |
| 2000 17 | " | " | " | " | 214.14 | 38.05 | 327.43 | 56.38 | 541.57 | 12363 | 185.44 | 1170.09 | 247.26 | 1566.80 | 16.96 | 115.77 |
| 18 | (3661) | 14.46 | 14.46 | 28.92 | 243.06 | " | 345.48 | 52.61 | 594.08 | 12950 | 194.25 | 1364.34 | 259.00 | 1825.80 | 18.66 | 134.43 |
| 19 | " | " | " | " | 271.98 | " | 409.53 | " | 646.54 | 16583 | 248.73 | 1613.07 | 331.64 | 2157.44 | 20.36 | 154.79 |
| 20 | " | 13.92 | 13.92 | 27.84 | 299.90 | " | 441.58 | " | 697.66 | 18743 | 281.44 | 1894.51 | 375.24 | 2532.70 | 21.05 | 175.84 |
| 21 | " | " | " | " | 327.82 | " | 474.63 | 51.07 | 748.73 | 19070 | 286.05 | 2165.56 | 381.40 | 2914.10 | 22.06 | 197.90 |
| 2005 22 | " | " | " | " | 355.74 | " | 517.68 | " | 799.80 | 19384 | 290.76 | 2456.32 | 387.68 | 3301.78 | " | 219.96 |
| 23 | " | " | " | " | 383.66 | " | 555.73 | " | 850.87 | 19514 | 292.71 | 2749.03 | 390.28 | 3692.06 | " | 242.02 |
| 2007 24 | " | " | 11.26 | 11.26 | 394.40 | " | 593.78 | 49.31 | 900.18 | 19644 | 294.66 | 3043.65 | 392.88 | 4084.94 | " | 264.05 |
| Discounted | 0.25 | 12.45 | 11.201 | 23.65 | | 35.05 | | 56.75 | | 16.102 | 242.55 | | 324.06 | | 22.06 | |

Appendix 11c. Costs and returns of prepared agroforestry scheme in high rainfall areas – tree seedling, plant

| Year | | Farm area planted 000 ha | Direct costs: Nursery P-y | Farm P-y | Total P-y | Cumulative total | Overhead cost: per year | Cumulative | Total cost: per year | Cumulative | Volume 000 m³ | Revenue: Stumpage 15% per m³ P-y | Cumulative | Stumpage per m³ P-y | Cumulative | 20% | Cumulative | Fertilizer at 114 per ha P-y | Income per ha Cumulative | UNIT'S MILL K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1982 | 0 | 54 | 4.63 | 6.17 | 10.80 | 10.80 | 0.77 | 0.77 | 11.57 | 11.57 | | | | | | | | | | |
| | 1 | 120 | 14.28 | 14.49 | 26.77 | 35.57 | 2.45 | 3.22 | 27.22 | 38.79 | | | | | | | | | | |
| 1985 | 2 | " | " | 15.44 | 25.72 | 61.25 | 4.17 | 7.35 | 29.89 | 68.60 | 1.17 | 1.76 | 1.76 | 2.34 | 2.34 | 0.54 | 0.54 | | | |
| | 3 | " | " | " | " | 87.01 | 5.85 | 13.24 | 31.57 | 100.25 | 3.77 | 5.65 | 7.41 | 7.54 | 9.88 | 1.74 | 2.28 | | | |
| | 4 | " | " | " | " | 112.73 | 7.61 | 20.85 | 33.33 | 133.58 | 4.37 | 4.56 | 16.97 | 12.74 | 22.62 | 2.94 | 5.22 | | | |
| | 5 | " | " | " | " | 38.45 | 9.33 | 30.18 | 35.05 | 168.63 | 8.97 | 13.45 | 30.42 | 17.94 | 40.56 | 4.14 | 9.36 | | | |
| | 6 | 165 | 14.14 | 21.35 | 35.49 | 173.74 | 11.05 | 41.83 | 47.14 | 215.77 | 21.43 | 32.44 | 62.88 | 43.24 | 83.82 | 5.34 | 14.70 | | | |
| 1990 | 7 | " | " | 23.71 | 37.85 | 211.75 | 14.05 | 55.88 | 51.90 | 267.63 | 35.35 | 53.03 | 115.89 | 70.70 | 154.52 | 6.00 | 20.70 | | | |
| | 8 | " | " | 24.66 | 38.80 | 250.55 | 16.41 | 72.29 | 55.21 | 322.84 | 38.39 | 57.58 | 173.47 | 76.78 | 231.30 | 6.99 | 27.69 | | | |
| | 9 | " | " | " | " | 284.35 | 18.77 | 91.06 | 57.57 | 380.41 | 43.95 | 65.93 | 239.40 | 87.90 | 319.20 | 8.64 | 36.33 | | | |
| | 10 | " | " | " | " | 328.15 | 21.13 | 112.19 | 59.93 | 440.34 | 49.51 | 74.26 | 313.66 | 99.02 | 418.23 | 10.29 | 46.62 | | | |
| | 11 | " | " | " | " | 366.99 | 23.49 | 135.68 | 62.29 | 502.67 | 55.07 | 82.61 | 396.27 | 110.14 | 528.38 | 11.94 | 58.56 | | | |
| 1995 | 12 | 147 | 14.31 | 26.30 | 40.61 | 407.60 | 25.88 | 161.56 | 66.49 | 569.16 | 86.50 | 129.75 | 526.02 | 173.00 | 701.36 | 13.59 | 72.15 | | | |
| | 13 | 170 | 16.57 | 29.03 | 45.60 | 451.20 | 28.31 | 189.87 | 71.41 | 641.07 | 110.40 | 165.60 | 691.62 | 220.80 | 922.16 | 14.25 | 86.40 | | | |
| | 14 | " | " | 30.02 | 44.54 | 495.79 | 30.74 | 220.61 | 75.33 | 716.40 | 113.98 | 170.97 | 862.55 | 227.96 | 1150.12 | 15.26 | 101.66 | | | |
| | 15 | " | " | " | " | 540.38 | 33.17 | 253.78 | 77.76 | 794.16 | 119.85 | 179.78 | 1042.37 | 239.70 | 1389.82 | 16.46 | 118.62 | | | |
| | 16 | " | " | " | " | 584.97 | 35.60 | 289.38 | 80.19 | 874.35 | 125.72 | 188.58 | 1230.95 | 251.44 | 1641.26 | 18.66 | 137.28 | | | |
| 2000 | 17 | " | " | " | " | 629.56 | 38.05 | 327.43 | 82.64 | 956.99 | 131.59 | 197.38 | 1428.33 | 263.18 | 1904.44 | 20.34 | 157.62 | | | |
| | 18 | (2661) | – | 12.06 | 12.06 | 641.62 | " | 365.48 | 50.11 | 1007.10 | 167.88 | 251.82 | 1680.15 | 335.76 | 2240.20 | 22.16 | 179.78 | | | |
| | 19 | – | – | 12.03 | 12.03 | 653.65 | " | 403.53 | 50.08 | 1057.18 | 189.62 | 284.43 | 1964.58 | 379.24 | 2619.44 | 22.75 | 202.53 | | | |
| | 20 | – | – | 12.02 | 12.02 | 666.67 | " | 441.58 | 51.07 | 1108.25 | 189.00 | 283.50 | 2248.08 | 378.00 | 2997.44 | 22.06 | 224.59 | | | |
| | 21 | – | – | " | " | 679.69 | " | 479.63 | " | 1159.32 | 190.30 | 285.45 | 2533.53 | 380.60 | 3378.04 | " | 246.65 | | | |
| 2005 | 22 | – | – | " | " | 692.71 | " | 517.68 | " | 1210.39 | 191.60 | 287.40 | 2820.93 | 383.20 | 3761.24 | " | 268.71 | | | |
| | 23 | – | – | " | " | 705.73 | " | 555.73 | " | 1261.46 | 192.90 | 289.35 | 3110.28 | 385.80 | 4147.04 | " | 290.77 | | | |
| 2007 | 24 | | | 11.26 | 11.26 | 716.99 | " | 593.78 | 49.31 | 1310.77 | 188.81 | 283.22 | 3393.50 | 377.62 | 4524.66 | " | 312.83 | | | |
| Steady state | | 230 R | 7.60 | 18.70 | 26.30 | | 38.05 | | 64.35 | | 170.30 | 255.45 | | 340.60 | | 22.06 | | | | |

App 11d. Labour requirements agroforestry systems: High potential areas

| | Year | Area planted 000 ha | Farm labour: Seeds planted Est | Thin & fell | Farm labour: Seedlings pltd Est. | Thin & fell | Nursery: Raising seedlings | Forestry extension work: Graduates Univ | College | Office staff | Total | Total paid workers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 0 | 54 | 285 | | 1144 | | 515 | 1 | 14 | 14 | 29 | 544 |
| | 1 | 120 | 781 | | 2685 | | 1144 | 5 | 46 | 41 | 92 | 1236 |
| 1985 | 2 | " | 1100 | | 2859 | 1343 | " | 8 | 78 | 70 | 156 | 1300 |
| | 3 | " | 1274 | 633 | " | 4242 | " | 11 | 110 | 98 | 219 | 1363 |
| | 4 | " | " | 2534 | " | 6905 | " | 14 | 142 | 127 | 283 | 1427 |
| | 5 | " | " | 4864 | " | 9235 | " | 17 | 173 | 157 | 347 | 1491 |
| | 6 | 165 | 1656 | 14263 | 3959 | 17888 | 1574 | 22 | 217 | 195 | 434 | 2008 |
| 1990 | 7 | " | 2093 | 24323 | 4396 | 27034 | " | 26 | 261 | 234 | 521 | 2095 |
| | 8 | " | 2385 | 26688 | 4570 | 30524 | " | 30 | 304 | 275 | 609 | 2183 |
| | 9 | " | " | 32320 | " | 36682 | " | 35 | 348 | 313 | 696 | 2270 |
| | 10 | " | " | 37953 | " | 42315 | " | 39 | 392 | 353 | 784 | 2358 |
| | 11 | " | " | 43856 | " | 47218 | " | 44 | 436 | 391 | 871 | 2445 |
| 1995 | 12 | 167 | 2659 | 64816 | 4874 | 68365 | 1593 | 48 | 480 | 431 | 959 | 2552 |
| | 13 | 170 | 3115 | 80749 | 5378 | 84298 | 1622 | 52 | 525 | 472 | 1049 | 2671 |
| | 14 | " | 3304 | 84814 | 5563 | 88409 | " | 57 | 570 | 512 | 1139 | 2761 |
| | 15 | " | 3311 | 91188 | 5559 | 94885 | " | 61 | 615 | 553 | 1229 | 2851 |
| | 16 | " | " | 97053 | 5563 | 100793 | " | 66 | 660 | 593 | 1319 | 2941 |
| 2000 | 17 | " | " | 102174 | 5559 | 105914 | " | 70 | 705 | 634 | 1409 | 3031 |
| | 18 | (246) | 2678 | 126726 | 2230 | 130626 | | " | " | " | " | 1409 |
| | 19 | | " | 141266 | 2226 | 145119 | | " | " | " | " | " |
| | 20 | | 2411 | 144791 | 2411 | 144407 | | " | " | " | " | " |
| | 21 | | " | 148306 | " | 145946 | | " | " | " | " | " |
| 2005 | 22 | | " | 149769 | " | 147409 | | " | " | " | " | " |
| | 23 | | " | 151116 | " | 148756 | | " | " | " | " | " |
| 2007 | 24 | | 2226 | 146194 | 2226 | 146194 | | " | " | " | " | " |
| Steady state | | | 2818 | 128125 | 3993 | 130641 | 814 | 70 | 705 | 634 | 1409 | 2255 |
| per ha md/yr | | | 0.74 | 13.04 | 0.41 | 13.30 | 0.09 | 0.01 | 0.07 | 0.06 | 0.14 | 0.23 |

Units Man years
270 mandays per year.

Appendix 11e. Costs and Returns of Proposed agroforestry scheme in Medium rainfall Area – Tree Seedlings Planted.

| YEAR | Farm Area Hundred 000ha | Direct costs: Seedlings | Farm | Total | cumulative total | Overhead Costs: per year | Cumulative Total | Total costs: Per Year | cumulative Total | Volume Production 000m³ | Revenue: Stumpage 15% Per Year | Cumulative | Stumpage 25% Per Year | Cumulative | Fertilisation income at 10% per ha. per Year | Cumulative | LINITS MILL KSH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 0 | 3 | 0.01 | 0.09 | 0.10 | 0.10 | 0.04 | 0.04 | 0.14 | 0.14 | | | | | | | | |
| 1 | 10 | 0.03 | 0.32 | 0.35 | 0.45 | 0.18 | 0.22 | 0.53 | 0.67 | | | | | | | | |
| 85 2 | 20 | 0.06 | 0.75 | 0.81 | 1.26 | 0.46 | 0.68 | 1.27 | 1.94 | | | | | | | | |
| 3 | " | " | 0.99 | 1.05 | 2.31 | 0.74 | 1.42 | 1.79 | 3.73 | 2 | 0.03 | 0.03 | 0.04 | 0.04 | 0.03 | 0.03 | |
| 4 | " | " | 1.13 | 1.19 | 3.50 | 1.02 | 2.44 | 2.21 | 5.94 | 10 | 0.15 | 0.18 | 0.20 | 0.24 | 0.3 | 0.16 | |
| 5 | " | " | " | " | 4.69 | 1.30 | 3.74 | 2.49 | 8.43 | 30 | 0.45 | 0.63 | 0.60 | 0.84 | 0.33 | 0.49 | |
| 6 | " | " | 1.17 | 1.23 | 5.92 | 1.58 | 5.32 | 2.81 | 11.24 | 91 | 1.34 | 1.97 | 1.76 | 2.60 | 0.53 | 1.02 | |
| 90 7 | " | " | 1.31 | 1.37 | 7.29 | 1.86 | 7.18 | 3.23 | 14.47 | 195 | 2.85 | 4.82 | 3.80 | 6.40 | 0.70 | 1.72 | |
| 8 | " | " | 1.55 | 1.61 | 8.90 | 2.14 | 9.32 | 3.75 | 18.22 | 332 | 4.86 | 9.68 | 6.48 | 12.88 | 0.83 | 2.55 | |
| 9 | " | " | 1.62 | 1.75 | 10.65 | 2.42 | 11.74 | 4.11 | 22.33 | 356 | 5.19 | 14.87 | 6.92 | 19.80 | 0.93 | 3.48 | |
| 10 | " | " | " | " | 12.40 | 2.70 | 14.44 | 4.45 | 26.84 | 399 | 5.85 | 20.72 | 7.80 | 27.60 | 1.13 | 4.61 | |
| 11 | " | " | " | " | 14.15 | 2.98 | 17.42 | 4.75 | 31.57 | 445 | 6.51 | 27.23 | 8.68 | 36.28 | 1.33 | 5.94 | |
| 95 12 | 22 | 0.06 | 1.79 | 1.85 | 16.00 | 3.29 | 20.71 | 5.14 | 36.71 | 545 | 7.58 | 35.12 | 10.64 | 46.92 | 1.53 | 7.47 | |
| 13 | 25 | 0.07 | 2.04 | 2.11 | 18.11 | 3.64 | 24.35 | 5.75 | 42.46 | 714 | 10.44 | 45.56 | 13.92 | 60.84 | 1.70 | 9.17 | |
| 14 | " | " | 1.65 | 1.72 | 19.83 | 3.99 | 28.34 | 5.71 | 48.17 | 928 | 13.58 | 59.14 | 18.10 | 78.94 | 1.83 | 11.00 | |
| 15 | " | " | 1.84 | 1.91 | 21.74 | 4.34 | 32.68 | 6.25 | 54.42 | 944 | 13.89 | 73.03 | 18.52 | 97.46 | 1.95 | 12.99 | |
| 16 | " | " | " | " | 23.65 | 4.69 | 37.37 | 6.60 | 61.02 | 994 | 14.55 | 87.58 | 19.40 | 116.86 | 2.20 | 15.19 | |
| 2000 17 | " | " | " | " | 25.56 | 5.04 | 42.41 | 6.95 | 67.97 | 1041 | 15.24 | 102.82 | 20.32 | 137.18 | 2.45 | 17.64 | |
| 18 | (360) | | 1.55 | 1.55 | 27.11 | " | 47.45 | 6.59 | 74.56 | 1101 | 16.28 | 119.10 | 22.04 | 159.22 | 2.70 | 20.34 | |
| 19 | | | 1.41 | 1.41 | 28.52 | " | 52.49 | 6.45 | 81.01 | 1349 | 19.72 | 139.52 | 26.30 | 186.12 | 2.90 | 23.24 | |
| 20 | | | 1.65 | 1.65 | 30.17 | " | 57.53 | 6.63 | 87.70 | 1545 | 22.58 | 162.10 | 30.10 | 216.22 | 3.05 | 26.25 | |
| 21 | | | 1.79 | 1.79 | 31.96 | " | 62.57 | 6.83 | 94.53 | 1554 | 22.74 | 184.84 | 30.32 | 246.54 | 2.95 | 29.20 | |
| 2005 22 | | | " | " | 33.75 | " | 67.61 | 6.83 | 101.36 | 1545 | 22.70 | 207.74 | 30.54 | 277.08 | 2.95 | 32.15 | |
| 23 | | | 1.46 | 1.46 | 35.21 | " | 72.65 | 6.50 | 107.86 | 1577 | 23.07 | 230.81 | 30.76 | 307.84 | 2.95 | 35.10 | |
| 2007 24 | | | 1.27 | 1.27 | 36.48 | " | 77.69 | 6.31 | 114.17 | 1372 | 20.08 | 250.89 | 20.71 | 334.62 | 2.95 | 38.05 | |
| Steady state | 30 R | 0.04 | 1.47 | 1.51 | | 3.59 | | 5.10 | | 1342 | 20.13 | | 20.87 | | 1.86 | | |

Appendix 11f. Costs and returns of Proposed agroforestry scheme in Medium rainfall Area – Seedlings Planted. UNITS IN MILLS KSH.

| YEAR | Farm Area per Hundred | Direct costs: Nursery | Farm | Total | cumulative | Overhead costs: Total | cumulative | Total costs: Per Year | cumulative | Volume Production 000m³ | Revenue: Stumpage 15% PY | Cumulative | Stumpage 25% PY | Cumulative | Fertilisation income at 10% per ha. PY | Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 0 | 3 | 0.26 | 0.34 | 0.60 | 0.60 | 0.04 | 0.04 | 0.64 | 0.64 | | | | | | | |
| 1 | 10 | 0.35 | 1.18 | 2.03 | 2.63 | 0.18 | 0.22 | 2.21 | 2.85 | | | | | | | |
| 85 2 | 20 | 1.71 | 2.42 | 4.13 | 6.76 | 0.46 | 0.68 | 4.55 | 7.44 | 4 | 0.06 | 0.06 | 0.08 | 0.08 | 0.03 | 0.03 |
| 3 | " | " | 2.56 | 4.27 | 11.03 | 0.74 | 1.42 | 5.01 | 12.45 | 17 | 0.26 | 0.32 | 0.34 | 0.42 | 0.13 | 0.16 |
| 4 | " | " | " | " | 15.30 | 1.02 | 2.44 | 5.29 | 17.74 | 43 | 0.64 | 0.96 | 0.86 | 1.28 | 0.33 | 0.49 |
| 5 | " | " | " | " | 19.57 | 1.30 | 3.74 | 5.57 | 23.31 | 69 | 1.04 | 2.00 | 1.38 | 2.66 | 0.53 | 1.02 |
| 6 | " | " | 2.60 | 4.31 | 23.88 | 1.58 | 5.32 | 5.89 | 29.20 | 126 | 1.89 | 3.87 | 2.52 | 5.18 | 0.73 | 1.75 |
| 90 7 | " | " | 2.74 | 4.45 | 28.33 | 1.86 | 7.18 | 6.31 | 35.51 | 222 | 3.31 | 7.22 | 4.44 | 9.62 | 0.90 | 2.65 |
| 8 | " | " | 2.98 | 4.69 | 33.02 | 2.14 | 9.32 | 6.83 | 42.34 | 347 | 5.20 | 12.42 | 6.94 | 16.56 | 1.03 | 3.68 |
| 9 | " | " | 3.13 | 4.83 | 37.85 | 2.42 | 11.74 | 7.25 | 49.59 | 370 | 5.59 | 18.01 | 7.40 | 23.96 | 1.13 | 4.81 |
| 10 | " | " | " | " | 42.68 | 2.70 | 14.44 | 7.53 | 57.12 | 415 | 6.22 | 24.23 | 8.30 | 32.26 | 1.33 | 6.14 |
| 11 | " | " | " | " | 47.51 | 2.98 | 17.42 | 7.81 | 64.93 | 461 | 6.92 | 31.15 | 9.22 | 41.48 | 1.53 | 7.67 |
| 12 | 22 | 1.88 | 3.38 | 5.26 | 52.77 | 3.29 | 20.71 | 8.55 | 73.48 | 561 | 8.42 | 39.57 | 11.22 | 52.70 | 1.73 | 9.40 |
| 13 | 25 | 2.14 | 3.90 | 6.04 | 58.81 | 3.64 | 24.35 | 9.68 | 83.16 | 730 | 10.95 | 50.52 | 14.60 | 67.30 | 1.90 | 11.30 |
| 14 | " | " | 4.18 | 6.32 | 65.13 | 3.99 | 28.34 | 10.31 | 93.47 | 946 | 14.19 | 64.71 | 18.92 | 86.22 | 2.05 | 13.35 |
| 15 | " | " | 4.32 | 6.46 | 71.59 | 4.34 | 32.68 | 10.80 | 104.27 | 965 | 14.48 | 79.19 | 19.30 | 105.52 | 2.20 | 15.55 |
| 16 | " | " | 4.30 | " | 78.05 | 4.69 | 37.37 | 11.19 | 115.46 | 1020 | 15.30 | 94.49 | 20.40 | 125.92 | 2.45 | 16.00 |
| 2000 17 | " | " | 4.32 | " | 84.51 | 5.04 | 42.41 | 11.50 | 126.96 | 1066 | 15.99 | 110.48 | 21.32 | 147.24 | 2.70 | 20.70 |
| 18 | (360) | | 1.54 | 1.54 | 86.05 | " | 47.45 | 6.58 | 133.54 | 1184 | 17.76 | 128.24 | 23.68 | 170.92 | 2.95 | 23.65 |
| 19 | | | 1.40 | 1.40 | 87.45 | " | 52.49 | 6.44 | 139.98 | 1368 | 20.52 | 148.76 | 27.36 | 198.28 | 2.15 | 25.80 |
| 20 | | | 1.68 | 1.68 | 89.13 | " | 57.53 | 6.72 | 146.70 | 1530 | 22.95 | 171.71 | 30.60 | 228.88 | 3.05 | 28.85 |
| 21 | | | 1.82 | 1.82 | 90.95 | " | 62.57 | 6.86 | 153.56 | 1524 | 22.86 | 194.57 | 30.48 | 259.36 | 2.95 | 31.80 |
| 2005 22 | | | " | 1.82 | 92.77 | " | 67.61 | 6.86 | 160.42 | 1535 | 23.02 | 217.59 | 30.70 | 290.06 | 2.95 | 34.75 |
| 23 | | | " | 1.82 | 94.59 | " | 72.65 | 6.86 | 167.28 | 1547 | 23.20 | 240.79 | 30.94 | 321.00 | 2.95 | 37.70 |
| 2007 24 | | | 1.54 | 1.54 | 96.13 | " | 77.69 | 6.56 | 173.86 | 1372 | 20.58 | 261.37 | 27.44 | 348.44 | 2.95 | 40.65 |
| Steady state | 6 | 1.05 | 2.75 | 3.81 | | 3.60 | | 7.11 | | 1355 | 20.32 | | 27.10 | | 1.94 | |

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App 11a Labour requirements agro forestry systems medium potential areas

Units million rupees

| | Year | area planted 000ha | Farm labour seedling plantation Est. | Farm labour seedling plantation Thinning/fell | Farm labour seedlings plantation Est. | Farm labour seedlings plantation Thinning/fell | Nursery raising seedlings | Forestry extension work Graduates Univ. | Graduates College | Office staff | Total | Total paid workers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 6 | 3 | 15 | | 63 | | 30 | 0 | 1 | 1 | 2 | 32 |
| | 7 | 10 | 59 | | 219 | | 96 | 0 | 4 | 3 | 7 | 103 |
| | 8 | 20 | 137 | | 448 | 65 | 184 | 1 | 8 | 8 | 17 | 206 |
| | 9 | " | 81 | 21 | 474 | 191 | " | 1 | 14 | 13 | 28 | 217 |
| | 1990 7 | " | 207 | 197 | " | 477 | " | 3 | 19 | 17 | 38 | 227 |
| | 5 | " | " | 294 | " | 735 | " | 2 | 25 | 22 | 49 | 238 |
| | 6 | " | 315 | 753 | 481 | 1171 | " | 3 | 30 | 26 | 54 | 248 |
| 1994 | 7 | " | 241 | 1464 | 507 | 1836 | " | 4 | 35 | 31 | 70 | 254 |
| | 8 | " | 285 | 2420 | 552 | 2702 | " | 4 | 40 | 36 | 80 | 269 |
| | 9 | " | 311 | 2674 | 578 | 2960 | " | 5 | 45 | 41 | 91 | 289 |
| | 10 | " | " | 3149 | " | 3451 | " | 5 | 51 | 46 | 102 | 291 |
| | 1 | " | " | 3619 | " | 3901 | " | 6 | 56 | 50 | 112 | 301 |
| 1995 | 12 | 22 | 330 | 4381 | 626 | 4443 | 207 | 6 | 62 | 56 | 124 | 331 |
| | 13 | 25 | 381 | 5537 | 722 | 5819 | 237 | 7 | 65 | 62 | 137 | 374 |
| | 14 | " | 741 | 6194 | 774 | 7305 | " | 8 | 75 | 67 | 150 | 387 |
| | 15 | " | 474 | 7235 | 800 | 7605 | " | 8 | 81 | 74 | 163 | 400 |
| | 16 | " | " | 7721 | " | 8112 | " | 9 | 88 | 79 | 176 | 413 |
| 2000 | 17 | " | " | 8174 | " | 8565 | " | 10 | 95 | 85 | 190 | 427 |
| | 18 | (340) | 365 | 4057 | 289 | 9433 | | " | " | " | " | 190 |
| | 19 | | 337 | 10341 | 263 | 9693 | | " | " | " | " | " |
| | 20 | | 315 | 11678 | 315 | 12030 | | " | " | " | " | " |
| | 21 | | 341 | 11815 | 316 | 11617 | | " | " | " | " | " |
| 2005 | 22 | | " | 11973 | " | 11775 | | " | " | " | " | " |
| | 23 | | " | 12134 | " | 11936 | | " | " | " | " | " |
| 2007 | 24 | | 289 | 10542 | " | 10542 | | " | " | " | " | " |
| Steady state | | | 380 | 10126 | 538 | 10348 | 114 | 10 | 95 | 85 | 190 | 304 |
| per ha | mill/yr | | 0.28 | 7.59 | 0.40 | 7.76 | 0.09 | 0.01 | 0.07 | 0.06 | 0.14 | 0.23 |
| man hours per yr | | | 2 | 61 | 3 | 62 | | | | | | |

Appendix 12a Costs and returns of proposed replanted forest schemes

UNITS MILLION RUPEES

| Year | Area replanted 000ha | Direct costs: Nursery | Direct costs: Per year Forest | Direct costs: Per year total | Direct costs: Cumulative total | Overhead costs: per year | Overhead costs: cumulative total | Total costs: per yr | Total costs: cumulative total | Vol prod mill m³ | Revenue from plantation: Stump price 15/- m³ p.y. | Revenue from plantation: Stump price 15/- m³ cumulative | Revenue from plantation: Stump price 20/- m³ p.y. | Revenue from plantation: Stump price 20/- m³ cumulative | Vol field clearing million m³ | Revenue from clearing (1): Sp. 15/- m³ p.y. | Revenue from clearing (1): Sp. 15/- m³ cumulative | Revenue from clearing (1): Sp. 20/- m³ p.y. | Revenue from clearing (1): Sp. 20/- m³ cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 0 | 6 | 1.44 | 5.28 | 6.72 | 6.72 | 1.20 | 1.20 | 7.92 | 7.92 | 6 | 7 | 7 | 9 | 9 | 0.45 | 6.75 | 6.75 | 9.00 | 9.00 |
| 1 | 10 | 2.54 | 9.52 | 12.06 | 18.78 | 3.20 | 4.40 | 15.26 | 23.18 | | | | | | 0.75 | 11.25 | 18.00 | 15.00 | 24.00 |
| 1985 2 | 4 | 2.64 | 10.60 | 13.24 | 32.02 | 5.20 | 9.60 | 18.44 | 41.62 | | | | | | " | " | 24.25 | " | 39.00 |
| 3 | " | " | 11.00 | 13.44 | 45.46 | 7.20 | 16.80 | 20.64 | 62.46 | | | | | | " | " | 40.50 | " | 54.00 |
| 4 | " | " | | | 54.30 | 9.20 | 26.00 | 22.34 | 85.30 | | | | | | " | " | 56.75 | " | 69.00 |
| 5 | " | " | | | 72.94 | 11.20 | 37.20 | 24.64 | 111.14 | | | | | | " | " | 63.00 | " | 85.00 |
| 6 | " | " | | | 86.58 | 13.20 | 50.40 | 26.84 | 136.98 | | | | | | " | " | 70.25 | " | 94.00 |
| 1990 7 | 15 | 3.84 | 15.60 | 19.24 | 105.82 | 16.20 | 66.60 | 35.44 | 172.42 | 0.23 | 3.45 | 3.45 | 4.60 | 4.60 | 1.12 | 16.80 | 91.05 | 22.40 | 121.40 |
| 8 | 20 | 5.16 | 20.40 | 25.56 | 131.38 | 20.20 | 86.80 | 45.76 | 218.18 | 0.38 | 5.70 | 9.15 | 7.60 | 12.20 | 1.50 | 22.50 | 113.55 | 30.00 | 151.40 |
| 9 | " | 5.23 | 21.50 | 26.78 | 158.16 | 24.20 | 111.00 | 50.98 | 269.16 | " | " | 14.85 | " | 19.80 | " | " | 136.05 | " | 181.40 |
| 10 | " | " | 22.48 | 27.76 | 185.92 | 28.20 | 139.20 | 55.96 | 325.12 | 1.53 | 22.95 | 37.80 | 30.60 | 50.40 | " | " | 159.55 | " | 211.40 |
| 11 | " | " | 23.16 | 28.44 | 214.36 | 31.60 | 170.80 | 60.04 | 385.16 | 2.30 | 34.50 | 72.30 | 46.00 | 96.40 | " | " | 181.05 | " | 241.40 |
| 1995 12 | " | " | 23.40 | 28.68 | 243.04 | 34.60 | 205.40 | 63.28 | 448.44 | " | " | 106.80 | " | 142.40 | " | " | 203.55 | " | 271.40 |
| 13 | 25 | 6.48 | 27.80 | 34.28 | 277.32 | 38.60 | 244.00 | 72.88 | 521.32 | " | " | 141.30 | " | 188.40 | 1.58 | 28.40 | 231.95 | 31.50 | 308.90 |
| 14 | " | 6.60 | 28.40 | 35.00 | 312.32 | 42.60 | 286.60 | 77.60 | 598.92 | 2.49 | 37.35 | 178.65 | 49.80 | 238.20 | 1.57 | 25.65 | 257.60 | " | 343.40 |
| 15 | " | " | 28.90 | 35.50 | 347.82 | 46.60 | 333.20 | 82.10 | 681.02 | 2.68 | 40.20 | 218.85 | 53.60 | 291.80 | 1.58 | 28.40 | 286.00 | " | 381.40 |
| 16 | " | " | " | | 383.32 | 50.60 | 383.80 | 86.10 | 767.12 | " | " | 259.05 | " | 345.40 | 1.57 | 28.65 | 316.05 | " | 421.40 |
| 2000 17 | " | " | 29.30 | 35.40 | 418.22 | 54.60 | 438.40 | 90.50 | 857.62 | 4.49 | 67.35 | 326.40 | 89.80 | 435.20 | 1.66 | 29.90 | 346.25 | " | 461.50 |
| 18 | (300) | 0.60 | 8.60 | 9.60 | 427.82 | 53.10 | 491.50 | 61.70 | 919.32 | 5.51 | 82.65 | 409.05 | 110.20 | 545.40 | | | " | | " |
| 19 | | | 5.30 | 5.30 | 433.12 | 51.10 | 542.60 | 56.40 | 975.72 | " | " | 487.20 | | 649.60 | | | " | | " |
| 20 | | | 3.28 | 3.28 | 436.40 | 49.10 | 591.70 | 52.38 | 1028.10 | 7.60 | 117.00 | 604.20 | 156.00 | 805.60 | | | " | | " |
| 21 | | | 3.46 | 3.46 | 440.86 | 47.10 | 638.80 | 51.06 | 1079.16 | 9.20 | 138.00 | 742.20 | 184.00 | 989.60 | | | " | | " |
| 2005 22 | | | 4.20 | 4.20 | 444.56 | 45.10 | 683.90 | 49.30 | 1128.46 | " | " | 880.20 | " | 1173.60 | | | " | | " |
| 23 | | | 4.60 | 4.60 | 449.16 | 43.10 | 727.00 | 47.70 | 1176.16 | 10.16 | 152.40 | 1032.60 | 203.20 | 1376.80 | | | " | | " |
| 24 | | | 4.90 | 4.90 | 454.06 | 40.66 | 767.66 | 45.50 | 1221.66 | 10.66 | 159.90 | 1192.50 | 213.20 | 1590.00 | | | " | | " |
| 2008 25 | | | [illegible] | [illegible] | [illegible] | 38.10 | 805.76 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | " | | " |
| Steady state | | 1.62 | 16.10 | 17.72 | | 37.77 | | 37.77 | | 1.55 | 23.25 | | 31.00 | | | | | | |

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Appendix 13a Costs and returns of proposed replanted forest schemes using the shambu system — UNITS MILLIKSHS

| Year | Area replt 000 ha | Direct costs per year: Nursery | Forest | Total | Cum^e total | Overhead costs per year | Cum^e total | Total costs per yr | Cum^e total | Vol pied mill m³ | Revenue from plantation: Stumpage 15/- m³ p.y. | Cum^e | Stumpage 20/- m³ p.y. | Cum^e | Rent 15/- ha p.y. | Cum^e | Revenue from clearing: vol mill m³ | Stumpage 15/- m³ p.y. | Cum^e | Stumpage 20/- m³ p.y. | Cum^e |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 83 -4 | | | | | | 2.00 | 2.00 | 2.00 | 2.00 | | | | | | 0.30 | 0.30 | 1.50 | 22.50 | 22.50 | 30.00 | 30.00 |
| -3 | | | | | | 4.00 | 6.00 | 4.00 | 6.00 | | | | | | 0.40 | 0.40 | " | " | 45.00 | " | 60.00 |
| 85 -2 | | | | | | 6.00 | 12.00 | 6.00 | 12.00 | | | | | | 0.40 | 1.80 | " | " | 67.50 | " | 90.00 |
| -1 | | | | | | 8.10 | 20.10 | 8.10 | 20.10 | | | | | | 1.22 | 3.02 | 1.56 | 23.42 | 91.12 | 31.50 | 121.50 |
| 87 0 | 20 | 4.80 | 10.40 | 15.20 | 15.20 | 10.10 | 30.20 | 25.30 | 45.40 | | | | | | " | 4.24 | 1.50 | 22.50 | 113.62 | 30.00 | 151.50 |
| 1 | " | 5.28 | 12.80 | 17.38 | 32.48 | 12.10 | 42.30 | 29.48 | 74.78 | | | | | | " | 5.46 | " | " | 136.12 | " | 181.50 |
| 2 | " | " | 14.00 | 19.38 | 51.76 | 14.10 | 56.40 | 33.38 | 108.16 | | | | | | " | 6.68 | " | " | 158.62 | " | 211.50 |
| 90 3 | 21 | 5.52 | 14.52 | 20.04 | 71.80 | 16.10 | 72.50 | 36.14 | 144.30 | | | | | | 1.20 | 7.88 | " | " | 181.12 | " | 241.50 |
| 4 | 20 | 5.30 | 14.08 | 19.38 | 91.18 | 18.10 | 90.60 | 37.48 | 181.78 | | | | | | " | 9.08 | " | " | 203.62 | " | 271.50 |
| 5 | " | 5.28 | 14.10 | " | 110.56 | 20.60 | 111.20 | 39.98 | 221.76 | | | | | | 1.28 | 10.36 | 1.88 | 28.13 | 231.75 | 37.50 | 309.00 |
| 6 | " | " | " | " | 129.94 | 23.10 | 134.30 | 42.48 | 264.24 | | | | | | 1.35 | 12.71 | " | 28.12 | 259.88 | " | 346.50 |
| 7 | " | " | 14.00 | 19.28 | 149.22 | 25.60 | 159.90 | 44.58 | 304.22 | 0.77 | 11.55 | 11.55 | 15.40 | 15.40 | 1.42 | 14.13 | " | 28.13 | 288.00 | " | 384.00 |
| 95 8 | " | " | " | " | 168.50 | 28.10 | 188.00 | 47.48 | 356.70 | " | " | 23.10 | " | 30.80 | 1.50 | 15.63 | " | 28.12 | 316.12 | " | 421.50 |
| 9 | 25 | 6.48 | 16.60 | 23.08 | 191.58 | 30.60 | 218.60 | 53.68 | 410.28 | " | " | 34.65 | " | 46.20 | " | 17.13 | " | 28.13 | 344.25 | " | 459.00 |
| 10 | " | 6.60 | 18.60 | 25.20 | 216.78 | " | 249.60 | 55.80 | 466.08 | 4.44 | 69.60 | 104.25 | 92.80 | 138.80 | 1.42 | 18.25 | | | | | |
| 11 | " | " | 20.30 | 26.90 | 243.68 | " | 279.60 | 57.50 | 523.68 | 4.60 | 69.00 | 173.25 | 92.00 | 230.80 | 0.75 | 19.00 | | | | | |
| 12 | " | " | " | " | 270.58 | " | 310.20 | " | 581.78 | " | " | 242.25 | " | 323.00 | 0.38 | 19.38 | | | | | |
| 00 13 | " | " | 20.38 | 26.48 | 297.06 | " | 340.80 | 57.58 | 638.76 | 4.79 | 71.85 | 314.10 | 95.80 | 418.80 | | | | | | | |
| 14 | (306) | 0.60 | 7.36 | 7.42 | 305.42 | " | 371.40 | 37.96 | 676.82 | 4.60 | 69.00 | 383.10 | 92.00 | 510.80 | | | | | | | |
| 15 | | | 5.30 | 5.30 | 310.72 | " | 402.00 | 35.90 | 712.62 | " | " | 452.10 | " | 602.80 | | | | | | | |
| 16 | | | 2.10 | 2.10 | 312.82 | " | 432.60 | 32.70 | 745.42 | 4.79 | 71.85 | 523.95 | 95.80 | 698.60 | | | | | | | |
| 17 | | | " | " | 315.42 | " | 463.20 | " | 778.62 | 6.61 | 99.15 | 623.10 | 132.20 | 830.80 | | | | | | | |
| 05 18 | | | " | " | 317.82 | " | 493.80 | " | 810.72 | " | " | 722.25 | " | 963.00 | | | | | | | |
| 19 | | | 3.50 | 3.50 | 320.82 | " | 524.40 | 34.10 | 844.82 | 7.67 | 115.55 | 837.80 | 153.40 | 1117.40 | | | | | | | |
| 20 | | | 4.10 | 4.10 | 324.92 | " | 555.00 | 34.70 | 879.92 | 14.60 | 219.00 | 1055.70 | 293.20 | 1410.60 | | | | | | | |
| 05 21 | | | 6.60 | 6.60 | 331.52 | " | 585.60 | 37.20 | 916.72 | 13.61 | 204.15 | 1259.85 | 272.20 | 1682.80 | | | | | | | |
| Steady state | (306) | | 7.36 | 9.38 | | 20.40 | | 30.43 | | 9.58 | | | | | | | | | | | |

Appl3b Labour requirements | Replanted forest – Shamba system | Lichinga budget | Unit: Man years

| Year | New Replanted 000 ha | Establishment labour: Nursery | Forest | Total | Thin 1 fell labour | Total replanted labour | Clearing standing crop | Total per year clearing | Supervision and management: Estab. labour | Thin 1 fell | Clearing | Total | Management skills: Graduates Univ | College | Office | Total workforce |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -4 83 | | | | | | | 5556 | 5556 | 96 | | 222 | 318 | 16 | 159 | 43 | 5874 |
| -3 | | | | | | | " | " | 193 | | " | 415 | 21 | 208 | 186 | 5971 |
| -2 85 | | | | | | | " | " | 289 | | " | 511 | 26 | 256 | 229 | 6067 |
| -1 | | | | | | | 5834 | 5834 | 390 | | 233 | 623 | 31 | 312 | 289 | 6457 |
| 0 87 | 20 | 889 | 1926 | 2815 | | 2815 | 5556 | 8371 | 486 | | 232 | 708 | 35 | 354 | 319 | 9079 |
| 1 | " | 978 | 2222 | 3200 | | 3200 | " | 8756 | 583 | | " | 805 | 40 | 402 | 363 | 9561 |
| 2 | " | 978 | 2592 | 3570 | | 3570 | " | 9306 | 679 | | " | 901 | 45 | 450 | 406 | 10207 |
| 3 90 | (81) 21 | 1022 | 2688 | 3710 | | 3710 | " | 9246 | 775 | | " | 997 | 50 | 498 | 449 | 10243 |
| 4 | 20 | 982 | 2703 | 3685 | | 3685 | " | 9341 | 871 | | " | 1093 | 55 | 546 | 492 | 10334 |
| 5 | " | 978 | 2722 | 3700 | | 3700 | 6944 | 10644 | 992 | | 278 | 1270 | 64 | 635 | 571 | 11914 |
| 6 | " | " | " | " | | " | " | " | 1112 | | | 1390 | 70 | 695 | 625 | 12034 |
| 7 | " | " | " | " | 3173 | 6873 | " | 13767 | 1232 | 114 | | 1625 | 81 | 812 | 732 | 15392 |
| 8 95 | " | " | " | " | " | " | " | " | 1353 | 114 | | 1745 | 87 | 872 | 786 | 15512 |
| 9 | 25 | 1200 | 3107 | 4307 | " | 7430 | " | 14374 | 1473 | 114 | " | 1865 | 93 | 932 | 840 | 16239 |
| 10 | " | 1222 | 3462 | 4684 | 17478 | 22162 | | 22162 | " | 687 | | 2160 | 108 | 1080 | 972 | 24322 |
| 11 | " | " | 3758 | 4980 | 17321 | 22301 | | 22301 | " | 682 | | 2155 | 108 | 1078 | 969 | 24456 |
| 12 | " | " | " | " | " | " | | | " | " | | 2155 | 108 | 1078 | 969 | 24456 |
| 13 2000 | " | " | 3773 | 4995 | 18030 | 23025 | | 23025 | " | 710 | | 2183 | 109 | 1092 | 982 | 25208 |
| 14 | (206) | 121 | 1377 | 1488 | 17321 | 18809 | | 18809 | " | 682 | | 2155 | 108 | 1078 | 969 | 20964 |
| 15 | | | 1007 | 1097 | " | 18328 | | 18328 | " | " | | 2155 | 108 | 1078 | 969 | 20483 |
| 16 | | | 544 | 544 | 18102 | 18646 | | 18646 | | 710 | | 2183 | 109 | 1092 | 982 | 20829 |
| 17 | | | " | " | 25517 | 26041 | | 26041 | " | 984 | | 2453 | 123 | 1226 | 1104 | 28514 |
| 18 2005 | | | " | " | " | " | | " | " | " | | 2453 | 123 | 1226 | 1104 | 28514 |
| 19 | | | 603 | 603 | 29066 | 29669 | | 29669 | " | 1122 | | 2595 | 130 | 1298 | 1167 | 32264 |
| 20 | | | 944 | 944 | 55363 | 56307 | | 56307 | " | 2172 | | 3665 | 182 | 1822 | 1641 | 59952 |
| 21 2008 | | | 1166 | 1166 | 51088 | 52254 | | 55254 | " | 2017 | | 3490 | 174 | 1745 | 1571 | 58744 |
| Steady state | | 299 | 1428 | 1727 | 36062 | 37789 | 1700 | 39489 | 1621 | 1414 | 68 | 3103 | 155 | 1552 | 1396 | 42592 |
| p.h.a.d/yr | | 0.36 | .36 | 1.52 | 3.82 | 33.34 | 1.50 | 34.84 | 1.43 | 1.25 | 0.06 | 3.74 | | | | 37.58 |
| ha per man yr. | | | | | 8.5 | 8 | | | | | | 9.85 | | | | 7 |

Appendix 1 Costs and returns of proposed peri urban plantation, high potential area low elevation Sesils planted

UNITS MILLIONS KSHS

| Year | New planted ha | Direct costs: Seedlings | Forest per year | Total per year | Cumulative total | Overhead costs: per year | Cumulative total | Total costs: per year | Cumulative total | Vol prod. $m^3$ | Revenue (1): 1st $m^3$ | 2nd $m^3$ | Fodder: wt 000 t | income 1st t | Total revenue from plantation: Income p.y | + wt. cleared Cumul. | Income p.y | Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 0 | 1 | 0.02 | 1.44 | 2.01 | 2.01 | 0.20 | 0.20 | 2.21 | 2.21 | – | – | – | – | – | – | – | – | – |
| 1 | 1 | 0.02 | 2.14 | 2.16 | 4.17 | " | 0.40 | 2.36 | 4.57 | – | 0.01 | 0.02 | 0.15 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 |
| 2 | 1 | 0.02 | " | " | 6.33 | " | 0.60 | " | 6.93 | 2 | 0.03 | 0.04 | 3.45 | 0.49 | 0.52 | 0.64 | 0.53 | 0.96 |
| 3 | 1 | 0.02 | " | " | 8.49 | " | 0.80 | " | 9.29 | 7 | 0.10 | 0.14 | 7.21 | 1.04 | 1.19 | 1.83 | 1.23 | 1.89 |
| 4 | 1 | 0.02 | " | " | 10.65 | " | 1.00 | " | 11.65 | 18 | 0.27 | 0.36 | 11.21 | 1.49 | 1.76 | 3.59 | 3.05 | 3.44 |
| 5 | | 0.01 | 1.13 | 1.14 | 11.79 | " | 1.20 | 1.34 | 12.99 | 52 | 0.78 | 1.04 | 15.21 | 2.29 | 3.07 | 6.66 | 3.23 | 7.27 |
| 6 | | | 0.86 | 0.86 | 12.65 | 0.10 | 1.30 | 0.96 | 13.95 | 52 | 0.78 | " | " | " | " | 9.43 | " | 10.60 |
| 7 | | | | | 13.51 | " | 1.40 | " | 14.91 | 53 | 0.80 | 1.06 | " | " | 3.09 | 13.42 | 3.25 | 13.95 |
| 8 | | | | | 14.37 | " | 1.50 | " | 15.87 | 57 | 0.86 | 1.14 | " | " | 3.15 | 16.17 | 3.43 | 17.38 |
| 9 | | | | | 15.23 | " | 1.60 | " | 16.83 | 67 | 1.00 | 1.34 | " | " | 3.29 | 19.46 | 3.63 | 21.01 |
| 2000 10 | | | | | 16.09 | " | 1.70 | " | 17.79 | 94 | 1.41 | 1.88 | " | " | 3.70 | 23.16 | 4.17 | 25.18 |
| 11 | | | | | 16.95 | " | 1.80 | " | 18.75 | 94 | " | " | " | " | " | 26.86 | " | 29.35 |
| 12 | | | | | 17.81 | " | 1.90 | " | 19.71 | 94 | " | " | " | " | " | 30.56 | " | 33.52 |
| 13 | | | | | 18.67 | " | 2.00 | " | 20.67 | 93 | 1.40 | 1.86 | " | " | 3.64 | 34.25 | 4.15 | 37.67 |
| 14 | | | | | 19.53 | " | 2.10 | " | 21.63 | 90 | 1.35 | 1.80 | " | " | 3.64 | 37.89 | 4.04 | 41.96 |
| 2005 15 | | | | | 20.39 | " | 2.20 | " | 22.54 | 83 | 1.24 | 1.66 | " | " | 3.53 | 41.42 | 3.95 | 45.71 |
| 16 | | | | | 21.25 | " | 2.30 | " | 23.55 | 83 | " | " | " | " | " | 44.95 | " | 49.66 |
| 17 | | | | | 22.11 | " | 2.40 | " | 24.51 | 82 | 1.23 | 1.64 | " | " | 3.52 | 48.47 | 3.93 | 53.55 |
| 2009 18 | | | | | 22.97 | " | 2.50 | " | 25.47 | 81 | 1.22 | 1.62 | – | " | 3.51 | 51.98 | 3.91 | 57.50 |
| Steady state | | 0.01 | 1.02 | 1.03 | | 0.12 | | 1.15 | | 70 | 105 | 1.40 | 15.25 | 2.29 | 3.34 | | 3.69 | |

(1) No allowance made for income from wood on cleared land.

## App 4b Labour requirements peri-urban plantation high potential forest, low elevation seedlings planted

| | | Area Planted 000 ha | Establishment labour: Seeds | Forest | Total | Thinning Fell | Coppicing Leaves | Total forest labour | Supervision: Estate | Thinning | Builder | Total | Management skill: Graduates Univ | College | Office Staff | Total workforce |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 0 | | 4 | 98 | 102 | | | 102 | 10 | – | – | 10 | 1 | 5 | 4 | 113 |
| | 1 | | 4 | 174 | 178 | 9 | 61 | 198 | 19 | 9 | | 20 | 1 | 10 | 9 | 219 |
| | 2 | | 4 | " | " | 24 | 265 | 417 | 29 | 9 | 6 | 35 | 2 | 18 | 15 | 452 |
| | 3 | | 4 | " | " | 70 | 591 | 789 | 39 | 1 | 13 | 53 | 2 | 26 | 24 | 842 |
| | 4 | 1 | 4 | " | " | 180 | 917 | 1225 | 48 | 3 | 21 | 72 | 4 | 36 | 32 | 1297 |
| 1995 | 5 | | 0 | 49 | 49 | 434 | 1243 | 1726 | 43 | 8 | 28 | 79 | 4 | 40 | 35 | 1805 |
| | 6 | | – | 22 | 22 | 441 | " | 1704 | 39 | 8 | " | 75 | 4 | 38 | 33 | 1781 |
| | 7 | | | " | " | 484 | " | 1719 | 34 | 8 | " | 70 | 4 | 35 | 31 | 1789 |
| | 8 | | | " | " | 492 | " | 1757 | 29 | 8 | " | 65 | 3 | 32 | 30 | 1822 |
| | 9 | | | " | " | 582 | " | 1847 | 24 | 10 | " | 62 | 3 | 31 | 28 | 1909 |
| 2000 | 10 | | | " | " | 775 | " | 2040 | " | 14 | " | 66 | 3 | 33 | 30 | 2106 |
| | 11 | | | " | " | 774 | " | 2039 | " | 14 | " | " | 3 | 33 | 30 | 2105 |
| | 12 | | | " | " | 770 | " | 2035 | " | 14 | " | " | " | " | " | 2101 |
| | 13 | | | " | " | 760 | " | 2025 | " | 14 | " | " | " | " | " | 2091 |
| | 14 | | | " | " | 737 | " | 2002 | " | 13 | " | 65 | " | 33 | 29 | 2067 |
| 2005 | 15 | | | " | " | 684 | " | 1949 | " | 12 | " | 64 | " | 32 | 29 | 2013 |
| | 16 | | | " | " | 682 | " | 1947 | " | 12 | " | " | " | " | " | 2011 |
| | 17 | | | " | " | 677 | " | 1942 | " | 12 | " | " | " | " | " | 2006 |
| 2010 | 18 | | | " | " | 663 | " | 1928 | " | 12 | " | " | " | " | " | 1942 |
| Steady state | | | 1 | 42 | 43 | 577 | 1243 | 1863 | 3 | 10 | 28 | 65 | 3 | 33 | 29 | 1928 |
| pha. md/yr | | | 0.04 | 2.31 | 2.35 | 31.14 | 67.10 | 100.63 | 1.66 | 0.56 | 1.52 | 3.73 | | | | 104 |
| hectares per man yr. | | | | | 115 | 9 | 4 | 3 | | | | 72 | | | | 3 |

UNITS Man Years (270 days/yr)



## Appendix 1b c: Costs and returns peri-urban plantation high potential high elevation seedlings planted

| Year | | Area plted 000 ha | Direct costs per year: nursery | forest | total | cumulative total | Overhead costs per year | cumulative total | Total costs per year | cumulative total | Vol prod 000 m³ | Revenue (1): Stumpage 15/- m³ p.y. | cumulative | Stumpage 20/- m³ p.y. | cumulative | UNITS MILLION KSHS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 83 | 0 | 3 | 0.72 | 2.64 | 3.36 | 3.36 | 0.60 | 0.60 | 3.48 | 3.48 | | | | | | |
| | 1 | " | 0.79 | 3.00 | 3.79 | 7.15 | 1.20 | 1.80 | 4.99 | 8.47 | | | | | | |
| | 2 | " | " | 3.30 | 4.09 | 11.24 | 1.80 | 3.60 | 5.89 | 14.36 | | | | | | |
| | 3 | " | " | " | " | 15.33 | 2.40 | 6.00 | 6.49 | 21.35 | | | | | | |
| | 4 | " | " | " | " | 19.42 | 3.00 | 9.00 | 7.09 | 28.44 | | | | | | |
| | 5 | " | " | " | " | 23.51 | 3.60 | 12.60 | 7.69 | 36.13 | | | | | | |
| | 6 | " | " | " | " | 27.60 | 4.20 | 16.80 | 8.29 | 44.42 | | | | | | |
| 90 | 7 | 3 | " | " | " | 31.69 | 4.80 | 21.60 | 8.89 | 53.31 | 115 | 1.73 | 1.72 | 2.34 | 2.30 | |
| | 8 | 5 | 1.27 | 5.06 | 6.33 | 38.02 | 5.40 | 27.00 | 12.13 | 65.44 | " | 1.73 | 3.45 | " | 4.60 | |
| | 9 | " | 1.32 | 5.30 | 6.62 | 44.64 | 6.80 | 34.20 | 13.42 | 78.86 | " | 1.72 | 5.17 | " | 6.90 | |
| | 10 | " | " | 5.74 | 7.06 | 51.70 | 7.50 | 42.00 | 14.86 | 93.72 | 690 | 10.35 | 15.52 | 13.80 | 20.70 | |
| | 11 | " | " | 5.92 | 7.24 | 58.94 | 8.50 | 50.50 | 15.74 | 109.44 | " | " | 25.87 | " | 34.50 | |
| 95 | 12 | " | " | " | " | 66.18 | 9.20 | 59.70 | 16.44 | 125.88 | " | " | 36.22 | " | 48.30 | |
| | 13 | " | " | " | " | 73.42 | 9.90 | 69.60 | 17.14 | 143.02 | " | " | 46.57 | " | 62.10 | |
| | 14 | " | " | " | " | 80.66 | 10.60 | 80.20 | 17.84 | 160.86 | " | " | 56.92 | " | 75.90 | |
| | 15 | " | " | " | " | 87.90 | 11.30 | 91.50 | 18.54 | 179.40 | 767 | 11.50 | 68.42 | 15.34 | 91.24 | |
| | 16 | " | " | " | " | 95.14 | 12.00 | 103.50 | 19.24 | 198.64 | " | 11.51 | 79.93 | " | 106.58 | |
| 2000 | 17 | 6 | 1.56 | 6.80 | 8.36 | 103.50 | 12.40 | 116.40 | 21.26 | 219.90 | 1040 | 15.60 | 95.53 | 20.66 | 127.36 | |
| | 18 | (75) | 0.14 | 1.80 | 1.94 | 105.44 | 12.60 | 129.00 | 14.54 | 234.44 | 1423 | 21.34 | 116.87 | 28.46 | 155.84 | |
| | 19 | | | 1.80 | 1.80 | 106.74 | 12.10 | 141.10 | 13.40 | 247.84 | " | 21.35 | 138.22 | " | 184.30 | |
| | 20 | | | 0.94 | 0.94 | 107.68 | 11.60 | 152.70 | 12.24 | 260.08 | 2473 | 37.10 | 175.32 | 49.46 | 233.76 | |
| | 21 | | | 1.12 | 1.12 | 108.80 | 11.10 | 163.80 | 12.22 | 272.30 | " | 37.04 | 212.41 | " | 283.22 | |
| 2005 | 22 | | | " | " | 109.92 | 10.60 | 174.40 | 11.72 | 284.02 | " | 37.10 | 249.51 | " | 332.68 | |
| | 23 | | | " | " | 111.04 | 10.10 | 184.50 | 11.22 | 295.24 | " | 37.04 | 286.60 | " | 382.14 | |
| 2007 | 24 | | | " | | 112.16 | 9.60 | 194.10 | 10.12 | 305.36 | 2511 | 37.67 | 324.27 | 50.22 | 432.36 | |
| Steady state | | | 0.40 | 2.44 | 2.84 | | 12.10 | | 15.01 | | 2146 | 35.10 | | 46.80 | | |

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## App 14d Labour requirements peri-urban plantation high potential high elevation

UNITS MAN YEARS

| Year | | Area planted ooo ha | Establishment Lab. nursery | forest | total | Thin and fell | Plantation total | Supervision & management Est. | Thin fell | Total | management skills Professional univ. | college | Office staff | Total workforce |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 0 | 3 | 133 | 489 | 622 | | 622 | 29 | | 29 | 1 | 15 | 13 | 651 |
| | 1 | " | 146 | 556 | 702 | | 702 | 58 | | 58 | 3 | 29 | 26 | 760 |
| | 2 | " | " | 61 | 757 | | 757 | 87 | | 87 | 4 | 44 | 39 | 844 |
| | 3 | " | " | " | " | | " | 116 | | 116 | 6 | 58 | 52 | 873 |
| | 4 | " | " | " | " | | " | 144 | | 144 | 7 | 72 | 65 | 901 |
| | 5 | " | " | " | " | | " | 173 | | 173 | 9 | 86 | 78 | 930 |
| | 6 | " | " | " | " | | " | 202 | | 202 | 10 | 101 | 91 | 959 |
| 1990 | 7 | " | " | " | " | 469 | 1276 | 231 | 17 | 248 | 12 | 124 | 112 | 1474 |
| | 8 | 5 | 235 | 937 | 1172 | " | 1641 | 279 | " | 296 | 15 | 148 | 133 | 1937 |
| | 9 | " | 244 | 981 | 1226 | " | 1685 | 327 | " | 344 | 17 | 172 | 155 | 2039 |
| | 10 | " | " | 1063 | 1307 | 2548 | 3905 | 376 | 102 | 478 | 24 | 239 | 215 | 4383 |
| | 11 | " | " | 1096 | 1341 | " | 3925 | 409 | " | 511 | 26 | 256 | 230 | 4450 |
| 1995 | 12 | " | " | " | " | " | " | 443 | " | 545 | 27 | 272 | 245 | 4484 |
| | 13 | " | " | " | " | " | " | 477 | " | 579 | 29 | 290 | 261 | 4518 |
| | 14 | " | " | " | " | " | " | 510 | " | 612 | 31 | 306 | 275 | 4551 |
| | 15 | " | " | " | " | 2912 | 4253 | 544 | 114 | 658 | 33 | 329 | 296 | 4911 |
| | 16 | " | " | " | " | " | " | 578 | " | 692 | 35 | 346 | 311 | 4945 |
| 2000 | 17 | 6 | 289 | 1259 | 1548 | 4024 | 5572 | 621 | 154 | 775 | 39 | 388 | 349 | 6347 |
| | 18 | (75) | 26 | 333 | 354 | 5443 | 5802 | 607 | 211 | 818 | 41 | 409 | 368 | 6620 |
| | 19 | | | 341 | 341 | " | 5684 | 583 | " | 794 | 40 | 397 | 357 | 6478 |
| | 20 | | | 174 | 174 | 9331 | 9505 | 559 | 366 | 925 | 46 | 462 | 416 | 10430 |
| | 21 | | | 207 | 207 | " | 9538 | 534 | " | 900 | 45 | 450 | 405 | 10438 |
| | 22 | | | " | " | " | " | 510 | " | 876 | 44 | 438 | 384 | 10414 |
| | 23 | | | " | " | " | " | 486 | " | 852 | 43 | 426 | 383 | 10390 |
| 2007 | 24 | | | " | " | 9486 | 9643 | 462 | 372 | 834 | 42 | 417 | 375 | 10527 |
| Steady state | | | 73 | 461 | 534 | 8839 | 9373 | 448 | 347 | 795 | 40 | 398 | 357 | 10168 |
| p.h. mil/yr. | | | 0.26 | 1.64 | 1.92 | 31.87 | 33.71 | 1.61 | 1.25 | 2.86 | | | | 36.60 |
| hectares per year | | | | | 141 | 8.5 | 8 | | | 94 | | | | 7 |

## App 14e. Costs and returns peri-urban plantation medium rainfall seeds planted

UNITS NILL SHS.

| Year | Area 000 ha | Direct costs Nursery P/y | Plant P/y | Total P/y | Cumu[e] | Overhead cost Total P/y | Cum[e] | Total costs P/y | Cum[e] | Volume 000 m³ | Revenue Freelpwood 15/m³ | 20/m³ | Pods 000 t | Honey t | Revenue Pods 300/- t | Honey 30 col t | Combined revenue P+H +FW GM-m² P/y | cum[e] | P+H +FW GM/m² P/y | cum[e] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 83.0 | 3 | 0.06 | 5.97 | 6.03 | 6.03 | 0.60 | 0.60 | 6.63 | 6.63 | | | | | | | | | | | |
| 1 | " | 0.07 | 6.40 | 6.47 | 12.50 | 1.20 | 1.80 | 7.67 | 14.30 | | | | | | | | | | | |
| 85.2 | " | " | 6.70 | 6.77 | 19.27 | 1.80 | 3.60 | 8.57 | 22.87 | | | | 2 | 30 | 0.60 | 0.09 | 0.69 | 0.69 | 0.69 | 0.69 |
| 3 | " | " | " | " | 26.04 | 2.40 | 6.00 | 9.17 | 32.04 | | | | 4 | 90 | 1.30 | 0.27 | 1.57 | 2.16 | 1.57 | 2.16 |
| 4 | " | " | " | " | 32.81 | 3.00 | 9.00 | 9.77 | 41.81 | | | | 8 | 150 | 2.70 | 0.45 | 3.15 | 5.31 | 3.15 | 5.31 |
| 5 | " | " | " | " | 39.58 | 3.60 | 12.60 | 10.37 | 52.18 | | | | 15 | 210 | 4.50 | 0.63 | 5.13 | 10.44 | 5.13 | 10.44 |
| 6 | " | " | " | " | 46.35 | 4.20 | 16.80 | 10.97 | 63.15 | | | | 21 | 270 | 6.30 | 0.81 | 7.11 | 17.55 | 7.11 | 17.55 |
| 90.7 | 5 | 0.11 | 10.68 | 10.79 | 57.14 | 5.20 | 22.00 | 16.99 | 79.14 | | | | 27 | 330 | 8.10 | 0.99 | 9.09 | 26.64 | 9.09 | 26.64 |
| 8 | " | " | 10.96 | 11.07 | 68.21 | 6.20 | 28.20 | 17.27 | 96.41 | | | | 33 | 390 | 9.90 | 1.17 | 11.07 | 37.71 | 11.07 | 37.71 |
| 9 | 6 | 0.13 | 13.15 | 13.28 | 81.49 | 7.40 | 35.60 | 20.68 | 117.09 | | | | 40 | 470 | 12.00 | 1.41 | 13.41 | 51.12 | 13.41 | 51.12 |
| 10 | " | " | 13.25 | 13.38 | 94.87 | 8.60 | 44.20 | 21.98 | 139.07 | 100 | 1.50 | 2.00 | 48 | 570 | 14.40 | 1.71 | 17.61 | 68.73 | 18.11 | 69.23 |
| 11 | " | " | 13.35 | 13.48 | 108.35 | 9.80 | 54.00 | 23.28 | 162.35 | " | " | " | 56 | 680 | 17.40 | 2.04 | 20.44 | 89.67 | 21.44 | 90.67 |
| 95.12 | " | " | " | " | 121.83 | 11.00 | 65.00 | 24.48 | 186.83 | " | " | " | 68 | 800 | 20.40 | 2.40 | 24.00 | 113.67 | 24.00 | 115.67 |
| 13 | " | " | " | " | 135.31 | 12.20 | 77.20 | 25.68 | 212.51 | " | " | " | 80 | 920 | 24.00 | 2.76 | 26.76 | 142.43 | 26.76 | 144.43 |
| 14 | " | " | " | " | 148.79 | 13.40 | 90.60 | 26.88 | 239.39 | " | " | " | 92 | 1040 | 27.60 | 3.12 | 32.72 | 175.45 | 32.72 | 176.95 |
| 15 | " | " | 15.34 | 15.52 | 164.31 | 14.60 | 105.20 | 30.12 | 269.51 | 501 | 7.52 | 10.02 | 104 | 1160 | 31.20 | 3.48 | 43.20 | 216.65 | 44.70 | 221.65 |
| 16 | " | " | 15.63 | 15.76 | 180.07 | 15.60 | 121.00 | 31.56 | 301.07 | " | " | " | 110 | 1220 | 33.00 | 3.66 | 44.18 | 260.83 | 44.68 | 266.33 |
| 00 17 | " | " | " | " | 195.83 | 17.00 | 138.00 | 32.76 | 333.53 | 568 | 8.52 | 11.36 | 118 | 1310 | 35.40 | 3.93 | 47.85 | 308.68 | 50.64 | 314.62 |
| 18 | (85) | 0.01 | 3.73 | 3.74 | 199.57 | " | 155.00 | 20.74 | 354.57 | " | " | " | 126 | 1430 | 37.80 | 4.29 | 50.01 | 358.69 | 53.43 | 371.47 |
| 19 | | | 2.88 | 2.88 | 202.45 | " | 172.00 | 19.88 | 374.45 | 691 | 9.02 | 12.02 | 134 | 1550 | 40.20 | 4.65 | 53.87 | 443.16 | 56.87 | 428.34 |
| 20 | | | 2.28 | 2.28 | 204.73 | " | 189.00 | 19.28 | 393.73 | " | " | " | 140 | 1010 | 42.00 | 4.83 | 55.85 | 469.01 | 58.85 | 480.19 |
| 21 | | | 2.28 | " | 207.01 | " | 206.00 | " | 413.01 | " | " | " | 143 | " | 42.90 | " | 56.75 | 525.76 | 59.75 | 540.94 |
| 22 | | | 3.64 | 3.64 | 210.65 | " | 223.00 | 20.64 | 433.65 | 848 | 13.02 | 17.36 | " | " | " | " | 60.75 | 586.51 | 65.04 | 613.07 |
| 23 | | | 3.80 | 3.80 | 214.45 | " | 240.00 | 20.80 | 454.45 | " | " | " | 134 | 1570 | 41.70 | 4.71 | 59.13 | 645.94 | 63.77 | 676.84 |
| 07 24 | | | 4.48 | 4.48 | 218.93 | " | 257.00 | 21.48 | 475.41 | 1002 | 15.03 | 20.02 | 136 | 1550 | 40.80 | 4.65 | 60.47 | 706.41 | 65.46 | 742.30 |
| Steady state | | 0.03 | 5.47 | 6.00 | | | 14.44 | | 20.44 | 1.20 | 19.00 | 26.40 | 142 | 1530 | 42.60 | 4.59 | 66.49 | | 73.69 | |

## App 14F Labour requirements peri-urban plantation medium rainfall seeds planted

UNITS MIN TO 1985

| Year | area plt. 000 ha | Establishment labour: nursery | forest | total | Thin & fell | Fodder/food collection: Pods | honey | total | Plant & thin total | Supervision and management: Est | Thin & Fell | Pods | honey | Total | Management skills: Graduates Univ | College | Office Staff | Total work force | 270 Man days/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 83.0 | 8 | 11 | 296 | 305 | | | | | 305 | 79 | | | | 79 | 1 | 14 | 14 | 334 | |
| 1 | 4 | 12 | 273 | 285 | | | | | 385 | 58 | | | | 58 | 3 | 21 | 26 | 443 | |
| 85 2 | 1 | 4 | 429 | 441 | | 163 | 8 | 171 | 612 | 87 | | 4 | 0 | 91 | 5 | 46 | 40 | 703 | |
| 3 | " | " | " | " | | 326 | 25 | 351 | 792 | 116 | | 7 | 1 | 124 | 6 | 62 | 56 | 916 | |
| 4 | " | " | " | " | | 733 | 42 | 775 | 1216 | 145 | | 17 | 1 | 163 | 8 | 82 | 73 | 1379 | |
| 5 | " | " | " | " | | 1222 | 58 | 1280 | 1721 | 174 | | 28 | 2 | 204 | 10 | 102 | 92 | 1925 | |
| 6 | " | " | " | " | | 1711 | 75 | 1786 | 2227 | 243 | | 34 | 2 | 244 | 12 | 122 | 110 | 2471 | |
| 90.7 | 5 | 20 | 626 | 646 | | 2200 | 92 | 2292 | 2938 | 251 | | 50 | 2 | 303 | 15 | 152 | 136 | 3241 | |
| 8 | 5 | 20 | 678 | 698 | | 2689 | 108 | 2797 | 3495 | 299 | | 61 | 3 | 363 | 18 | 182 | 163 | 3858 | |
| 9 | 6 | 24 | 813 | 837 | | 3259 | 131 | 3390 | 4227 | 357 | | 74 | 3 | 434 | 22 | 217 | 195 | 4661 | |
| 10 | " | 24 | 840 | 864 | 407 | 3911 | 158 | 4476 | 5340 | 415 | 15 | 84 | 4 | 523 | 26 | 262 | 235 | 5863 | |
| 11 | " | " | 858 | 882 | 407 | 4726 | 189 | 5322 | 6204 | 473 | " | 107 | 5 | 600 | 30 | 390 | 279 | 6804 | |
| 96.12 | " | " | " | " | " | 5541 | 222 | 6170 | 7052 | 531 | " | 126 | 6 | 678 | 34 | 339 | 305 | 7730 | |
| 13 | " | " | " | " | " | 6519 | 256 | 7162 | 8064 | 589 | " | 145 | 7 | 759 | 38 | 380 | 341 | 8823 | |
| 14 | " | " | " | " | " | 7496 | 289 | 8192 | 9074 | 647 | " | 170 | 8 | 840 | 42 | 420 | 388 | 9914 | |
| 15 | " | " | 902 | 926 | 1892 | 8474 | 322 | 10668 | 11614 | 705 | 74 | 193 | 9 | 981 | 49 | 499 | 442 | 12595 | |
| 16 | " | " | 946 | 972 | 1842 | 8963 | 339 | 11194 | 12166 | 763 | " | 204 | 9 | 1050 | 52 | 525 | 473 | 13216 | |
| 00 17 | " | " | " | " | 2165 | 9615 | 364 | 12144 | 13116 | 821 | 84 | 219 | 10 | 1134 | 57 | 567 | 510 | 14250 | |
| 18 | (85) | 2 | 357 | 359 | 2165 | 10267 | 397 | 12824 | 13188 | " | " | 233 | 11 | 1149 | 57 | 574 | 518 | 14337 | |
| 19 | | | 199 | 199 | 2300 | 10919 | 431 | 13650 | 13849 | " | 84 | 248 | 11 | 1169 | 58 | 584 | 527 | 15018 | |
| 20 | | | 88 | 88 | 2300 | 11407 | 447 | 14154 | 14242 | " | " | 259 | 12 | 1181 | 59 | 590 | 532 | 15423 | |
| 21 | | | " | " | " | 11652 | " | 14399 | 14487 | " | " | 265 | 12 | 1187 | 59 | 594 | 534 | 15674 | |
| 05.22 | | | 118 | 118 | 3289 | 11452 | " | 15388 | 15506 | " | 129 | " | 12 | 1227 | 61 | 614 | 552 | 16733 | |
| 23 | | | 148 | 148 | 3289 | 11324 | 436 | 15051 | 15199 | " | " | 257 | 12 | 1219 | 61 | 610 | 548 | 16418 | |
| 07.24 | | | 163 | 163 | 3782 | 11081 | 431 | 15244 | 15457 | " | 148 | 252 | 11 | 1232 | 62 | 616 | 554 | 16689 | |
| Steady state | 5 | 296 | 301 | 5001 | 11543 | 425 | 16969 | 17270 | 818 | 196 | 262 | 11 | 1287 | 64 | 644 | 579 | 18557 | |
| p.ha md/yr | 0.92 | 0.84 | 0.86 | 15.88 | 3667 | 1.35 | 53.70 | 54.86 | 2.63 | 0.62 | 0.83 | 0.04 | 4.12 | | | | 58.98 | |
| hectares per yr | | | 281 | 17 | 7 | 200 | 5 | 5 | | | | | 66 | | | | 4½ | |

## Appendix 14G Cost and returns of proposed peri-urban scheme medium rainfall area Seedling plants

UNITS MIN TO SIM

| Year | Area planted 000 ha | Direct cost per year: Nursery | Forest | Total | Cumulative | Overhead cost: p/y | Cumulative | Total costs: p/y | Cumulative | Volume cut m³ | Revenue (see App 4c): Pole nursery plus fuelwood & illumination p/y | Cumulative | Pedestrian nursery plus fuel & illumination p/y | Cumulative | Pulp 000 t | Illumination t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 0 | 3 | 0.72 | 7.11 | 7.83 | 7.83 | 0.60 | 0.60 | 8.43 | 8.43 | | | | | | | |
| 1 | 4 | 0.74 | 7.47 | 8.36 | 16.09 | 1.20 | 1.80 | 9.46 | 17.89 | | | | | | | |
| 2 | " | " | 7.77 | 8.56 | 24.65 | 1.80 | 3.60 | 10.36 | 28.25 | | 0.69 | 0.69 | 0.64 | 0.64 | 2 | 30 |
| 3 | " | " | " | " | 33.21 | 2.40 | 6.00 | 10.46 | 39.21 | | 1.47 | 2.16 | 1.47 | 2.16 | 4 | 40 |
| 4 | " | " | " | " | 41.77 | 3.00 | 9.00 | 11.56 | 50.77 | | 3.15 | 5.31 | 3.15 | 5.31 | 9 | 150 |
| 5 | 4 | " | " | " | 50.33 | 3.60 | 12.60 | 12.16 | 62.93 | | 5.13 | 10.44 | 5.13 | 10.44 | 15 | 210 |
| 6 | " | " | " | " | 58.89 | 4.20 | 16.80 | 12.76 | 75.69 | | 7.11 | 17.55 | 7.11 | 17.55 | 21 | 270 |
| 1990 7 | 5 | 1.27 | 12.51 | 13.78 | 72.67 | 5.20 | 22.00 | 18.98 | 94.67 | | 9.09 | 26.64 | 9.04 | 26.64 | 27 | 330 |
| 8 | " | 1.32 | 12.75 | 14.07 | 86.74 | 6.20 | 28.20 | 20.27 | 114.94 | | 11.07 | 37.71 | 11.07 | 37.71 | 33 | 390 |
| 9 | 6 | 1.56 | 15.32 | 16.88 | 103.62 | 7.40 | 35.60 | 24.28 | 139.22 | 100 | 13.41 | 51.12 | 13.41 | 51.12 | 40 | 470 |
| 10 | " | 1.58 | 15.44 | 17.02 | 120.64 | 8.60 | 44.20 | 25.64 | 164.84 | " | 17.61 | 68.73 | 18.11 | 69.23 | 48 | 570 |
| 11 | " | " | 15.54 | 17.12 | 137.76 | 9.80 | 54.00 | 26.92 | 191.76 | " | 20.94 | 89.67 | 21.46 | 90.67 | 58 | 680 |
| 1995 12 | " | " | " | " | 154.88 | 11.00 | 65.00 | 28.12 | 219.88 | " | 24.30 | 113.97 | 24.50 | 115.47 | 68 | 800 |
| 13 | " | " | " | " | 172.00 | 12.20 | 77.20 | 29.32 | 249.20 | " | 28.26 | 142.23 | 28.76 | 144.23 | 80 | 920 |
| 14 | " | " | " | " | 189.12 | 13.40 | 90.60 | 30.52 | 279.72 | " | 32.22 | 174.45 | 32.72 | 176.45 | 92 | 1040 |
| 15 | " | " | 17.58 | 19.16 | 208.28 | 14.60 | 105.20 | 33.76 | 313.48 | 501 | 42.20 | 216.65 | 44.70 | 221.65 | 104 | 1160 |
| 16 | " | " | 17.72 | 19.30 | 227.58 | 15.80 | 121.00 | 35.10 | 348.58 | " | 44.18 | 260.83 | 46.68 | 268.33 | 110 | 1220 |
| 2000 17 | " | " | " | " | 246.88 | 17.00 | 138.00 | 36.30 | 384.88 | 508 | 47.85 | 308.68 | 50.69 | 319.02 | 116 | 1310 |
| 18 | (85) | 0.14 | 3.60 | 3.74 | 250.62 | | 155.00 | 20.74 | 405.62 | " | 50.61 | 359.29 | 53.45 | 372.47 | 126 | 1430 |
| 19 | | | 3.88 | 3.88 | 253.50 | " | 172.00 | 19.88 | 425.50 | 601 | 53.87 | 413.16 | 56.57 | 429.34 | 134 | 1550 |
| 20 | | | 2.28 | 2.28 | 255.78 | " | 189.00 | 19.28 | 444.78 | " | 55.85 | 469.01 | 58.85 | 488.19 | 140 | 1610 |
| 21 | | | " | " | 258.06 | " | 206.00 | " | 464.06 | " | 56.75 | 525.76 | 59.75 | 547.94 | 143 | " |
| 2005 22 | | | 3.64 | 3.64 | 261.70 | " | 223.00 | 20.64 | 484.70 | 868 | 60.75 | 586.51 | 65.04 | 613.03 | " | " |
| 23 | | | 3.80 | 3.80 | 265.50 | " | 240.00 | 20.80 | 505.50 | " | 59.43 | 645.44 | 63.77 | 676.80 | 134 | 1670 |
| 2007 24 | | | 4.48 | 4.48 | 269.98 | " | 257.00 | 21.48 | 526.98 | 1002 | 60.47 | 706.11 | 63.46 | 740.26 | 136 | 1550 |
| Steady state | | 0.20 | 6.55 | 6.68 | | 14.44 | | 21.47 | | 1.326 | 66.44 | | 16.54 | | 144 | 136 |

## Appendix 14 b). Labour requirements of proposed peri-urban scheme modelled on Kitui - Kwa Mutonga

| Year | | area plant per year | Direct labour: Establishment: Nursery | Pfm | total | Thin Fell | Intervenes: Poles | Honey | Total | Est Village Total | Supervision and management: Est. | Thin Fell | Poles | Honey | Total | Supervision Skilled: Graduates units | For. Agric college | office staff | Total work force | UNITS MAN YEARS -270 man days/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 0 | 9 | 133 | 506 | 639 | | | | | 639 | 29 | | | | 29 | 1 | 14 | 14 | 688 | |
| | 1 | " | 147 | 572 | 719 | | | | | 719 | 58 | | | | 58 | 3 | 29 | 26 | 777 | |
| 1985 | 2 | " | " | 628 | 775 | | 163 | 8 | 171 | 946 | 87 | | 4 | 0 | 91 | 5 | 46 | 40 | 1037 | |
| | 3 | " | " | " | " | | 326 | 25 | 351 | 1126 | 116 | | 7 | 1 | 124 | 6 | 62 | 56 | 1250 | |
| | 4 | " | " | " | " | | 733 | 42 | 775 | 1550 | 145 | | 17 | 1 | 163 | 8 | 82 | 73 | 1713 | |
| | 5 | " | " | " | " | | 1233 | 58 | 1290 | 2055 | 174 | | 28 | 2 | 204 | 10 | 102 | 92 | 2259 | |
| | 6 | " | " | " | " | | 1711 | 75 | 1786 | 2561 | 203 | | 34 | " | 244 | 12 | 122 | 110 | 2805 | |
| 1990 | 7 | 5 | 236 | 945 | 1181 | | 2300 | 92 | 2392 | 3473 | 251 | | 50 | " | 303 | 15 | 152 | 136 | 3778 | |
| | 8 | " | 244 | 1009 | 1253 | | 2489 | 108 | 2747 | 4050 | 299 | | 61 | 3 | 363 | 18 | 182 | 163 | 4413 | |
| | 9 | 6 | 289 | 1215 | 1504 | | 3259 | 131 | 3390 | 4894 | 367 | | 74 | " | 434 | 22 | 217 | 195 | 5328 | |
| | 10 | " | 293 | 1297 | 1590 | 407 | 3911 | 158 | 4476 | 6066 | 415 | 15 | 89 | 4 | 523 | 26 | 262 | 235 | 6529 | |
| | 11 | " | " | 1256 | 1549 | " | 4726 | 189 | 5422 | 6871 | 473 | " | 107 | 5 | 600 | 30 | 300 | 270 | 7471 | |
| 1995 | 12 | " | " | " | " | " | 5541 | 232 | 6170 | 7719 | 531 | " | 126 | 6 | 675 | 34 | 339 | 305 | 8397 | |
| | 13 | " | " | " | " | " | 6519 | 256 | 7182 | 8731 | 589 | " | 148 | 7 | 754 | 38 | 380 | 341 | 9490 | |
| | 14 | " | " | " | " | " | 7496 | 289 | 8192 | 9741 | 647 | " | 170 | 8 | 840 | 42 | 420 | 388 | 10581 | |
| | 15 | " | " | 1300 | 1593 | 1892 | 8674 | 322 | 10688 | 12281 | 705 | 74 | 193 | 9 | 951 | 49 | 490 | 442 | 13263 | |
| | 16 | " | " | 1344 | 1637 | " | 8963 | 339 | 11194 | 12831 | 763 | " | 204 | " | 1050 | 52 | 525 | 473 | 13881 | |
| 2000 | 17 | " | " | " | " | 2165 | 9615 | 364 | 12446 | 13981 | 821 | 84 | 219 | 10 | 1134 | 57 | 567 | 510 | 14415 | |
| | 18 | (85) | 27 | 333 | 360 | " | 10767 | 357 | 12929 | 13189 | " | " | 233 | " | 1149 | 57 | 574 | 515 | 14338 | |
| | 19 | | | 200 | 200 | 2300 | 10919 | 431 | 13650 | 13850 | " | 89 | 248 | " | 1149 | 58 | 584 | 527 | 15019 | |
| | 20 | | | 89 | 89 | " | 11407 | 447 | 14154 | 14243 | " | " | 259 | 12 | 1181 | 59 | 590 | 532 | 15424 | |
| | 21 | | | " | " | " | 11652 | " | 14399 | 14488 | " | " | 265 | " | 1187 | " | 594 | 534 | 15675 | |
| 2005 | 22 | | | 119 | 119 | 3284 | " | " | 15388 | 15507 | " | 129 | " | " | 1227 | 61 | 614 | 552 | 16734 | |
| | 23 | | | 148 | 148 | " | 11326 | 436 | 15951 | 15999 | " | " | 257 | 4 | 1219 | " | 610 | 548 | 16418 | |
| 2007 | 24 | | | 163 | 163 | 3782 | 11081 | 431 | 15244 | 15457 | " | 148 | 252 | " | 1232 | 62 | 616 | 554 | 16689 | |
| Steady state | | | 55 | 372 | 427 | 5001 | 11543 | 445 | 16991 | 17396 | 818 | 196 | 262 | " | 1287 | 64 | 644 | 579 | 18683 | |
| Man days per ha | | | 0.18 | 1.8 | 1.36 | 15.88 | 3667 | 1.35 | 5390 | 5526 | 2.63 | 0.02 | 0.83 | 0.04 | 4.12 | | | | 5938 | |
| Hectares per m/y | | | | | 199 | 17 | 7 | 200 | 5 | 5 | | | | | 46 | | | | 46 | |

## App 15a) Costs and returns of managed natural forests

UNITS MILLIONS KSHS

| New | | Area of forest: New | Far | Total | Supervision costs: per year | Cumulative total | Volume: Total 000 m³ | of which FW | Revenue from fuelwood at 15/- per m³: p.y | cumulative | @ 20/- per m³: p.y | cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 0 | 14.44 | 10.00 | 24.44 | 2.44 | 2.44 | 257 | 208 | 3.12 | 3.12 | 4.16 | 4.16 |
| | 1 | " | " | " | 4.88 | 7.32 | 513 | 416 | 6.23 | 9.35 | 8.31 | 12.47 |
| 1985 | 2 | " | " | " | 7.32 | 14.64 | 770 | 623 | 9.35 | 18.70 | 12.47 | 24.94 |
| | 3 | " | " | " | 9.76 | 24.40 | 1027 | 831 | 12.47 | 31.17 | 16.62 | 41.56 |
| | 4 | " | " | " | 12.20 | 36.60 | 1283 | 1039 | 15.58 | 46.75 | 20.78 | 61.64 |
| | 5 | " | " | " | 14.64 | 51.24 | 1540 | 1247 | 18.70 | 65.45 | 24.94 | 86.58 |
| | 6 | " | " | " | 17.08 | 68.32 | 1797 | 1454 | 21.82 | 87.27 | 29.08 | 115.66 |
| 1990 | 7 | " | " | " | 19.52 | 87.84 | 2053 | 1662 | 24.93 | 112.20 | 33.24 | 148.90 |
| | 8 | " | " | " | 21.96 | 109.80 | 2310 | 1870 | 28.05 | 140.25 | 37.40 | 186.30 |
| | 9 | " | " | " | 24.40 | 135.20 | 2567 | 2078 | 31.17 | 171.42 | 41.56 | 227.86 |
| | 10 | " | " | " | 26.84 | 161.04 | 2823 | 2286 | 34.28 | 205.70 | 45.71 | 273.57 |
| | 11 | " | " | " | 29.28 | 190.32 | 3080 | 2493 | 37.40 | 243.10 | 49.87 | 323.44 |
| 1995 | 12 | " | " | " | 31.72 | 222.04 | 3337 | 2701 | 40.52 | 283.62 | 54.02 | 377.46 |
| | 13 | " | " | " | 34.16 | 256.20 | 3593 | 2904 | 43.63 | 327.25 | 58.18 | 435.64 |
| | 14 | " | " | " | 36.60 | 292.80 | 3850 | 3117 | 46.75 | 374.00 | 62.33 | 497.97 |
| | 15 | " | " | " | 39.04 | 331.84 | 4107 | 3324 | 49.86 | 423.86 | 66.49 | 564.46 |
| | 16 | " | " | " | 41.48 | 373.32 | 4363 | 3532 | 52.98 | 476.84 | 70.64 | 635.10 |
| 2000 | 17 | " | " | " | 43.92 | 417.24 | 4620 | 3740 | 56.10 | 532.94 | 74.80 | 709.90 |
| | 18 | (360) | (180) | (440) | " | 461.16 | " | " | " | 589.04 | " | 784.70 |
| | 19 | | | | " | 505.08 | " | " | " | 645.14 | " | 859.50 |
| | 20 | | | | " | 549.00 | " | " | " | 701.24 | " | 934.30 |
| | 21 | | | | " | 592.92 | " | " | " | 757.34 | " | 1009.10 |
| 2005 | 22 | | | | " | 636.84 | " | " | " | 813.44 | " | 1083.90 |
| | 23 | | | | " | 680.76 | " | " | " | 869.54 | " | 1158.70 |
| 2007 | 24 | | | | " | 724.68 | " | " | " | 925.64 | " | 1233.50 |
| Steady state (440) | | | | | 44.44 | | 4620 | 3740 | 56.10 | | 74.80 | |
| per ha (3½) (m³) | | | | | 100.1 | | 104 | 8.5 | 15 | | 20 | |

Assumptions

In unmanaged state potential volume production 525 m³/ha, but 60% non-commercial. Therefore only 2.1 m³ exploited. Of this 2.1 m³, 1.75 is skim wood, of which only about 1.0 m³ is actually removed in the log form, the other 0.75 m³ is not suitable for peeling or sawing because of degrade. In the managed state 10.50 m³/ha is removed, 2.0 m³ as sawnwood and 8.5 as fuelwood and poles.

Supervision costs assumed to be Kshs 100 per ha per year.

Table 50 Employment requirements in industrial forests

UNITS number of workers

| Year | New Forest area Ha | Supervisory labour: Thinning felling | Forest | Thinning Fell | Total | Graduate | Foreman/ Fellers | Office | Total paid workers |
|---|---|---|---|---|---|---|---|---|---|
| 83 0 | 2444 | TTP | 117 | 31 | 148 | 7 | 74 | 67 | 918 |
| 1 | " | 1541 | 235 | 62 | 297 | 15 | 148 | 134 | 1838 |
| 85 2 | " | 2311 | 353 | 92 | 445 | 22 | 222 | 201 | 2756 |
| 3 | " | 3081 | 471 | 123 | 594 | 30 | 297 | 267 | 3675 |
| 4 | " | 3852 | 588 | 154 | 742 | 37 | 371 | 334 | 4594 |
| 5 | " | 4622 | 706 | 185 | 891 | 45 | 446 | 409 | 5513 |
| 6 | " | 5393 | 823 | 215 | 1038 | 52 | 519 | 467 | 6431 |
| 90 7 | " | 6163 | 941 | 246 | 1187 | 59 | 594 | 535 | 7350 |
| 8 | " | 6933 | 1059 | 277 | 1336 | 67 | 668 | 601 | 8269 |
| 9 | " | 7704 | 1177 | 308 | 1485 | 74 | 742 | 668 | 9189 |
| 10 | " | 8474 | 1295 | 339 | 1634 | 82 | 817 | 735 | 10108 |
| 11 | " | 9244 | 1411 | 369 | 1781 | 89 | 890 | 802 | 11025 |
| 95 12 | " | 10015 | 1530 | 400 | 1930 | 96 | 965 | 869 | 11945 |
| 13 | " | 10785 | 1647 | 431 | 2078 | 104 | 1039 | 935 | 12863 |
| 14 | " | 11556 | 1765 | 462 | 2227 | 111 | 1134 | 1022 | 13783 |
| 15 | " | 12326 | 1883 | 492 | 2375 | 119 | 1188 | 1068 | 14701 |
| 16 | " | 13096 | 2001 | 523 | 2524 | 126 | 1262 | 1136 | 15620 |
| 00 17 | " | 13866 | 2119 | 554 | 2673 | 134 | 1336 | 1203 | 16539 |
| 18 | (440) | " | " | " | " | " | " | " | " |
| 19 | | " | " | " | " | " | " | " | " |
| 20 | | " | " | " | " | " | " | " | " |
| 21 | | " | " | " | " | " | " | " | " |
| 05. 22 | | " | " | " | " | " | " | " | " |
| 23 | | " | " | " | " | " | " | " | " |
| 07. 24 | | " | " | " | " | " | " | " | " |
| Steady state | | 13866 | 2119 | 554 | 2673 | 134 | 1336 | 1203 | 16539 |

270 man days/yr



Appendix 16a Costs and returns of proposed industrial scheme in high rainfall areas seedlings planted

| Year | Area planted ha. | Direct costs per year: Nursery | Forest | Total | Cumulative total | Overhead costs: Per year | Cumulative | Total costs: per yr. | Cumulative | Volume prod. 000 m³ | Revenue: Stumpage rate per m³ p.y. | Cum^n | Stumpage per ha p.y. | Cum^n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19.88 0 | 4 | 4.46 | 2.52 | 4.48 | 4.48 | 0.80 | 0.80 | 5.28 | 5.28 | | | | | |
| 1 | 5 | 1.36 | 4.88 | 6.18 | 10.66 | 1.80 | 2.60 | 7.98 | 13.26 | | | | | |
| 1990 2 | " | 1.32 | 5.40 | 6.72 | 17.38 | 2.50 | 5.40 | 9.52 | 22.78 | | | | | |
| 3 | " | " | 5.50 | 6.82 | 34.20 | 3.80 | 9.20 | 10.62 | 33.40 | | | | | |
| 4 | " | " | " | " | 31.02 | 4.80 | 14.00 | 11.62 | 45.02 | | | | | |
| 5 | " | " | " | " | 37.64 | 5.80 | 19.80 | 12.62 | 57.64 | | | | | |
| 6 | " | " | " | " | 44.26 | 6.80 | 26.60 | 13.62 | 71.26 | | | | | |
| 1995 7 | " | " | " | " | 51.48 | 7.80 | 34.40 | 14.62 | 85.88 | 147 | 2.20 | 220 | 2.94 | 2.94 |
| 8 | | 0.12 | 1.10 | 1.22 | 52.70 | " | 42.20 | 9.02 | 94.90 | 164 | 2.76 | 4.96 | 3.28 | 6.22 |
| 9 | | | 0.50 | 0.50 | 53.20 | " | 50.00 | 8.30 | 103.20 | " | " | 7.72 | " | 10.50 |
| 10 | | | 0.32 | 0.32 | 53.52 | " | 57.80 | 8.12 | 111.32 | 1021 | 13.82 | 21.54 | 18.42 | 28.92 |
| 11 | | | 0.64 | 0.64 | 54.16 | 7.40 | 65.20 | 8.04 | 119.36 | 1106 | 16.59 | 38.13 | 22.12 | 50.84 |
| 2000 12 | | | 0.70 | 0.70 | 54.86 | 6.40 | 72.10 | 7.60 | 126.46 | " | " | 54.72 | " | 72.46 |
| 13 | (39) | | " | " | 55.56 | 6.40 | 78.50 | 7.10 | 134.06 | " | " | 71.31 | " | 95.08 |
| 14 | | | " | " | 56.26 | 5.40 | 84.40 | 6.60 | 140.66 | " | " | 87.40 | " | 117.20 |
| 15 | | | " | " | 56.96 | 5.40 | 89.80 | 6.10 | 146.76 | 932 | 13.83 | 101.13 | 18.41 | 135.44 |
| 16 | | | " | " | 57.66 | 4.90 | 94.70 | 5.60 | 152.36 | 932 | " | 115.56 | " | 154.08 |
| 2005 17 | | | " | " | 58.36 | 4.40 | 99.10 | 5.10 | 157.46 | 1282 | 19.08 | 134.64 | 25.44 | 179.52 |
| 18 | | | 0.30 | 0.30 | 58.66 | 3.40 | 103.00 | 4.20 | 161.66 | 1338 | 6.57 | 141.21 | 8.76 | 188.28 |
| 19 | | | 0.00 | 0.00 | 58.66 | " | 106.90 | 3.90 | 165.56 | 438 | " | 147.78 | " | 197.04 |
| 2008 20 | | | 0.32 | 0.32 | 58.98 | " | 110.80 | 4.22 | 169.78 | 1802 | 27.03 | 174.81 | 36.04 | 232.08 |
| Steady state | | 0.21 | 1.29 | 1.50 | | 4.56 | | 6.06 | | 1217 | 18.26 | | 2434 | |

UNITS MILLIONS KSHS

Appendix 16b | Manpower requirements of proposed industrial scheme in high rainfall areas.

| Year | | Area planted acres | Direct labour: Nursery P.y | Direct labour: Forest P.y | Direct labour: N.&F. P.y | Thinning Full P.y | Plantation Total P.y | Supervision: Estab. P.y | Supervision: Thin Full P.y | Supervision: Total | Management skills: Graduates univ | Management skills: College | Management skills: other staff | Total workforce |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 0 | 4 | 178 | 652 | 830 | | 830 | 34 | | 34 | 2 | 20 | 17 | 869 |
| | 1 | 5 | 240 | 904 | 1144 | | 1144 | 87 | | 87 | 4 | 44 | 39 | 1231 |
| | 2 | " | 244 | 1000 | 1244 | | 1244 | 135 | | 135 | 7 | 68 | 60 | 1379 |
| | 3 | " | " | 1019 | 1263 | | 1263 | 183 | | 183 | 9 | 92 | 82 | 1446 |
| | 4 | " | " | " | " | | " | 231 | | 231 | 12 | 116 | 103 | 1494 |
| | 5 | " | " | " | " | | " | 279 | | 279 | 14 | 140 | 125 | 1542 |
| | 6 | " | " | " | " | | " | 327 | | 327 | 16 | 164 | 147 | 1590 |
| 1995 | 7 | " | " | " | " | 600 | 1863 | 376 | 22 | 398 | 19 | 194 | 175 | 2251 |
| | 8 | | 22 | 294 | 226 | 750 | 1976 | " | 27 | 403 | 20 | 202 | 181 | 1379 |
| | 9 | | | 93 | 93 | " | 843 | " | " | " | " | 202 | 181 | 1246 |
| | 10 | | | 59 | 59 | 3480 | 3539 | " | 136 | 512 | 26 | 256 | 230 | 4051 |
| | 11 | | | 118 | 118 | 4165 | 4283 | " | 164 | 540 | 27 | 270 | 243 | 4823 |
| 2000 | 12 | | | 130 | 130 | " | 4245 | 356 | " | 520 | 26 | 260 | 234 | 4815 |
| | 13 | (34) | | " | " | " | " | 332 | " | 496 | 25 | 248 | 223 | 4791 |
| | 14 | | | " | " | " | " | 308 | " | 472 | 24 | 236 | 212 | 4767 |
| | 15 | | | " | " | 3345 | 3345 | 284 | 137 | 421 | 21 | 210 | 190 | 3766 |
| | 16 | | | " | " | " | " | 260 | " | 397 | 20 | 198 | 179 | 3742 |
| 2005 | 17 | | | " | " | 4841 | 4971 | 236 | 188 | 424 | 21 | 212 | 191 | 5395 |
| | 18 | | | 56 | 56 | 1784 | 1840 | 212 | 65 | 277 | 14 | 138 | 125 | 2117 |
| | 19 | | | 0 | 0 | " | 1784 | 188 | " | 253 | 13 | 126 | 114 | 2037 |
| 2008 | 20 | | | 59 | 59 | 6836 | 6895 | " | 267 | 455 | 23 | 228 | 204 | 7350 |
| Steady state | | | 38 | 240 | 278 | 4596 | 4874 | 233 | 180 | 413 | 21 | 206 | 186 | 5287 |
| p.hectare/yr | | | 0.26 | 1.66 | 1.92 | 31.82 | 33.74 | 1.61 | 1.25 | 2.86 | | | | 36.60 |
| ha/man/yr | | | | | 141 | 8.5 | 8 | | | 91 | | | | 7 |

UNITS
MAN YEARS
270 man days/yr.