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PROCEEDINGS

ENERGY FOR RURAL DEVELOPMENT ACTIVITY SET III: FIXING CRITERIA FOR SELECTION OF FUELWOOD SPECIES

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WELCOME REMARKS

HIGINO A. ABLES
Vice-Chancellor for Academic Affairs
U. P. at Los Baños, College, Laguna

I am pleased to welcome the participants of this Seminar-Workshop.

My usual statement in occasions like this only goes as far as introducing the University to foreign delegates by stating some data about it. But because the topic strikes too close to home, I thought I would venture to say a few words on the importance of your workshop. First, about the University. . .

This campus was established almost 72 years ago as one of the first units of the University of the Philippines. On Friday, we shall be observing our Foundation Day. It was on June 14, 1909 when four American professors and 12 students started classes on the slopes of this legendary Mt. Makiling.

Now, the University of the Philippines at Los Baños is an autonomous university, headed by a Chancellor, assisted by 3 vice-chancellors, 7 deans for 6 colleges and a graduate school, about 700 full-time faculty members, 200 of whom have the PhD. We have 6,000 students, 60% of whom are female.

Aside from agriculture and forestry, economics, agricultural engineering, statistics, mathematics, physics, sociology, communication, agricultural education and social forestry courses are also offered.

In our pursuit of excellence, relevance and growth, our faculty members have organized programs, institutes and centers for research and training. We can say that it is in this campus where science is being harnessed in the service of agricultural and rural development especially for the rural poor. We are also addressing the manifold problems that confront the developing world: the food crisis, population explosion, the energy crunch, and environmental degradation. Studies on energy, one of the research thrusts, are aimed at developing cheap, available, safe sources of energy.

And now to the Workshop topic. When I first heard of your Workshop, I thought how simple it is that it probably does not merit an international seminar-workshop of this magnitude. But I changed my view when I learned that over 95% of households in developing countries

where woodfuel is readily available, use it as a primary source of energy, according to an article in the New Scientist (Jan. 31,1974). This falls to 80% when all developing countries, including wood poor regions and desert countries are counted. In the Philippines, about 70% may be safe guess-estimate of the proportion of the households using woodfuel 1980, 35% fuelwood, 65% charcoal.

It was surprising for me to find that about 65% of 1972 wood use was for woodfuel. Considering this statistic made me feel that there indeed is a need to discuss criteria for mass selection of fuelwood species.

Where forest trees abound, the first option is to gather dead branches for fuel. But when these run out, young saplings are taken, And eventually mature trees are felled. As population pressure grows greater every day and as oil prices keep on escalating, we can imagine this demand to grow. What trees should these be?

If a decision is made by tree farmers to grow trees for fuelwood how does one select the species that will yield the most in the shortest time span? How can these species be reproduced, managed, harvested and hauled for use?

As this Workshop attempts to find answers to these questions, I hope it will consider the small rural dweller, especially the landless lot, who now know nothing about silviculture, dendrology and wood technology. I feel we have to focus some attention on how we can get our criteria, our technology disseminated to them. For they who live near forests are really the ones that will determine the regeneration and utility of our forest resources. We should be aiming at the twin goals of spreading the benefits of forest resources to as many people as possbile while assuring ourselves of a sound ecology, a healthful and safe environment.

I am sure this Workshop is a significant step towards attaining these universal goals.

I wish you a pleasant stay and a fruitful round of discussion.

Thank you.

COUNTRY REPORTS

BANGLADESH

FUELWOOD SITUATION IN BANGLADESH

M.A. HAI[1/]

ABSTRACT

There is an acute shortage of fuelwood required for cooking both in the rural and urban areas, particularly in the northern districts of Bangladesh. The pressure of such shortage falls upon the homestead fruit or timber trees, as well as dry cowdung, jute sticks, rice straw, rice hulls or bagasse which are being used as a substitute to firewood. As a result, ecological imbalance in the environment is imminent.

The proposed project will be to maximize production of fuelwood in the northern districts to reduce pressure on the ecology and on other valuable industrial raw materials and therefore solve the shortage.

With the objective of maximizing production of fuelwood within the shortest possible time and at an economic cost, local people will have to be motivated to grow fast growing fuelwood species in their homestead and marginal lands so that in the near future, the deficit area is turned into a surplus area with respect to fuelwood.

On the basis of past experiences and available information some fuelwood species will be selected. The suitable planting sites will also be selected after proper field investigation. The seeds will be procured either locally or by import from other countries. The seed provenances, viability and the like will be tested.

Based on previous researches conducted, Leucaena leucocephala commonly known as Ipil-Ipil, and Sasbania grandis were found to have satisfactory growth. In the year 1980-81, ten million seedlings of various species will be raised in 63 Forest Department Nurseries and will be distributed to the people to increase the production of fuelwood, timber, fodder, and the like.

[1/] Deputy Conservator of Forests Rajshahi, Bangladesh.

FUELWOOD SITUATION IN BANGLADESH

Per Capita Consumption of fuelwood in Bangladesh is only 0.4 cft. as against 24 cft. in Nepal. This is because of limited supply of fuelwood from our managed forests as well as from village groves. There has been fast and continuous denudation of forest due to population pressure and scarcity of alternative fuel resources. The forest area is also scanty and more so in the northern district of Bangladesh. This situation has caused misuse of cowdung, jute, sticks, rice husk, rice hulls, bagasse etc. which could have been profitably utilized for other suitable purposes. This calls for action for maximizing the fuelwood production in the country, particularly in the Northern district of Bangladesh. This is constrained by scarcity of land which has other uses. Therefore it will be necessary to increase per acre yield of fuelwood so that the forest area becomes competitive with agricultural land. This is possible only if fast growing plants can be evolved. It is therefore proposed that suitable fuelwood species will be selected and seeds will be collected. Seedlings will be raised and the fuelwood plantation will be grown both in the nursery as well as in the marginal lands and homestead of selected villages. People of the project area will have direct and active participation in the entire process of growing new fuelwood plantation. The benefit derived from such plantation will fully be shared by initally the participants and gradually the results will be diffused to neighboring areas by the participants themselves ultimately with the aim of developing community forests.

The Bangladesh Energy study estimated fuelwood consumption at 0.4 cft. per capita annum in 1975. Forest Department estimates timber consumption at about 0.3 cft. per capita per annum. The position can well be ascertained if her position is compared with some of the neighboring countries.

TABLE - I

CONSUMPTION PER CAPITA PER ANNUM (Cfts.) - 1970

Country	Timber	Fuelwood	Total Wood
India	0.76	7.07	7.83
Burma	2.60	21.97	24.57
Thailand	4.50	8.83	13.13
Nepal	1.40	24.00	25.40
Bangladesh	0.30	0.40	0.70

The requirements of fuelwood per year in Bangladesh is approximately 150 million cft. (1.75 cft./cap), whereas the supply position for the last few years from the government managed forests and village groves are estimated as follows:

(FIGURES IN MILLION CFT.)

Year	Government Managed Forests	Village groves	Total
1975-76	10.93	18.00	28.93
1976-77	13.07	18.00	31.07
1977-78	22.73	18.00	40.73
1978-79	16.59	18.00	34.59

There are 3.25 million acres (9% of total area) of Bangladesh forest managed by the Forest Department. This area is not evenly distributed and is mainly concentrated in the south and eastern parts of the country with small area in the central districts. The northern districts are almost devoid of forests. There exists at present only .1% land (55.89 sq. miles) under unproductive forests and there is no provision for extraction and marketing of fuelwood and timber from those forests. The fuelwood and timbers being produced in the concentrated area in the south and eastern parts cannot be transported to the nothern districts because of high carrying cost. Moreover, natural gas is not at present available in the northern districts.

Naturally the pressure for such shortage particularly in the northern districts falls upon the homestead fruit or timber trees. Besides these, dry cowdung, jute sticks, rice straw, rice hulls, bagasse, etc. are used there as fuel as a substitute of firewood. According to one estimate of 1973-74, the consumption of dry cowdung as fuel in Bangladesh was nearly 6 million tons; jute sticks, 1 million tons; rice straw, 3 million tons; rice hulls, 4 million tons; and sugarcane bagasse, 1.5 million tons.

If the cowdung is used as manure for the crop fields, the jute sticks, rice straw and bagasse are used in the industries and the rice hulls are used as fish and poultry feed, the fuelwood problem will be much more alarming in near future.

Because of acute shortage of fuelwood in the northern region, the valuable mango and other fruit bearing tree gardens are cleared and ecological imbalance in environment is imminent. The proposed project will be to maximize production of fuelwood in nothern districts of Bangladesh to reduce pressure on the ecology and on other valuable industrial raw materials and therefore it is higly relevant to the solution of the problem.

There is great scope for growing fuelwood species in the marginal lands and homestead in the project area.

As there is acute shortage of fuelwood required for cooking both in the rural and urban areas, the objective is maximizing production of fuelwood within shortest possible time and at a cheaper cost. In doing so, local people will be brought in the process. They will be motivated to grow fast growing fuelwood species in their homestad and marginal lands so that in near future, the deficit area is turned into a surplus area with respect to fuelwood. The result so obtained will gradually be transferred to the other villages thereby covering the entire area of Bangladesh with emphasis on the development of community forests.

On the basis of past experiences and available information some fuelwood species will be selected. The suitable planting sites will also be selected after proper field investigations. The seeds will be procured either locally or by import from other countries. The seed provenances, viability, etc. will be tested. The seedlings will be raised in polyethelene bags of suitable size in the nursery. Planting by direct seed sowing or dibbling and seedling transplanting will be done both in the forest nursery as well as in the selected village homestead, marginal lands involving local people's participation. Spacing, hoeing, weeding, watering, pruning, thinning will be done by the forestry personnel. Regular supervision will be arranged and at regular intervals, measurement or observation will be recorded in the nursery and plantation journal.

From the past experience and observation the Leucaena leucocephala commonly known as Ipil-ipil and Sasbania grandis planted recently and found satisfactory growth as follows:

Name of Species	Location plantation	Date When planted	Date of measurement	Max. height	Max. girth at B.H.	Ave. height.	Ave. girth
Leucaena leucocephala	Rangpur.	13.7.79	17.1.81	29'-0"	19"	17'-0	12"
Leucaena leucocephala	Thakurgaen	13.7.79	18.1.81	27'-0"	17"	16'-0	9"
Sasbania grandis	Rajshahi	12.7.80	28.2.81	12'-0"	8.5"	10'	5.5"

From the above observation we can suggest the following species for planting as fuelwood around homestead, marginal lands inter-cropping in the agricultural crop.

1. Giant Ipil-ipil
2. Sasbania grandis and other suitable species may be selected such as:

   a. Calliandra
   b. Eucalyptus camadullensis
   c. Rain tree
   d. Dalvergia Sissee
   e. Acacia arabica
   f. Albigia procera

In the year 1980-81 Crore seedlings of various species will be raised in 63 Forest Department Nurseries situated in the Bangladesh and will be distributed to the people to increase the production of fuelwood, timber, fruit, fodder, etc.

TRADITIONAL ENERGY RESOURCES WITH PARTICULAR REFERENCE TO FUEL-WOOD IN BANGLADESH

NURUDDIN M. KAMAL[1/]

ABSTRACT

Over 66% of the total energy supply in Bangladesh comes from traditional sources while some 20% of the requirements are met through import of commercial fuel oil and coal. Cowdung (25 percent), rice hulls (24 percent), and rice straws (18 percent) are the major sources of traditional fuel. Fuelwood constitutes only 3.5% of the total fuel supply while leaves and twigs provides 9%.

Trends showed that the per capita availability of fuel had been on the decline. The sharp drop on fuelwood production from the reserve forest is attributed to widespread unauthorized felling even in the restricted areas and inadequate replantation.

The area of 665,000 acres occupied by homestead was estimated to be crown-covered area suitable for producing both roundwood and fuelwood. It is estimated that each acre of crown-covered area can provide 24 cu. ft. roundwood and 20 cu. ft. of fuelwood.

Ninety-one percent (91%) of the population in Bangladesh live in the rural areas and 51% are functionally landless. The rural populace is continuously on the rise making it increasingly difficult for the majority of the population to grow homestead forest for supply of firewood. With this kind of socio-economic structure, tree plantation, which are considered as one of the best ways of augmenting rural energy supply, would bring benefit only to land owners, but do little for redeeming the energy deprivation of the poor. Socially and economically disadvantaged groups of the population are gradually being forced to buy their fuel for parboiling of paddy rice cooking and other needs from the market at costs that are rising with the decline of supply.

[1/] Chief, Rural Energy Section, Planning Commission, Bangladesh.

The future strategies for rural energy supply have to lay sufficient emphasis on production of fuelwood both from forest areas and homesteads. Potential for augmenting supply of fuelwood by plantation (and preservation) of short cycle species along flood embankments, road sides and canal banks under various rural work programmes, and also Khas (Government) Lands in forest areas leased to the landless should have a brighter prospect.

* * * * *

Over 66% of the total energy supply in Bangladesh comes from the traditional sources while some 20% of the requirements are met through import of commercial fuel oil and coal. The direct and indirect consequences of international oil price increase are now posing to be major threat to economic development and growth of the country.

In terms of per capita GNP, Bangladesh happens today to be the second poorest country in the world, and this backwardness is reflected also in her low energy consumption. Table 1 (please see attached) shows a comparison of the basic energy indicators for the commercial forms of primary energy for Bangladesh with those of a few other countries in the regions as well as average of those of other developing and industrialized countries.

Whereas table 1 shows the consumption of commercial fuels only for 1978, the balance between the consumption of commercial and traditional fuels in Bangladesh for 1979-80 expressed in coal and oil equivalent/capita is indicated in Table 2 (please see attached).

There are however, very few studies on the consumption of different energy sources used in villages. The resulting lack of quantitative data has led to several problems. Thus in discussions rural household energy consumption has been considered to represent total energy consumption. The absence of reliable and comprehensive data regarding rural energy consumption patterns, the absolute and relative magnitudes of the various end use of energy in villages cannot be derived. Under these circumstances, the best that can be achieved is to identify the different end uses and perhaps rank them. Even this attempt is complicated by the fact that the end use pattern would depend upon agro-climatic conditions, the level of productive activities, the life style and the availability and accessibility of technologies.

Data base and statistics are not up to date and are also not very reliable. However, trends showed that the per capita availability of fuel had been on the decline (fuelwood production from reserve forests was estimated to have dropped from about 500,000 tons in 1965

to about 50,000 tons in 10 years). The inevitable consequence of this had been increase of demands on commercial sources of energy which has ominous portends. It is estimated that a 10% decline in the supply of traditional sources of fuel would require correspondingly 30% expansion of the commercial sources in order to maintain the same overall availability of energy. Besides, the issue has also some serious social implications owning to the fact that landlessness among the rural populace is continuously on the rise, making it increasingly difficult for the majority of the population to grow homestead forest for supply of firewood. Increase in population and depletion of forest is making full collection of twigs and leaves by the village women and children more and more difficult. Stagnancy in the development of livestock in making animal dungs scarer. All these indicate that the socially and economically disadvantaged groups of the population are gradually being forced to buy their fuel for parboiling of paddy, cooking and other needs from the market at costs that are rising with the decline of supply. Poverty does not permit a very large section of the rural populace to buy enough kerosene for illumination which forces them to reduce the length of their active day. Correct identification of the need of energy in the rural areas, planning for increase in supply of traditional fuel and supplementing the same with commercial fuel have important implications for the economy of Bangladesh where 91% of the population live in the rural areas and 51% of the population are functionally landless (general definition of landlessness denote possession of less than 0.5 acre of land, but 70% of this class do not have any land at all or have nothing besides the homestead). It may be argued that with this kind of socio-economic structure, even plantation of trees which is considered as one of the best ways of augmenting rural energy supply, would bring benefit only to owners of land, doing little for redeeming the energy deprevation of the poor.

So far the only major attempt ever made to gather information on traditional fuels was in connection with the Bangladesh Energy Study (BES) conducted by the Planning Commission in 1974-76 with UNDP assistance. Their estimates for 1973-74 conditions indicated that cowdung, rice hulls and rice straw happended to be the major sources of traditional fuel, forming respectively 25% and 18% component of all traditional fuels. Surprisingly fuelwood constituted only 3.5% of the total supply while leaves and twigs provides 9%. Table 3 (please see attached) show the pattern of consumption of energy supplied by traditional fuels in 1973-74.

Out of her total land area of approximately 36 million acres, Bangladesh has about 5.7 million acres of forest land of which approximately 3.3 million acres are reserve forest managed by the government while the rest is what is known as unclassified forest land. The sharp drop in fuelwood production from the reserve forest is attributed to widespread unauthorized felling even in the restricted areas and inadequate replantation. The total area occupied by homestead complex in the country is estimated to be 2.4 million acres of which 665,000 acres

was estimated in 1974-75 to be crown covered area suitable for producing both round wood and fuelwood. It is estimated that each acre of crown covered area can provide 24 cu. ft. of round wood and 20 cu. ft. of fuelwood (each cu. ft. wood would weigh about 45 lbs.).

The availability of fuelwood from the reserve forest in the past has been estimated to be as follows:

Table 4

Year	Million cu. ft.	Year	Million cu. ft.
1970 - 71	18.15	1975-76	10.80.
1971 - 72	2.56	1976-77	13.47
1972 - 73	8.50	1977-78	10.83
1973 - 74	10.70	1978-79	10.99
1974 - 75	10.90	1979-80	10.90

Source: Directorate of forests in Bangladesh.

On the basis of normal cycles of plantation and extraction, the potential supply of fuelwood on sustained basis is estimated to be around 600,000 tons per year. In addition, there is also a potential for 500,000 tons/year of fuelwood production from the Chittagong Hill Tracts very little of which is being currently exploited. Obviously the future strategies for rural energy supply has to lay sufficient emphasis on production of fuelwood both from forest areas and homesteads. Potential for augmenting supply of fuelwood by plantation (and preservation) of short cycle species along flood embankments, road sides and canal banks under various rural works programme and also Khas (Government) Lands in forest areas leased to the landless should have brighter prospects.

Under BES, study was made of the energy sectors as a system that was a part of the larger economic system of the country. Among others, attempts were made to make a forecast of energy demands for a period of 25 years, analysing various supply alternatives through appropriate economic analyses and studies and also recommend an investment programme for the period up to 1985. During the 7 year period reviewed (1972 - 73 to 1979 - 80), the GDP at constant prices grew at 4.3% per annum while energy sector has been on the average only 1.04% of the GDP and 11.15% of the annual development expenditure. Percent share of the energy sector in the total GDP grew at a rate of 7.5% which is considered a good performance with such rates of investments while the GDP was only 4.3%.

Tables 5-A and 5-B below show the energy consumption for fuelwood expressed in terms of their heating values:

Table 5-A

Energy Consumption (Fuelwood only) (In Trillion BTU)

TYPE	Y				E		A		R		
	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
Fuelwood (Reserve forest)	6.0	5.89	0.83	2.76	3.48	3.54	3.51	4.38	3.52	3.57	3.68

Table 5-B. Projection of energy consumption during 1980- 85 (Fuelwood)

TYPE	Y	E	A	R	
	1980-81	1981-82	1982-83	1983-84	1984-85
Fuelwood (Reserved Forest)	11.0	11.25	11.50	11.75	12.00

While drafting the Second Five Year Plan (SFYP) of Bangladesh, it was presumed that the trend in traditional energy demand would change with the rapid increase in use of natural gas and rural electricity. In 1979-80, the traditional energy consumption was 66.3% which might be reduced to 56.1% by 1984-85.

Like other developing countries, the problems of rural energy demand and supply must be discussed separately, because of the patterns of energy consumption and sources of supply in rural areas differ basically from these in towm and cities. Firstly, the intensity of energy consumption is comparatively lower in rural areas. Secondly, the relative share of the various consumption categories in the total energy consumption in urban areas is quite different from that in rural areas where household energy consumption dominates the situation. Thirdly, the share of non-commercial energy in rural areas is much higher than in urban areas. Fourthly, a major portion of the energy supply in rural needs is secured by the private efforts

at a very low or even zero private cost and an energy policy which depends on fiscal and administrative controls on energy distribution may not have impact in most rural areas. Finally, a large fraction of the rural population is too poor to buy commercial energy even when the supply of these is made available. Among others, the basic issues in formulating a ' Rural Energy Policy' in Bangladesh are:

i. The estimation of the quantities of non-commercial energy use in rural areas for various consumption and production purpose, and the possible identification of the determinants of shifts from non-commercial and animal energy to commercial energy.

ii. The estimation of likely changes in the pattern of rural consumption of different fuels with the growth of agricultural production and with improvements in the economic condition of the rural population.

iii. The encouragement or discouragement of the normal trends of replacement of non-commercial energy by commercial energy and the promotion or restriction of the extent of utilization of non-commercial energy in view of the growing shortage and increasing costs of commercial energy.

iv. The feasibility of adequately meeting the energy needs of rural areas from centralized energy supply systems and the extent to which decentralized energy system can be evolved to cater to these energy needs.

Table - I

Countries	Per capita GNP US $ 1978	Annual growth rate of energy consumption % 1974-78	Per capita Energy consumption kg of coal equivalent 1978	Energy consumption per Dollar of GDP kg of coal equivalent 1978	Energy imports as % or merchandise exports 1978
Bangladesh	90	16.5	43	0.3	48
Burma	150	4.9	64	0.5	12
India	180	5.1	176	1.2	26
Average of 38 low income countries	200	6.8	161	1.0	16
Average 18 industrialized countries	8070	1.5	7060	1.1	23

Source: World Development Report, 1980 (World Bank)

Table 2

1979 - 80	Kg. or coal equivalent per capita	Kg or oil equivalent per capita	Imp. Gal. or oil equivalent per capita
Commercial	51.69	29.94	7.72
Traditional	110.72	64.13	15.55

Source: Planning Commission Report (Energy in Bangladesh: An overview)

Energy Balance: Traditional fuels including commercially sold firewood is used mainly as the source of heat for the rural and suburban areas inhabited by over 91% of the population.

Table 3. Consumption of Energy Supplied by Traditional Fuels (1973-74 estimates)

F U E L	Percent of total production used as Fuel	BTU per lb	Amount used as fuel in Million LT	Total BTU content x 10^{12}	Percentage of total traditional fuel
1. Cowdung	35	3700	6	50	25
2. Rice hulls	80	5400	4	48	24
3. Rice straw	10	5400	3	36	18
4. Twigs and leaves	-	5400	1.5	18	9
5. Jute stick	50	5400	11	12	6
6. Bagasse	75	3200	1.5	18	5.5
7. Fuelwood	-	6500	0.5	7	3.5
8. Other Wastes	-	5400	1.5	18	9
TOTAL			29.0	207	100

All fuels (Total 10.6 x 10^6 LT)

Source: Bangladesh Energy Study, 1976

CRITERIA FOR MASS SELECTION OF FUELWOOD SPECIES WITH REFERENCE TO AGRICULTURAL RESOURCE OF TAMIL NADU

S. KONDAS and T. ACHAYA [1/]

ABSTRACT

Tamil Nadu, one of the 22 states of the Indian Union, is a distinct geographical entity of 130,000 sq. km. occupying the southeastern region of the Indian Peninsula. Except for 1.3 million hectares of problem soils (saline and alkaline), the tract is one of predominantly red loam-black soils with coastal sands. The average rainfall is 750 mm., mostly in the cooler months of October-November. Of the total geographical area, 47% is under cultivation. Nearly 29,000 sq. km. are under irrigated farming. The area under rainfed farming is about 34,000 sq. km. The bovine population is 13.9 million. The human population is 47 million (1981) of which 12 million are estimated to be urban and 35 million rural. At the rate of 5 kg. of wood per family of seven persons per day, the total annual requirement of fuel of the State comes close to 10 million tons. The supply from state forests is a mere 3%.

Besides the domestic demand, there are other demands from brick manufacturers, jaggery manufacturers, and for cremation of dead bodies (for every 18.5 persons per 1000 per year, 250,000 tons of firewood and cowdung cakes are required). The total demand is not readily ascertainable. Besides firewood and cowdung cakes, the other domestic fuels are kerosene, gas and electricity. A precise account of the segment of the population depending upon these sources is not known. It is obvious that there is a growing scarcity of fuel as evidenced by escalation of firewood price and the scramble to use anything as domestic fuel. An attempt is made to find out how agricultural residue which is available in great quantities (3.4 million tons) together which cowdung comes handy to meet a large chunk of domestic demand, particularly in dry land farming region. How the valuable natural resources like light, water and soil with which this State is amply endowed could be mobilised to optimum utilization for augmenting wood production to meet a much larger demand for fuel is closely examined. The irrigated farming region with 29,000 sq. km where water and light are far in excess of the needs

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1/ Conservator of Forests (Research), Tamil Nadu State and Chief Conservator of Forests, Tamil Nadu, respectively.

The irrigated farming region with 29,000 sq. km where water and light are far in excess of the needs of agricultural crops can be of agricultural crops can be put to sylvagricultural treatment of combining plough crops with tree crops. This would generate nearly 3 million tons of firewood per annum.

Another 3.2 tons can be harvested from planting river, canal banks and foreshores of tanks. So there is a great potential, hitherto untapped, for producing nearly 6.2 million tons per annum. This will become a reality only if the farmers lay aside their unsubstantiated fear of lesser grain yield due to trees. It is simple economics of a higher net return from one's land that is going to influence them in favor of combining agriculture with tree husbandry.

INTRODUCTION

Out of the physical features of a country orginate certain natural resources. Over ages these resources have been systematically mobilised to satisfy human needs. It is human ingenuity that exploits this resource base more thoroughly to produce a variety of goods and services. Traditionally forests are considered to be the exclusive source of wood and wood-products. This is a dangerous view because it gives the impression that trees are not necessarily an integral part of a land farming system. They are looked down upon as incidental or tolerable intrusion. In thickly populated Asian countries with a well developed agricultural base there is a strong case for utilization of agricultural potential to produce wood along with food grains etc. In India there was a green revolution in the sixties but there was no matching brown revolution meaning an ambitious plan to produce sufficient wood to cook every kg. of grains produced. The green revolution and increase in the standard of living has lead many families having to cook two meals a day as against one only in the past, resulting in the increased demand for fuel. In this paper, Tamil Nadu one of 22 states of Indian Union, is taken as a case study typical of many Asian countries, with all their assets and liabilities, and its agricultural potential and examined for diversified utilization.

THE TRACT

Physical features

The tract considered here is the southeastern region of the Indian Peninsula called Tamil Nadu (1,30,069 sq. km) falling between 8°5' and 13°35' N and 76°15' and 80°20' E. It is predominantly a plain country bounded by a mountain range forming an important watershed called the Western Ghats on the west and a thousand km. long coast of Bay of Bengal

on the east. The tract is traversed by eight river systems of which the Cauveri, the Vaigai and the Tamparaparani systems are the most important. The soil varies from coastal sand, red loam to black types in the plain region. The average rainfall in the plains is 750 mm. mostly received in the cool October-November months. It goes up to 3000 mm. in the hills and 1000 mm. in the northern coastal area gradually coming down to 600 mm. in the South. There are 2500 tanks scattered all over the State. They serve to impound run off and floods in rivers and provide for irrigated farming. There are 16,600 km. of canals distributing water for irrigation purposes. The forests (2173 sq. km.) being the property of State are mostly restricted to the Western Ghats and to some extent isolated hills and scattered in the plains.

Mobilization of natural resources

Of the total geographical area of the State excluding forest areas, 65% is cultivated of which 40% is under irrigated crops and 60% under rainfed crops. This much of irrigated farming is made possible because of the numerous tanks scattered all over the State and a well developed system of distributary canals approximating 16,600 km. The well developed electricity system have made possible irrigation by wells to more than a million ha. Thus the irrigation potential has been highly developed. Under tropical conditions there is unrestricted solar energy for photosynthesis. The availability of abundant drought, animal power and human labour have enabled the exploitation of the agricultural potential to a great extent. This is typical of many South-East Asian countries.

Towards complete utilization

Traditionally this agricultural potential is utilized for raising plough-crops (paddy, sugarcane, etc.) almost to the total exclusion of tree species. Plough-crop culture occupies a space of 2 to 3 m height and this is incomplete utilization of environment. Greater use of land and water is possible only with a vertical direction which means a two storey agriculture with trees above tilled crops. This is the region where water and light are far in excess of the requirements of agricultural cropping and it would certainly permit raising a few trees per ha. without affecting agricultural productivity. The availability of land area in the form of field bunds is really great although not striking. For every ha. of land it works out to 400 m. approximately. At a 20 m. interval 20 trees can be grown on bunds. On a five year rotation the yield is expected to be 5 tonnes per ha. The productivity works out to 1 tonne/ha./annum.

ATTITUDE OF FARMERS

This much of agricultural potential lies with farmers and remains incompletely utilized. It is mostly a case of attitude on the part of farmers. It is the unfounded fear of lesser grain yield due to trees that makes him hesitant or reluctant to combine tree husbandry with agricultural cropping. This strikes one as odd when the dry land farmer looks upon trees in the midst of his crops as a kind of gainful agricultural enterprise. This unhelpful attitude of the wet land farmer does not appear to be one of the sentiments. Recent years have witnessed an escalation of wood prices for pulpwood and fuel. It is simple economics of a better net return from his land that is going to influence him in favour of combining traditional agriculture with tree husbandry. That day is not far off.

THE PEOPLE

The total population of the State as projected for 1981 is 47 million of which nearly 12 million form the urban and the rest rural sectors. The urban population is scattered in 436 towns (including Madras-City) with population of 5000 and above per town while the rural population live in about 16,600 villages. The average per village is 2100. Agriculture is the primary sector of the State economy. The main food grain crop is paddy cultivated in about 2,173,000 ha. while millets, oilseeds and cotton aggregate to 3,414,000 ha. The total bovine population is 13.9 million and its concentration is more in irrigated than in rainfed areas.

FIREWOOD DEMAND

At the rate of 5 kg. of wood per family of seven persons (an average size) per day the total requirement of wood fuel of the State comes close to 10 million tonnes per annum. The State forests meet a mere 3% of the total demand. There is also a great demand for wood fuel from brick kiln owners, jaggery manufacturers and for other purposes like dyeing and cremation of dead bodies, etc. Besides firewood and cowdung cakes the other domestic fuels are kerosene, cooking gas and electricity. A precise account of the segment of population depending upon these sources is not known. It is obvious that there is a growing scarcity of fuel as evidenced by the escalation of price of firewood and the scramble to use anything as a domestic fuel. An attempt is made to find out how agricultural residue which is available in great quantities together with cowdung comes handy to meet a large chunk of demand in dryland farming region. How the valuable natural

resources like soil, water and solar energy, which this State is amply endowed with, could be mobilised to optimum utilization for augmenting wood production to meet a much larger demand for fuel is closely examined.

SOCIO ECONOMIC REGIONS

For the purpose of study of rural energy position, the State can be divided into coastal, dry land farming, irrigated farming, hill and lastly urban regions based on socio-economic conditions. There is sufficient fuel grown in hills and it is only a question of regulating its availability. This region is excluded from the scope of our present study.

Coastal region: The coastal region is considered in terms of people who depend upon the sea for their livelihood (fishing, salt making) and alternately on Palmyra for tapping sweet sap 'neera' and its conversion into jaggery. They are extremely poor and their daily earnings may not exceed Rs. 6/- to Rs. 8/-. Their requirement of fuel is minimal, exclusively for cooking, which is a very simple fare of boiling rice. They require some fuel for converting 'neera' into jaggery. They are so poor that they can afford to buy brushwood, palmyra fronds and some other trash only. There are about 400 villages in the coast and the estimated population will be about 0.2 million tonnes per annum. This can be met from 35,000 ha. of Acacia planifrons, Casuarina woodlots managed under a 5-year rotation which can be raised in the existing palmyra stands or a fresh in sandy tracts. Casuarina will succeed where moisture conditions are better.

Dry land farming region: This region is by far the largest in extent. Though mainly rainfed it includes a number of well-irrigated farms. The soil is black or red type. The crops grown are sorghum, pearl millet and lesser millets, where well irrigation is possible cash crops like cotton, oil seeds, vegetables like brinjal (egg plant) are grown. The total will be about 3,400,000 ha.

The agricultural residue consisting of spent straw of millets, stalks of cotton, oil seeds and other vegetable crops like brinjal provide a sizable quantity of biomass which are used as domestic fuel. At an average rate of 1.5 tonnes/ha. the quantity of residue will be of the order of 5 million tonnes per annum. After providing for fodder and other uses, poor cropping it is expected that at least 50% i.e. 2.5 million tonnes may be available. The residue is consumed locally almost in the farm it is produced since it is bulky and not economical to transport. Even well-to-do farmers do not go for wood fuel inspite of the fact that agricultural residue is a clumsy one to use. Since cowdung is not used for organic manuring, in dry land farming it is available as domestic fuel. Cowdung has come to stay as handy and cheap domestic fuel for more than one reasons.

The dry land farming tract presents something of a 'savanna' landscape of scattered trees in sharp contrast to the irrigated farm lands. On an average 15 trees/ha. of Acacia species are tended. It can be safely assumed that the entire region of dryland farming of 34000 sq. km. contains 50 million trees. Although there is no fixed rotation, trees are not felled earlier than 15 years of age. Often it is done in years of crop failures to find money to tide over difficult periods. The trunk and larger limbs are sold to consumers in towns while the branchwood is used locally. The growth rate is such that 8 trees will make a tonne and the total quantity available per year would be 3.3 million trees yielding 0.41 million tonnes of which 0.31 million tonnes consumed in towns and the rest locally. As regards fuel position the dryland farming region is capable of subsisting on agricultural residues besides supplying some quantity to urban areas nearby.

Irrigated farming region: Agriculturally speaking this is the most important region (29,00,000 ha.) with paddy occupying the largest extent (27,00,000 ha.). Sugarcane and banana occupy a much smaller area. Next to urban areas the density of human population is highest here. The concentration of bovine population is also greatest. The available agricultural residue as fuel is in no way significant because the paddy straw is used as cattle feed and bagasse as fuel by sugar and jaggery manufacturing industries. The cowdung will be increasingly used as farmyard manure in view of the increasing prices and difficulty in securing chemical fertilizers at the right time. In this context, wood as a fuel assumes great importance. As discussed earlier, this region alone with 29,00,000 ha. under cultivation can produce 14.5 million tonnes of wood in addition to agricultural crops. On a five-year rotation the annual harvest will be of the order of 2.9 million tonnes of wood. River delta districts are ideal and which can produce one tonne of wood fuel per hectare every year. Such situations are common in agriculturally dominant countries of South-East Asia. As pointed out earlier it is only a matter of time before the wet land farmer takes to it. Bund planting of trees is already popular in certain Asian countries like Taiwan and Philippines.

Within each command area considerable potential areas for planting lie outside private holding like Government wasteland, bunds of minor distributaries etc. These areas can be tackled first to demonstrate the profitability of growing trees to farmers. The yield will marginally increase the overall production of each command area.

The resources of an agricultural State offers sites for planting. The network of canals running for a length of 16,600 km. provide nearly 20,000 ha. for planting at 1,000 trees/ha. There are numerous irrigation tanks, big and small, with an aggregate foreshore plantable area of 600,000 ha. The canal bank planting will yield 5 million tonnes over a 5-year rotation i.e. one million tonnes every year. The

tank foreshore planting on a rotation of 10 years at 30 tonnes/ha. will yield 1.8 million tonnes per annum. In addition the eight river systems with an aggregate length of 1800 km. offer area for planting 2.8 million trees which on 10-year rotation will provide 56,000 tonnes per annum.

To sum up, the yield of wood fuel from irrigated farming region will be of the order of 6.1 million tonnes including 0.4 million tonnes contributed by the dryland farming region. This will be in addition to the present supply from various sources. The requirement of this region which has to depend upon wood fuel will be around 5 million tonnes per annum presuming that the population is about 20 million.

Urban Sector: The urban sector population is estimated to be 12 million. By the norm mentioned above the annual requirement would be 3 million tonnes of wood fuel. No doubt there are other kinds of domestic fuel like kerosene, cooking gas, electricity. It is not clear how much of the total demand is met by these modern fuels. In this context it is safe to presume that the annual demand of the urban sector will not be less than 3 to 4 million tonnes of wood fuel.

With the possible mobilisation and greater utilization of all agricultural resources, it is possible to meet just the current demand not withstanding the fact that there are other domestic fossil fuels. This is the present position. As the population increases at 2.5% per annum the fuel position will become more difficult by 1990. The forest resource which is limited and earmarked for more than one use cannot be stretched any further for fuel production. The good agricultural base already developed over ages needs to be fully utilized for augmenting wood production. This is typical of thickly populated, agriculturally oriented countries with little forest resources and diminishing access to fossil fuels.

CRITERIA FOR SELECTION OF SPECIES

Based on the biology of growth, ecological adaptations, suitability to silvicultural treatments and socio-economic values the species need to be screened before the choice is made for a particular environment. These form the criteria for selection of species. They are given below:

1. The species should be capable of early vigorous growth and yield a worthwhile harvest within a few years, say five years e.g. Eucalyptus, Casuarina.

2. In species like Eucalyptus with strong apical dominance the main trunk contains bulk of the biomass. Such species on conversion result in billets of larger dimensions which do not find favour with the rural poor in view of extra cost of energy and money for splitting. Species like Acacias with the biomass distributed between the trunk and branches lend themselves for conversion into different fractions like main trunk, larger branches, smaller branches, faggot wood, thorns, etc. and will meet the needs of a wider section of population from the rich to the poor. This is an important criterion of socio-economic importance.

3. Generally tree crops managed under short rotations do not offer intermediary yields. Leaf litter at 2 to 3 tonnes/ha./annum may be available which is removed as fuel although it is against the basic principle of maintaining soil fertility. A species like Casuarina comes very handy. The woody 'cones' shed annually may amount to 2 to 3 tonnes/ha./annum and these are available as fuel. In India the poor sweep the floor of Casuarina plantations for this purpose. This is one virtue that makes it a popular species of social forestry importance.

4. The species should be a good coppicer i.e. after the tree is felled the cut remnant of the trunk should be able to sprout after repeated harvest, at least thrice. This will obviate the need for planting every time the crop is felled. Secondly coppice harvest gives increasing yield and capable of manipulation of the end-use.

5. If the species is a leguminous one the land gets enriched nitrogenously. In the coastal district of Tamil Nadu Acacia planifrons is cultivated on a regular tree husbandry basis in poor sterile sandy tracts. After 5-6 years the tree crop is harvested; but it is not followed immediately by tree planting. The fertility which accrued over 5 years by root modules and leaffall is cashed by growing agricultural (sorghum and other millets) horticultural (egg plant, cucumber, etc.) crops for a handsome return. After a year or two the tree crop is raised and the cycle is followed. In this case agriculture is tied to the apron strings of silviculture.

6. In addition to fuel value if there is fodder value it will facilitate animal husbandry (goats, sheep) to develop as a subsidiary source of income to the rural people. Acacias yield 10 to 20 kg. of pods per tree at the end of ten years which is a good cattle feed.

7. Considerable area for raising fuel species is available within the excellent agricultural base, rainfed as well as irrigated, developed in southeast Asian countries. Although a number of species ecologically suitable is available selection criteria will weigh more with regard to their side effects, root and shade effect, on agricultural species. Trees with narrow open crown casting thin shade and provided with deep root system are preferred e.g. Eucalyptus, Acacia nilotica.

The species should not be an alternate host for agricultural pests nor attract birds to nest.

Choice of Species:

Coastal sands:

High rainfall area:
Casuarina equisetifolia
Eucalyptus camaldulensis
Eucalyptus tereticornis
Eucalyptus toreliana

Low rainfall area:
Casuarina equisetifolia
Casuarina junghuniana
Acacia planifrons
Acacia leucopholea
Palmyrah

Red loam:

High Rainfall area:
Casuarina equisetifolia
Azadirachta indica
Albizzia lebbeck
Eucalyptus species
Leucaena leucocephala

Low Rainfall area:
Acacia leucophloea
Acacia planifrons
Azadirachta indica

Black Soil:

Low Rainfall area: Prosopis juliflora
Acacia leucophloea
Acacia arabica
Acacia planifrons
Azadirachta indica
Albizzia lebbeck

High moisture areas like river canal banks and field bunds:

Eucalyptus
Casuarina
Acacia arabica
Leucaena leucocephala
Terminalia arjuna
Somania saman
Thespesia populnea

TECHNOLOGY OF FUEL WOOD PRODUCTION

Regarding the technology of fuel wood production two treatments vis silvicultural and sylvagricultural are available. The former is purely a forestry practice and the later basically agriculture combining tree husbandry. The conventional silviculture needs to be modified or innovated to suit the change of times. Rotations fixed on the culmination of mean annual increment consideration have to be based on maximum volume production of a particular end-use in mind. In other words wood of smaller dimensions are extremely popular with weaker sections and this should be given due consideration. Coppice system on shorter rotations produce more wood per unit area and time. Planting of multiple seedlings (2 to 3) in the place of one has increased the overall yield by 30% for nearly the same cost. There is a possibility of securing quicker establishment and better growth if some elementary agricultural inputs like ploughing at least with country ploughs, impounding of run off by check bunds are included. A continuous search for provenances of higher productivity per unit of land, water and time needs to be kept up for each situation, so that the right genome is matched to the environment. These are applicable not only to crops raised in forests but also block-planting in agricultural areas. The tree species that has become increasingly popular with farmers in India is Casuarina equisetifolia and the other one of late is Eucalyptus tereticornis.

The sylvagricultural system though not known by this name is already well understood by the farmers of dryland farming region. There are tree species which will grow in harmony with crops without causing strong root competition and thick shade effects. They are Acacia arabica, Albizzia lebbeck, Azadirachta indica, Morinda tinctoria, Casuarina, Samania s[illegible]an, Thespesia populnea Terminalia arjuna, Trewia nudiflora et[illegible]in wet land areas. Eucalyptus and Teack are becoming pop[illegible]r. The species and their population in agricultural areas can be so adjusted as to have minimal competition with agricultural crops.

There are certain other tree attributes of socio-economic importance. A species like Casuarina or Acacia planifrons when converted into fuel of different classes like main trunk and large branches, faggot wood, brush wood, thorns etc. meet the demand of a broad spectrum of consumers from the rich to the poor. This will have to be borne in mind while choosing the species. Otherwise a scheme intended to meet their needs will not be effective.

FIXING PARAMETERS FOR SELECTING TREE SPECIES FOR FUELWOOD PLANTATIONS

A. GNANAM [1/]

ABSTRACT

Though it is known that harvesting of solar energy through photosynthesis is the basis of all plant productivity, very few studies have been done to establish a correlation between photosynthesis and productivity in fuelwood species. We have made a beginning to establish criteria for selecting tree species suitable for fuelwood plantations on marginal lands and canal beds. Relative photosynthetic performance and growth rates of Albizzia, Hudwigia, Casuarina, Erythrina, Leucaena, Millingtonia and Moringa were determined to establish the correlation between photosynthesis and productivity. Both field and laboratory measurements of CO_2 fixation with Infra Red Gas Analyzer (IRGA) were compared with established methods of measuring photosynthetic competence. The cambial activity and dry weight increments were measured to determine the productivity rates of the selected trees.

Compared to the established methods of determining the photosynthetic potential through chlorophyll content and leaf area index, rapid measurement of CO_2 exchange through IRGA constituted a better index for photosynthetic efficiency. Likewise measurements of both cambial activity and dry-weight increments are found to be better indications of productivity.

Based on the results, the relative merits of using various methods of fixing parameters for selecting tree species for fuelwood plantation are discussed.

* * * * *

One-sixth of the world's annual fuel supplies are wood fuel and about half of all the trees cut down are used for cooking and heating. In developing countries non-commercial fuel, mostly fuelwood, often comprises up to 90% of their total energy use. Total fuelwood consumption is probably three times that usually shown in statistics and about one-half of the world's population relies mainly on wood for their cooking.

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The so called 'Second Energy Crisis' has arisen as a result of the dwindling supplies of fuelwood to the rural masses of the developing countries who generally are not directly affected by the fossil fuel crisis that rock the developed nations and the urban populations of the developing countries. To alleviate this crisis, fuelwood plantation programmes of varying sorts are being considered in many developing countries but the major difficulty with implementing them seems to be the lack of adequate basic scientific base for selection of a suitable tree form for different agroclimatic conditions and to improve their productivity. Fuelwood plantation efforts cannot be capital intensive as in the case of commercial crops and also have to be confined to the marginal and wastelands which are otherwise not fit for agriculture. Therefore criteria for selection of fuelwood species for small or large scale plantation should take a number of factors into consideration.

They include:

a) Selection of tree species that has best adapted to the set of agro-climatic-stress-conditions of the regions.

b) Selection amongst the forms that out performs the rest in terms of their growth and biomass production.

c) Selection based on energy use criteria such as specific gravity of wood and calorific value, feasibility for conversion into charcoal, etc.

d) Should be able to fix atmospheric nitrogen or be able to grow along with nitrogen fixing species.

e) Preferably should possess natural resistance to grazing.

f) Should have short cropping cycle with coppicing potential.

g) Selection based on their photosynthetic efficiency under given set of conditions.

While most of the above selection criteria for choosing the fuelwood species to a set of conditions can be applied with ease to screen the plant forms, very little dependable methodology is

available for selecting a plant for its photosynthetic efficiency. This report discusses methods of determining the relative photosynthetic competence of a set of selected plant species for growth in a given agro-climatic condition.

Photosynthesis is the basis of all productivity in plant systems, whether it is crop plants or fuelwood trees. This is the process by which the green parts of the plants harvest solar energy and convert into organic substances utilizing the ambient carbon dioxide. Each year plant photosynthesis fixes about 2×10^{11} tons of carbon with an energy content of 3×10^{21} tons. This is about 10 times the world's annual energy use. All the atmospheric CO_2 is cycled through plants every 300 years and all O_2 every 2000 years. The magnitude and role of photosynthesis is largely unrecognized. Photosynthesis of the past has given us coal, oil and gas and we should exploit the present day photosynthesis to generate adequate fuel for our immediate use in addition to the food and fibre.

The rate of photosynthesis is well correlated with dry matter (organic) production. In cereals including maize and rice, this means more grain and in the case of fuelwood trees, more of firewood and biomass for use as fuels. This significant correlation between bioproductivity of plants with their photosynthetic competence is shown in Tbale 1 under very different climatic, soil and cultivation conditions.

Table 1 : Photosynthesis and plant productivity

Type	Photosynthesis of the leaf* mg CO_2 assimilation $dm^2 \times h$	Productivity** kg dry matter hectare land x day	Cultivation area
Maize	46-50	420-510	USA, Japan, Israel
Cane sugar	52	420	Hawaii
Tobacco	17	260	USA
Wheat	14-17	210	Various European countries
Rice	12-30	290-360	Japan, Philippines
Sugar beet	24-28	280-310	Netherlands, Canada

* In air under optimal laboratory conditions, referred to dm^2 surface of one side of leaf.

** Maximal growth rates under field conditions; determination of parts of plant above the surface of the soil except in the case of sugar beet.

Photosynthesis, as developed by plants can be simply represented as:

$$H_2O + CO_2 \xrightarrow[\text{Solar Energy}]{\text{Plants}} \text{Organic Materials} = O_2$$

In addition to carbon, hydrogen and oxygen, the plants also incorporate nitrogen and sulphur into organic material via light dependent reactions - this latter point is often not fully appreciated. Though photosynthesis forms the basis of plant productivity, it in turn depends on the availability of inorganic nutrients, adequate supplies of water and carbon dioxide, favourable temperature and light. These factors are part of the environment and may be varied rather widely giving rise to different levels of plant productivity.

Productivity of fuelwood species in general both in terms of photosynthetic efficiency and in terms of other agronomic practices have not been studied in any detail as compared to agricultural crop plants.

Photosynthetic criteria for selection:

As shown in Table 1, different plant species vary quite markedly with reference to their photosynthetic efficiency even under identical conditions and is directly related to the productivity. Consequently it is reasonable to consider the photosynthetic competence under a set of agroclimatic conditions as a major criteria for selection while screening the plant species.

In the past, leaf area and leaf area index and chlorophyll content of the leaf, etc., were taken as a measure of the photosynthetic competence. While the leaf area index can be taken as a reasonable indication of gross photosynthetic potential, the pigment content cannot be taken as a criteria. Plants grown in shaded conditions often contain more pigment per unit area than those grown in direct sunlight without any significant increase in their photosynthetic rates. In Table 2 the effect of defoliation on the total growth of peanut plant which is having an indeterminate growth and in the case of fuelwood trees are shown.

Table 2 : Crop growth rate (g/l^2/fortnight) of intact and defoliated groundnut plants for three consecutive two-week periods.

Weeks after sowing	Defoliation		
	Nil	50%	75%
17 - 19	214.7	176.5	145.0
19 - 21	132.4	125.6	55.2
21 - 23	166.8	122.5	101.9
Mean	171.3	141.5	100.7

Among various methods of determining the relative photosynthetic efficiency of a plant quickly, use of infra red gas analyzer (IRGA) to measure the CO_2 assimilation per unit area has been found highly correlatable with the productivity as measured in terms of growth rate. In Table 3 the CO_2 assimilation rates of different tree species on leaf area and dry weight basis are compared. These data on carbon assimilation rates are reasonably correlated with the growth performance in Madurai District, where semi-arid conditions of the tropics prevails.

Table 3

Name	mg CO_2/m^2/sec fixed
Albizzia lebbeck	4.86 ± 1.39
Hardwickia binata	12.50 ± 4.00
Casuarina equisetifolia	3.33 ± 1.19
Erythrina indica	8.44 ± 3.45
Leucaena glauca	12.82 ± 5.72
Millingtonia sp.	13.78 ± 4.80
Moringa oleifera	15.67 ± 6.50

Stomatal conductance as a measure of photosynthetic competence:

There is always a correlation between photosynthetic efficiency and stomatal conductance although yet we do not know which one is controlling the other. Therefore the measurement of stomatal conductance using autoporometer would tell us something about the photosynthetic efficiency and in turn the productivity under field conditions.

Choice of photosynthetic types:

On the basis of the photosynthetic mechanism - the way in which CO_2 is assimilated - lants are broadly divisible into C_3, C_4 and CAM plants. Most of crop plants such as paddy, wheat and a number of pulses belong to C_3 types which produce a C_3 compound, phosphoglyceric acid, as the primary product of photosynthesis with CO_2. The plants like sugarcane, maize and a number of tropical grasses assimilate the atmospheric CO_2 into a C_4 acid-malic acid and hence called as C_4 plants. Plants having crassulacean acid metabolism (CAM) fix CO_2 to C_4 acids at night when their stomata are open and during the day (stomata closed and no water loss) the prefixed carbon is reduced to the level of carbohydrates. In the CAM plants, thus a photosynthetic system has developed which can take place with minimal water loss. Such an attribute would be very useful in fuelwood species for plantation in marginal lands.

Depending upon the soil, water, light intensity and temperature of the region, tree species of suitable photosynthetic types can be selected for fuelwood. In most of the tropical conditions high temperature and high irradiance prevail. In the marginal and waste land of tropics where water is scarce C_4 type of trees are most ideal as they seem to have developed their photochemical system to withstand low ambient CO_2, high temperature and high sunlight intensity.

For agro-forestry and/or social forestry where availability of water may not be a limiting factor, photosynthetically efficient C_3 type of plant species may be selected as they seem to grow better in intercropping ecosystems.

Tree species having CAM type of photosynthesis or with potential to switch back and forth to CAM metabolism are known to thrive successfully under conditions where water is scarce or where watér is highly saline and the soil is alkaline. For the coastal belts where salinity causes the physiological dryness, plants with CAM type of photosynthesis would succeed better.

The major constraint in using the criteria of photosynthetic types for selection of tree species is however, the lack of information about the photosynthetic characteristics of most of the tree species that are generally used as fuelwood. Extensive work had to be taken to establish the photosynthetic mechanism of a large number of tree species and to classify them into these three major photosynthetic types.

In Table 4, representative taxonomic distribution of C_3, C_4 and CAM type of photosynthetic forms are shown.

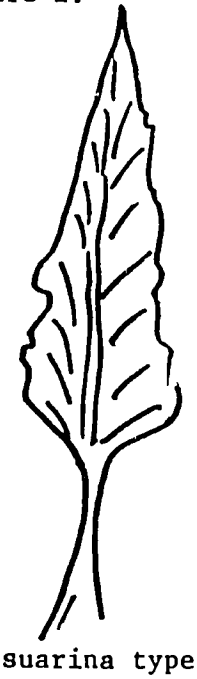
Table 4:

C_3	C_4	CAM
Leguminoceae	Aizoaceae	Agavaceae
Myrtaceae	Boraginaceae	Aizoaceae
Rubiaceae	Caryophyllaceae	Cactaceae
Palmae	Euphorbiaceae	Euphorbiacea

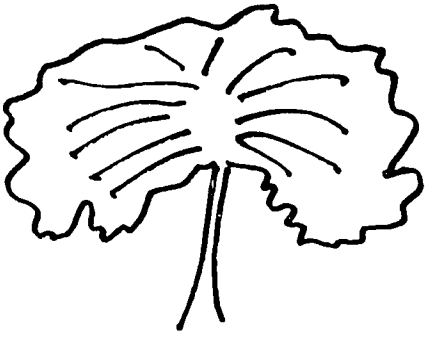
Choice of tree shape to improve light interception:

The selection criteria based on plant shape for maximizing the fuelwood productivity is very important. For maximal photosynthetic productivity, it has been suggested that we must use plant species having a leaf area index of at least 8. In other words, one acre of land should have the equivalent of at least 8 acres of leaf surface. To achieve this, if tree forms having horizontal canopy are planted in close proximity in narrow rows, the lower leaves will be shaded and may not contribute to the productivity. Therefore trees with vertical or near vertical canopy are ideally suited for planting more plants per unit area and facilitate the interception of most of the light. Trees like Casuarina, Hudwigia are preferred for their vertical canopy as compared to Albizzia or Acacia planiformis. Graphic representation of the two distinctive plant-types are shown in Figure 1.

Graphic representation of tree types



Casuarina type



Acacia type

Choice of plants for nitrogen fixing potential:

Most of the tree forms that grow in wild seem to depend on either the organic decay or on their ability to fix nitrogen for their nutrition of nitrogenous materials. Several of the common fuelwood species are leguminous and consequently self sustaining. Many non-leguminous species seem to have nitrogen fixing potential as seen in Casuarina and a few members of Uritcaceae and these characteristics are not well documented and exploited. Nonetheless photosynthesis is the supplier of reductants and carbon skeleton for the assimilation of nitrogen fixation. Suitable screening based on their potential for providing themselves with nitrogenous material would constitute an ideal criterion.

Hence, while applying a number of selection criteria for fuel plantation, it would be advantageous to use photosynthetic competence of plant species as an important trait, for maximizing the productivity.

INDONESIA

THE ESTABLISHMENT OF FIREWOOD FOREST BY PRIVATES

RAFIOEDDIN ACHLIL[1/]

ABSTRACT

The present increasing demand for firewood tends to devastate the natural resources and still the farmer does not think of establishing the forest, due to the high marketing risks.

In Java the estimated critical land area is approximately 2.5 million has., about 700,000 has. of which are suitable for firewood forest.

These areas are privately owned so that their utilization is directed to the establishment of private forest.

In the determination of a proper location, some considerations must be taken:

a. the current firewood market (in the industrial areas using firewood)

b. a reasonable size of the forest (1,500 - 2,500 ha)

c. gradually planted, according to the rotation of the chosen firewood species.

Above all, the multiple use of the forest must be taken into consideration, especially for food, so that the planting of firewood must be based on "the"taungya system" in order to get a diversification of the yield and an increase in its productivity.

Its management must be developed cooperatively and supported by the facilities in processing the product and by the regulations in the market mechanism.

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B A C K G R O U N D

Firewood constitutes one of the main sources of energy for the rural community. Besides supplying the need for the rural household, firewood proves to be useful also as energy source in behalf of various rural industries, and many more.

Firewood consumption in Java and Bali in the decade of 1964 - 1974 has increased from 17.7 million tons to 32.6 million tons, thus giving the average increase of 8.5% a year. In the same period an increase of production has been observed from 16 million tons to 22.6 million tons, conforming to an annual increment of 4.1%. This leads to a deficiency of firewood supply in 1974 of more than 10 million tons, with a tendency to rise at the rate of 4% a year.

This shortage has been partly met by utilization of various kinds of substitute, mostly by means of residual waste from harvests, and by clear-cutting of river-sides, valleys and hill slopes. These actions have given rise to the enlargements of denuded land areas, and threatening the effectiveness of programs for forest, soil and water conservation, with all its accompanying destructive effects upon the environment in a frightening scale.

Attempts to substitute firewood as energy source by using other kinds of resources are faced with various unsurmountable obstacles, particularly in relation to the fulfilment of rural demands for energy. The problem has become more and more complicated along with dwindling kerosene reserves which before has been hoped capable of replacing the position of firewood as fuel.

Critical land areas having been robbed of their productive capacity and having even become an undesirable source of various catastrophes, appear here despitefully to become the potential means towards the possible solution of the problem. From the 2.5 million ha of spoilt land owned by the rural population in the provinces outside the island of Java, 1.8 million ha are estimated capable of conversion into forest in the frame of the projected optimization of forest area. From the area referred to above, 700,000 ha have been valued suitable for firewood production.

Firewood as a renewable energy source has the potential possibility to help solve the energy problem for the rural community and is therefore to be recommended for development. Thus, in coincidence with the overcoming of the energy problem, the development of firewood forests will equally be of significance as a means to tackle the problem of critical denuded land, improvement of the environment as well as the people's income and prosperity. Nevertheless, the endeavors will meet success only if they are carried out on the basis of stabilized and sound programs with due regard to various factors of management, various aspects of production and marketing, as well as socio-economic points of consideration.

THE FARMER AND THE FIREWOOD PRODUCTION

Most Indonesian farmers are food-crops growing farmers. This has even come to such a pass that the term agriculture is now associated with the raising of food crops. Among the latter, rice has become a farming activity of prime importance, followed by maize and cassava next. In the first instance the farmer will grow rice where possible, and in case of failure the next crop to be grown is maize, and the final instance cassava will be resorted to, owing to its high rate of tolerance as regards the conditions for growth. When even cassava does not thrive well, this is usually an indication for the soil condition having reached the final stage of depletion. In such cases the land area is usually left to its own fate. It is this process which has given rise to such terrifying extent of devastated land covering an area of 20% of the Indonesian land surface.

Conditions as shown above are not without motivation. Every undertaking, every farmer in the process of decision making, will always base his conclusions upon economic considerations, including the risk factor which has to be faced in consequence of his decision. A long process in the course of history has made the Indonesian farmer managing only very small units of enterprise. In densely populated areas as in the case with the island of Java, the small unit of farm management is caused by the extremely limited size of land that is under their control. However, in sparsely populated regions, mostly on the islands outside Java, the small unit of farm management is consequent of the limited labour force. This small unit for the farmer has led to an extraordinarily high risk factor.

This high risk which must be faced by the farmer in his management is the motivating factor impelling him to focus his attention to the raising of food crops. By this decision the risk of sustenance for himself and his family can be suppressed, mainly in relation to his food demand.

Such conditions have caused the reduction of forest areas and the increase of depleted soils bringing about a disturbance in the equilibrium of existing ecosystems with the ensuing harmful effects. To prevent and suppress further deterioration of natural resources, we have to give encouragement and guidance to small-holder farmers in order that they be willing and capable of liberating themselves from the bondage caused by their attachment to the food-crop pattern of farming.

The question of lack of energy, in particular as concerns the rural community, should advicably be associated, where possible, with the problem relating to our environment. Thus, solution of the problem is not sought after by mere increase of production, such as

the conversion of state forests into firewood forests or by stimulating farmers to establish firewood cultivations in their yards and fields sporadically. On the contrary, we have to make efforts to persuade farmers and give guidance to them, to be willing in establishing firewood producing forests based on the principle of modern forest management.

The habit found among farmers of attaching themselves to the pattern of food-crop growing, has since long been adopted in the rural life of the farmer. Making a change in such a condition that is well rooted in the community, is certainly not an easy task, as naturally is to be expected. Any attempts to such reformation will meet suspicion and doubt, not only from the part of the farmer, but wider circles will be affected.

In view of introducing the firewood farming, first requisite will be the elimination of this doubt, this uncertainty, involving the following aspects:

1. How are the farmers to meet their demand for food if they do not produce it?

   This kind of uncertainty in its extreme case may be eliminated by acknowledging the fact that those active in the field of industry and services, have not experienced difficulty in meeting their demand for food despite the fact that they do not produce their own food. We have to admit that this kind of extreme reasoning is far from realistic. In view of the introduction of firewood farming, therefore, priority of attention is to be given to areas left fallowed by the farmer. This will prove to be one way of making soils, otherwise unproductive or even becoming a source of catastrophes, productive of firewood.

   On soils still capable for growing food crops, a kind of intercropping system (so called "tumpang-sari" system) is recommended to be applied in the first and second year when the firewood producing trees are still in their sapling stage. In view of this consideration on the harvesting system to be recommended is the clear-cutting followed by artificial regeneration, and not a coppice-system, neither a selective cutting system.

2. The source of income for the farmer to sustain his life during the period waiting for the first harvest, in this relatively long term undertaking, is another question to be dealt with.

   As referred to above, the farmer will for the first and second year obtain income from the intercropping (tumpangsari). For the following years before the harvest, the approach based

upon the multiple-use of forestry may be applied, such as cultivation of forages for cattle under the forest trees (sylvo-pasturage), growing of tuberous plants, income from thinning, apiculture (culture of bees), and the like. The choice as to type and kind of undertaking is to be adapted to existing demands as well as the farmer's capacity and the economic potential of the surrounding community. To prevent interruption in the farmer's income and avoiding monoculture in the stand, attention should be focussed to the diversity of the species projected for planting on every unit of area, including the following:

a. Main species: species to be planted in the main stand

b. Milling species: species used to fill in the gaps among trees of the main stand. Its function is to make the stand heterogeneous. This filling species is to be distributed between members of the main stand so as to cover about 20% of the stem number of main stand.

c. Interplanted species: being the plant species functioning for erosion control, this interplanting is to be laid out in an uninterrupted rows along (horizontal) contour lines. The planting of this species is an obligatory precept if tumpang-sari system is applied.

d. Soil cover plants: functioning mainly to protect the soil against exposure, and its application until the tumpang-sari is finished.

e. Border plants: functioning as a means of isolation from fire hazards.

f. Hedge plants: playing the role of barrier to prevent intruders such as cattle or other animals. The hedge is planted along the periphery of the cultivated area.

g. Ornamental plants: these are for the sake of aesthetics, having the role of beautifying the environment by sparsely planted fancy tree species.

h. Way-side trees: serve as decorative, reinforcement and shading of road sides.

By appropriate choice of species referred to above conforming to their functions and adapted to the farmer's requirement and demands made by the surrounding community, the choice for the main species may undergo some moderation.

3. We are now in the position to find out whether this activity of firewood farming is equally profitable as or even more profitable than the usual food crop farming.

Results drawn from surveys and interviews made in several localities have shown that firewood production on depleted soils in Java are capable of yielding a far higher income when compared to food crop farming.

Each Ha of critical land area will yield a mere production of three quantals of tapioca (cassava in dried condition), priced at Rp. 5,000,- per quintal (hundred-weight). Taking into consideration that the harvesting age of cassava is about 1 year, the gross income will yield Rp. 15,000,-/Ha/year.(per Ha per year).

However, the question still remains whether the prices do not change when the time arrives for the farmer to harvest his crop.

4. Still another question is whether, under the present condition of population density, the firewood farm forestry will be capable of supporting farmer's life.

Every undertaking (enterprise) needs labour force, and the farm forestry discussed above is no exception to the rule. For the requirements of forest exploitation, since cultivation (tumpang-sari system), up to the final logging operations (without mechanization) during one rotational period, the needed labour for each Ha is as follows:

a. For Teak forest using a rotation of 60 years = 6000 man-days
b. For Pinus forest using a rotation of 25 years= 5000 man-days
c. For Albizia forest with rotation of 6 years = 3000 man-days

The figures quoted above can be used to derived the conclusion that each labour force is sustained by a continual working opportunity:

a. of 3 Ha for the Teak forest
b. of 1.5 Ha for the Pine forest
c. of 0.6 Ha for the Albizia forest

The estimates noted above are calculated without including manpower for processing of forest products, the pruning of stand, transportation activities, and other supporting services. Excluded from calculation are also the requirements for auxiliary labour ; in case the forestry principle of multiple use is introduced.

PROCEDURE OF FOREST ESTABLISHMENT

A. CHOICE OF LOCATION

In the choice of the appropriate location for a people's forest suited for firewood production, factors worth of consideration are factors related to suitability of the soil and marketing of the products.

As concerns the soil suitability for firewood production the procedure of determination is not too difficult. Every piece of unused or depleted land is suited for the purpose. In view of this fact, first attention is to be directed to areas having extensive concentrations of denuded land. By converting these depleted soils into firewood forests, besides our contribution to the solution of energy problem as pointed out before, we also take part in efforts related to rehabilitations of environment without interfering with areas destined for food production.

As concerns factors associated to product marketing, attention is to be paid to the real market potentials. Firewood farming as a productive undertaking should yield a real income to the farmer. Almost everyone in the rural community needs firewood, but not everyone is capable or is willing to pay for it. The real market for this firewood is therefore the rural industry using firewood as their energy supply. Thus, the criterion for the existence of a firewood market lies in the concentrations of people's industries using firewood and the existence of sufficient high flow of firewood transportation out of the production areas.

B. CHOICE OF SPECIES

The species chosen for the establishment of the main stand of the firewood forest unit should be adapted to the market demand and the conditions of the growing site, to be chosen out of the variety of species having high increment rates, highly qualified for firewood production, with easily obtainable seed and belonging to the pioneer type. Characteristics of some firewood species related to growing site conditions, tree shape, rotation and yield are given in the appendix.

To prevent monocultures and to improve the farmer's income and diversification of product, other species are to be planted in addition to the main stand species. Fruit trees enjoying the favour of the rural people or having a ready market and capable of growing properly on the plant site, are recommended as

these "other species" additional to the main species.

C. SYLVICULTURAL SYSTEM

The sylvicultural system most in favour is the clearcutting with artificial regeneration. This system is in accord with the farmer's need for food. Moreover this system is simpler to apply, mainly when the market demands big-sized assortments. Nevertheless, application of the system is limited to soils with slopes not exceeding the limit of 45%. In case the application of the system is no more permittable, the coppice system in the selective cutting become relevant. The coppice system appears to be more appropriate if the need for food is less urgent while the market demands small size assortments.

The selective cutting system becomes obligatory in case the slope surpasses the allowable 45% while the market requires big size assortments.

D. SIZE OF UNIT AREA AND DIVISION IN COMPARTMENTS

Every economic undertaking requires a minimum size of management unit; the same applies to the firewood farming. With the unit having an appropriate size the application of an efficient management system is made possible. This size should be above the so called "break-even point" for the proper application of the sustained-yield principle.

Management of firewood forest where emphasis is laid upon its educative function the determination of the unit size may be approached by using the formula: $L = d \times p$

where: P = size of the management unit:
d = the rotation period in years; and
p = size of the working area for the consulting instructor

Experience has shown that the working capacity of a consulting instructor in his educational efforts to the farmer, is about 300 Ha. Broadly speaking, the rotation for a firewood forest varies from 5 to 8 years. These data yield a size for the management unit of 1500 - 2500 Ha.

The unit is to be divided into compartments of 25 Ha each. The farmers occupying a compartment are organized in a group choosing their own chairman as group leader. The size of 25 Ha conforms to the working capacity of a supervisor. The chairman is assigned the task of such a supervisor. Using the farmer's group as basis the educational/instructional activities can be conducted.

A certain number of adjacent compartments form a sub-unit. The number of compartments in a sub-unit is 2d, so that each unit will consist of p/5 or 6 sub-units. It is expected that each sub-unit can be developed into a "circle-unit". Each sub-unit can be placed under the guidance of an assistant-instructor who is to be chosen among the farmers themselves.

E. ECONOMIC UNLOCKING OF THE AREA AND MANAGEMENT

Since the very start of the planning activity, attention is to be focused to the transportation network of significance for the area to make it more accessible, taking into account existing public network of transportation, distribution of forests, location of administrative centers, processing of products and their marketing possibility.

Means for processing of products, such as kilns for charcoal may be of importance for product-preservation (to assure price stability), product diversification, quality improvement and increase of surplus values. Equipment in the shape of offices and buildings are to be included in the planning.

F. CULTIVATION

The cultivation of the forest is to be carried out in stages with the objective to build up a "normal growing stock". Each successive year only a part of the area is to be cultivated of a size conforming to the working capacity of the consulting instructor, that is to say ± 300 Ha, to be evenly distributed over all units, which have a cultivation area of the size of a compartment(namely 25 Ha).

G. GUIDANCE

For each unit of firewood forest its guiding principle should be directed towards a unit of cooperative, for which purpose a start has to be made from the very beginning of the forest establishment. To increase the productive capacity the principle of multiple-use should be developed, such as apiculture, planting of cattle forage, cattle breeding,culture of fungi, orchids, tuberous plants and many others.

The Government takes care that continual service be provided as regards supply of means for production, price control and educative instruction.

IV. CONCLUSIONS

1. Unsatisfactory fulfilment in the energy demand of the society as a threatening feature of the kerosene crisis, the vast extent of critical land areas, and the low income level of our rural population, are problems which should be tackled in an integrated way by establishing farmer's firewood forests.

2. To approximate the objective of an efficient firewood forest, serious attention should be paid to factors associated with socio-economic interests of the people involved, the aspects of production and marketing. This concern should be started from the very beginning of the planning and be continued in the management and development of the undertaking.

3. The establishment of firewood forests is mainly to be directed to areas where concentrations of denuded and depleted soils are found. Such areas are faced with the additional problem of lack in the supply of firewood for the rural industries of the surrounding community.

4. The following points are of significance, to be taken into consideration when establishing a firewood forest:

   a. A management unit should have a size sufficiently large to allow the application of a rational management. This size varies from 1,500 to 2,500 Ha.

   b. Forest planting at the moment of establishment should be carried out in stages such in order to build up a "normal growing stock".

   c. The sylvicultural system to be applied is, where possible, the clear-cutting system followed by artificial regeneration, so as to enable the application of tumpang-sari.

   d. At the establishment of cultivation due care should be taken to prevent the development of homogeneous forest stands by introducing species diversity in the main stand.

e. By the introduction of "other species" as discussed above in an as rational as possible way, the possibility is opened for development of the multiple-use principle, such to improve soil productivity and to ensure a perpetual income for the farmer. Thus, no unnecessarily high demands are required as concerns the choice for the main species.

5. It is of important consideration that every unit of firewood forest be directed towards a unit of cooperative, where as the Government is to take the necessary measures as concerns product supply, price control and education.

APPENDIX:

SOME SPECIES SUITABLE FOR FIREWOOD PRODUCTION AND THEIR CHARACTER

1. Acacia auriculiformis, A. Cunn. (Mimosaceae)

a. Growing conditions:

Requires no high demands as regards conditions of soil as well as climate. This species is still capable of growing on less fertile soils and in dry climates (climate type D). The required altitude is 0 - 400 m above sea level.

b. Description of tree:

Small shaped tree, height up to about 15 m and diameter up to 20 cm. Stem ugly shaped, much branching, with wide, not too dense crown. Root system well developed and young seedlings resistent against oxygen-free soil conditions, up to 75 days.

c. Rotation and production:

The technical rotation is fixed at about 8 years. First thinning at the age of 3 years may produce ± 6 m3/Ha whereas its productivity is pictured in the following table:

Increment .....

Increment and production of A. auriculiformis

A g e (years)	Height (m)	Diameter (cm)	Total prod. per Ha (m3/Ha)	Mean annual increment (m3/Ha/years)
1	2	3	4	5
4	9,8	6,6	18,0	5,0
5	12,4	5,0	70,0	13,0
6	14,0	11,4	110,0	18,0
7	15,2	13,3	145,0	21,0
8	16,2	15,1	171,0	23,0
9	17,0	16,6	192,0	23,0
10	17,8	18,0	210,0	21,0
11	17,8	19,0	224,0	20,0
12	18,0	20,0	236,0	17,0

2. Acacia decurrens, WILL. var. Mollis Lindi (Mimosaceae)

a. Growing conditions:

For favourable growth a porous soil is needed at an altitude varying between 1000 and 2000 m above sea level. Nevertheless this tree species still grows on less fertile soils under conditions of moderate to dry seasons.

b. Description of tree:

A height of 30 m can be reached with diameter size of 40 cm. Stem cylindrical of shape, moderately straight, with blackish grey and rough bark. Crown thin and at young age conically shaped, later on shield-shaped (peltatous). This tree belongs to the light-demanders.

c. Rotation and production:

The technical rotation is estimated at about 8 years. Production from first thinning at the age of 3 years yields ± 14 m3 per Ha. In addition to the production of firewood the bark of the stem is exploitable owing to its tannin content. An idea of its productive capacity is shown by the following table:

Increment and production of A. decurrens (site quality III)

A g e (years)	Height (m)	Diameter (cm)	Total prod. per Ha (m3/Ha)	Mean annual increment (m3/Ha/years)
1	2	3	4	5
2	8.8	7.1	10.0	5.0
3	12.8	10.3	38.0	12.7
4	16.0	13.0	73.0	18.2
5	18.4	15.7	113.0	22.6
6	20.2	18.4	151.0	25.2
7	21.6	20.8	183.5	26.2
8	22.6	22.6	212.0	26.5
9	23.3	24.5	239.7	26.6
10	23.7	25.3	256.5	25.6
11	23.9	26.1	275.5	25.0
12	24.2	26.4	291.0	24.2

3. Dalbergia latifolia, ROXB. (Leguminosae)

a. Growth conditions:

Growth altitude lower than 600 m above sea level, under conditions of moderate to severe dry-season (maximum of 4 rainy days during 4 dry months). Growth is still possible on bad soils, stony or hard soils.

b. Description of tree:

The tree reaches a height of 40 m and a diameter of 100 cm. The crown is fairly dense, sheds its leaves but is never completely leafless. The tap root is quick growing, at young age slightly branched, at older age the root system is well developed horizontally as well as vertically.

c. Rotation and production:

Usually this tree is planted for its timber, for the heartwood is very finely textured. To obtain a heartwood of more than 30 cm, a rotation of 50 years may be applied. In view of its adaptability to badly conditioned soils and dry climates, additional to its moderately high increment of its thick-wood, and its easy regeneration by cuttings, it is a suitable species for firewood production. The following table shows an idea of its production capacity:

Increment and production of D. latifolia (Site quality II)

A g e (years)	Height (m)	Diameter (cm)	Total prod. per Ha (m3/Ha)	Mean annual increment (m3/Ha/years)
1	2	3	4	5
5	9.2	6.5	28	5.6
10	15.9	16.5	149	14.9
15	20.9	23.3	284	18.9
20	24.7	31.6	407	20.4
25	27.4	36.4	507	20.3

4. Eucalyptus platyphylla, P. MUELL (Myrtaceae)

a. Growth conditions:

This species requires a tropical climate with an outstanding dry season. It grows at altitude lower than 1000 m above sea level. This species is considered valuable for cultivation on non-porous soils.

b. Tree description:

It attains a height of 30 m and a diameter of 80 cm. The stem is free from buttress, thin-barked, white coloured, slightly bent, long cylindrical ofshape, about 40% of its length branchless. Crown evergreen, sparse, intolerance against shade, specific light-demander.

c. Rotation and production:

Its wood is classified under quality class I and durability class II/III, not easily workable, and splits readily. In Timor used housing, bridges, telephone posts, and the like. Its firewood is of good quality, likewise its charcoal. Its growth is less quick, with a mean annual increment of 15 m3/Ha thickwood, at a rotation of 10 - 15 years.

5. Calliandra spp. (Leguminosae)

a. Growth conditions:

Optimal growth is found in wet climates with a minimum rainfall of 1000 mm per year. This species grows on relatively bad soil conditions at an altitude of 150 - 1500 m above sea level.

b. Description of tree:

This species is a shrub-like tree, and in particular the red-flowered Calliandra (Calliandra calothyrsus) attains a height of 10 m and a diameter of 20 cm. This red-flowered Calliandra has a brownish black coloured stem, whereas the white-flowered variety (Calliandra tetragona) a whitish green stem. The crown is dense and the root system varies from superficial to deeply penetrating.

c. Rotation and production:

At the end of the first year its yields firewood of about 100 sm/Ha (stacked cubic meter per Ha) and after the second year and afterwards, the firewood production reaches 200 - 250 sm/Ha.

6. Gliricideae (Leguminosae)

a. Growth conditions:

No high demands as concerns soil or climate. It still grows well on less fertile soils, and in dry climates (climate type D). It requires altitudes up to 1500 m above sea level.

b. Description of tree:

Shrub-shaped tree, reaching a height of 15 m and a diameter of 25 cm. Stem colour whitish grey. Crown sparse, and root system superficial to deep penetrating.

c. Rotation and production:

Suitable for exploitation by coppice system with a production capacity of about half that of Calliandra.

7. Leucaena glauca, syn. Leucaena leucocephala

a. Growth conditions:

Growth altitudes 0 - 1000 m above sea level, on fertile to moderate soils, with a wet to fairly dry season.

b. Tree description:

Shrub-shaped tree, attaining a height of 13 m and a diameter of 25 cm. Stem fairly straight, about 40% of unbranched. Crown evergreen and sparse. At present a variety has been developed known under the name of Lamtorogung (the well-known "Giant Ipil-ipil" of the Philippines) with an extremely quick growth.

c. Rotation and production:

Suitable for exploitation under the coppice system with an increment of about 15 m3/Ha/year. Lamtorogung, now in its experimental state, has a much higher increment, possibly up to 50 m3/Ha/year.

SOME CHARACTERISTICS OF FUELWOOD TREE SPECIES IN INDONESIA

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ABSTRACT

The characteristics which must be possessed by fuelwood tree species are: fast growing rate (short rotation), high wood production, capability to produce quantity of seed and able to grow on various soil types and climate. Other characteristics which must be possessed are high caloric value and capability to coppice. Based on the aforementioned criteria, the following trees species can be recommended for fuelwood among others: Leucaena leucocephala, Glirisida maculata, Sesbania grandiflora Eucalyptus urophylla, Cassia siamea, Calliandra calothyrsus, Lagerstroemia speciosa. Other species that can also be recommended but not highly capable of coppicing are Acacia auriculiformis, Acacia decurens, Delbergia Latifolia, Albizia leucophloea, Tamarindus indica, Swietenia macrophylla, Schmia noronhae, Schleichera oleosa, Bruguiera sp., Rhizophora sp., Casuarina quisetifolia, Pterocarpus indica and Gigantochloa apus.

INTRODUCTION

Fuelwood as a source of energy has been playing an important role for villagers in Indonesia. According to a survey result in 1979 it was estimated that fuel wood demand in 2000 will increase to 105-441 million cubic meter. This is based on Indonesia's population in 2000 will reach 210 million and the estimation of fuelwood consumption between 0,5-2, $1m^3$ per capita (Salim, 1979).

The solution of the above problem can't be expected for a long termed period from wood production out of natural forests because:

a. Generally, natural forests are located far enough from the village or settlement, causing a high cost of wood transportation, while the price of fuelwood is usually to be kept low.

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b. To manage natural forest based on the sustained yield principle is not easy. It needs skill and experience.

Based on the above mentioned ideas, one of the alternatives in fulfilling fuelwood demand is the establishment of forest or fuelwood plantation on state owned or private land.

There are several factors that must be considered for the successful establishment of the forest or fuelwood plantaion, i.e.:

a. Selected tree species must be adapted to the site condition.

b. Selected tree species should possess the good characteristics for fuelwood such as high calorific value, fast growth and high production of fuelwood, having the ability to coppice when cut.

In this paper, some characteristics of fuelwood producing tree species which grow in Indonesia will be described. It is hoped that these information are useful and able to stimulate further research.

SOME TREE SPECIES CHARACTERISTICS FOR FUELWOOD

Calorific value

Basically, all tree species can be used for fuelwood since they can produce heating value. If viewed from usage efficiency of fuelwood quantity for combustion (for example for cooking), it is assumed that wood species having a low calorific value will need a larger quantity of fuelwood, than if fuelwood is used which belong to a high calorific value, to obtain an equal quantity of heating value at the same period of combustion (Rienrink, 1938).

For that reason, it is necessary to select tree species based on the calorific value. In this case, further study is needed to get a criterion to select tree species for fuelwood based on its calorific value.

Based on available data of wood calorific value, tree species recommendable to be selected as fuelwood are: *Acacia auriculiformis*, *Acacia decurens*, *Gliricidia maculata*, *Leucaena leucocephala*, *Schleichera oleosa*, *Swietenia macrophylla*, *Tamarindus indica*, *Rhizophora* sp, *Pterocarpus indica*, *Cassia siamea*, *Albizia falcataria*, *Anthocephalus cadamba*, *Calliandra calothyrsus*, *Dalbergia latifolia*, *Eucalyptus* sp, *Schima noronhae*, *Sesbania grandiflora*, *Trema orientalis*, *Casuarina equisetifolia*, *Gigantochloa apus*, *Acacia leucophloea* and *Lagerstroemia spesiosa* (Appendix 1).

Distribution

Most tree species usable for fuelwood come from local species except Swietenia macrophylla, Leucaena leucocephala, Calliandra calothyrsus and Acacia decurens. Those species have been planted in Indonesia since the beginning of the 20th century.

The distribution of local and exotic tree species are presented in Appendix 2.

Habitat

Generally every species requires different site condition. To gain good plantations, site must be suitable to the ecology of species that will be planted. Therefore it is very important to use seed from the best adapted sources.

The usage of tree species unsuitable for plantation site can cause:

a. Failure of plantation due to high percentage of plant mortality.

b. Less suitable tree species are sensitive to pest and diseases and decrease of tree growth.

c. Sometimes wood quality changes at unsuitable sites.

Habitat factors must be considered in the frame work of plantation especially topography, climate and soil, topography based on altitude above sea level, climate factors based on rainfall and the length of dry season and soil factors especially soil physics characteristics such as tolerance to oxygen deficiency. Data on characteristics of soil chemistry are not available, further research should be conducted. Appendix 2 presents data on condition of plantation site based on topography, climate and soil.

Growth and yield

According to experimental result of plantations, the tree species belonging to the fast growing type are among others leucaena leucocephala, Sesbania grandiflora, Glirisidia maculata, Eucalyptus urophylla, Albizia falcataria, Calliandra calothyrsus, Acacia auriculiformis, Acacia decurens, Trema orientalis, Cassia siamea and Pterocarpus indicus, beside other fuelwood species belonging to the slow growing type (Becking, 1944; Anonymous, 1955).

Fast growth relates to the volume of fuelwood produced per hectare or in some cases per tree each year; the shorter rotation is obviously more appealing for the interest of rural communities.

Most foresters concentrate their attention on the volume of the main stem for the production of sawnwood. They may revise their view as regards fuelwood. Because all parts of the tree such as stem, branchwood or crown can be used for fuelwood. Therefore production of fuelwood must be based on biomas production.

Wood production of various fuelwood species is dealt with in appendix 3. These data are based on the volume of main stem only, because the data of biomas production of fuelwood species are not available and further research must be done.

Regeneration system

To manage man-made forests sylvicultural system can be used including clearcutting with artificial regeneration or coppice system. In principle both regeneration system are easily to be operated. Which one of the regeneration systems must be used depends upon the characteristic of tree species to be planted and tree plantation purposes. For example the clear cutting with coppice system can be used only on the forest stand that has strong coppicing ability

For forest of fuelwood species the use of clear cutting with coppice system can be recommended because this system can reduce the cost of establishment and tending in the second crops. However, research is still required to ensure that the yield of coppice crops is not significantly lower than that of original crops from seedling.

In appendix 3 regeneration system of several fuelwood species is dealt with. It showed that the trees able to be coppiced are among others Leucaena leucocephala, Calliandra calothyrsus, Dalbergia latifolia, Cassia siamea, Lagerstroemia speciosa, Gliricida maculata and Eucalyptus urophylla. Other species belong to those uncapable to be coppiced.

FUELWOOD SPECIES FOR PLANTATION

Several factors must be considered in the selection of fuelwood species for plantation, among others: (a) Selected tree species must be suitable for planting on the site; (b) Selected tree species have to possess characteristic appropriate for fuelwood such as high calorific value, fast growth, high production of fuelwood, having the ability to coppice when cut; (c) The seed of selected tree must be available in large quantity and sufficient for the purpose.

To select a fuelwood species based on high heating (or calorific) value the size of wood specific gravity (density) can be used. Because wood specific gravity (density) is commonly used as indicator of heating value at constant moisture content and the relationship depends upon whether heating value is expressed per unit of weight or volume.

In this case, the wood which has high specific gravity (density) is usually assumed capable to produce high calorific value and on the contrary the wood which has low specific gravity (density) will produce low calorific content (Rienrink, 1938; Becking, 1944; Burley, 1978).

Becking (1944) have dealt with the classification of fuelwood based on specific gravity (density), see table 1. Following their evaluation that the wood of tree species which can be used for fuelwood belongs to fuelwood classes of 1-4 while fuelwood class five comprises low-quality.

Table 1. Fuelwood classification based on specific gravity density.

Fuelwood classes	Wood specific gravity (density)	Quality
I	Over 0.90	Superior
II	0.75 - 0.90	Very good
III	0.60 - 0.75	Good
IV	0.45 - 0.60	Moderate
V	Under 0.45	B a d

Fuelwood species to be recommended for planting based on the data of table 1, with strong coppicing ability, having high fuelwood production and with easily obtainable seed in large quantity, are Leucaena leucocephala, Gliricidia maculata, Sesbania grandiflora, Cassia siamea, Lagerstroemia speciosa, Gigantochloa apus and Calliandra calothyrsus (Appendix 2-3).

CONCLUSION

1. The characteristics which must be possessed by fuelwood producing tree species are among others: the high calorific (or heating) value of woods, their high fuelwood production with short rotation and their ability to coppice when cut.

2. Based on seed available and the species characteristics as mentioned above the fuelwood species which can be recommended for cultivation are Leucaena leucocephala, Calliandra calothyrsus, Gliricidia maculata, Sesbania grandiflora, Cassia siamea, Lagerstroemia speciosa and Gigantochloa apus.

3. Other species which can also be recommended for fuelwood but uncapable to be coppiced are:

   a. Belonging to fast growing species:

      Acacia auriculiformis, Acacia decurens, Acacia leucophloea.

   b. Belonging to slow growing species:

      Swietenia macrophylla, Tamarindus indica, Dalbergia latifolia, Schleichera oleosa, Schima noronhae, Rhizophora mucronata and Bruguiera gymnorhiza.

4. The development of fuelwood plantations in a large scale and for a long-termed period must be supported by programs on tree breeding to improve the required tree species characteristics for fuelwood as drought resistance, high production, ability to coppice etc. Besides, research must be done on fuelwood production per tree species (yield of coppice crop) which is based on biomas production. Also study on management cost of plantation, seed production per hectare must be implemented.

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Appendix 1. Calorific value (cal./gram) of some fuelwood species (Rienrink, 1938; Becking, 1944; Anonymous 1979)

Nos.	Botanical name	Local name	Calorific value
1.	*Acacia auriculiformis*	Kasia	4907
2.	*Lagerstroemia speciosa*	Bungur	4829
3.	*Acacia decurens*	Akasia	4462
4.	*Gliricidia maculata*	Gamal	4548
5.	*Leucaena leucocephala*	Kemlandingan	4464
6.	*Schleichera oleosa*	Kesambi	4459
7.	*Swietenia macrophylla*	Mahoni	4936
8.	*Tamarindus indica*	A s a m	4829
9.	*Acacia leucophleoa*	Pilang	5218
10.	*Rhizophora sp.*	Bakau	5086
11.	*Bruguiera sp.*	Tanjang	5310
12.	*Pterocarpus indica*	Kayu merah	4529
13.	*Cassia siamea*	Johar	4483
14.	*Albizia falcataria*	Sengon	4464
15.	*Anthocephalus cadamba*	Jabon	4731
16.	*Calliandra calothyrsus*	Kaliandra	4617,8
17.	*Dalbergia latifolia*	Sonokeling	4722
18.	*Eucalyptus sp.*	H u e	4721
19.	*Sesbania grandiflora*	T u r i	4610
20.	*Schima noronhae*	Puspa	4773
21.	*Treme orientalis*	-	4576
22.	*Casuarina equisetifolia*	Cemara laut	5041
23.	*Gigantochloa apus*	Bambu	4407

Appendix 2. Distribution and habitat of some fuelwood producing tree species (Becking, 1944; Anonymous 1979; Letourneux, 1970, PPHI, 1958; Berger 1926)

Species	Distribution of tree species	Habitat of tree species	
1. *Acacia auriculiformis*	From the savanas area of Irian (Indonesia) to the northern areas of Australia	Altitude :	0-600 m above sea level
		Climate :	Mean annual rainfall varying from 1500 to 1800 mm with dry season of 6 months. Mean annual temperature range from 26°C to over 30°C.
		Soils :	Grow on variety of soils type even on poor soils. It belongs to light demanding species and the wood has specific gravity range from 0.69 - 0.75.
2. *Acacia decurens*	Sub tropical areas of Australia and southern of Africa introduced to Indonesia in 1900	Altitude :	200-800 m above sea level
		Climate :	In Java, grow very well at mean annual rainfall of over 2500 mm. with a dry season of 3-4 months, with mean annual temperature range from 20°C to 28°C.
		Soils :	Grow very well on fertile soil. It belongs to light demanding species and the wood has specific gravity of 0.70.

Species	Distribution of tree species	Habitat of tree species
3. Albizia leucophloea	From the western part of India, Burma, Ceylon to Indonesia (Timor, Sumbawa, East Java)	Altitude : 0-500 m above sea level Climate : Mean annual rainfall varying from 1000 to 1800 mm with a dry season of 4-5 months. Annual temperature ranges from 25°C - 30°C. Soils : Grow ability on poor soils. Evergreen on fertile soils. It belongs to light demanding species and the wood has specific gravity ranges from 0.70 - 0.85.
4. Albizia falcataria	Malucas south Sulawesi, and Java (Indonesia)	Altitude : 0-1500 m above sea level Climate : Mean annual rainfall varying from 1600 to 2500 mm up with a dry season of 3-5 months. Annual temperature ranges from 26°C - 30°C. Soils : Grow very well on fertile soils, but still adapted itselp on poor soils. It belongs to light demanding species and the wood has specific gravity of 0.39.
5. Anthocephalus cadamba	From Indonesia (all the main island) to Philippines	Altitude : 0-1000 m above sea level Climate : Mean annual rainfall varying from 2000 mm to 3000 mm up with a dry season of 3-4 months. Mean annual temperature ranges from 28°C-30°C. Soils : Grow very well on fertile soils. It belongs to light demanding species and the wood has specific gravity of 0.42.

Species	Distribution of tree species	Habitat of tree species	
6. Bruguiera gymnorhiza	From Sumatra to Irian Jaya	Altitude :	0 m above sea level
		Climate :	Monsoon climate to wet climate, with mean annual rainfall over 1800 mm.
		Soils :	A long of sea costal on alluvial soils. The wood has high specific gravity of 0.90.
7. Casuarina equisetifolia	Found widely throughout tropical countries of Asia, Australia, Oceania and Indonesia	Altitude :	0 m above sea level In Java, it still grows at altitude 250 m above sea level
		Climate :	Mean annual rainfall 700 mm and up
		Soils :	Grow on sandy soils. In Java it still grows on latosol soils type. It belongs to light demanding species but tolerant to some shade when young. The wood has specific gravity of 1.04.
8. Cassia siamea	Indochina, Indonesia (Java)	Altitude :	0 - 800 m above sea level
		Climate :	Mean annual rainfall varying from 1000 to 1500 mm with a dry season of 5 - 7 months.
		Soils :	Grows on all variety of soils, but grows badly in the shade of large trees and on poor soils. It belongs to semi light demanding species and the wood has specific gravity of 0.84.

Species	Distribution of tree species	Habitat of tree species	
9. Calliandra calothyrsus	A native species of Tropical America. In Indonesia, it is used for afforestation purposes.	Altitude :	In Java, it is planted at altitude 150 - 1000 m above sea level.
		Climate :	Mean annual rainfall varying from 1800 to 2800 mm and up, with dry season pf 4-5 months.
		Soils :	Grows very well on fertile soil, but still able on poor soils the wood has specific gravity of 0.70 - 0.85.
10. Dalbergia latifolia	A native of southern India. Planted in Indonesia (Java) since 1900.	Altitude :	0 - 1500 m above sea level.
		Rainfall :	Mean annual rainfall varying from 1000 to 1500 m with a dry season of 6 months, with large saturation deficit.
		Soils :	Prefers moist deep soils, but is very adaptable and adjusts itself to fairly poor, to clay soils, but does not tolerate badly-drained soils. It belongs to semi light demanding species and the wood has species gravity of 0.85.
11. Eucalyptus urophylla	From East Nusa Tenggara (Indonesia) to North Australia	Altitude :	0 - 1000 m above sea level
		Rainfall :	Mean annual rainfall varying from 600 - 2000 mm and a short dry season. Mean annual ranges from 26°C to 29°C up.
		Soils :	Adapts itself to all types of soil. The wood has specific gravity of 0.89.

Species	Distribution of tree species	Habitat of tree species
12. *Gliricida maculata*	From Central America. Sri Lanka, India, Guyana, Philippines, Malaysia to Indonesia.	Altitude : 0 - 500 m above seal level Rainfall : Mean annual rainfall varying from 1270 -2050 mm, with a dry season of 4-6 months. Soils : Grows on variety of soils type, even on lime soils. The wood has specific gravity of 0.94.
13. *Lagerstroemia speciosa*	Wide spread throughout tropical Asia in dense forest with semi deciduous foliage. In Indonesia distributed from Sumatra, Java, Kalimantan to Irian Jaya.	Altitude : 0 - 1200 m above sea level Rainfall : Mean annual rainfall over 1200 mm. Soils : Grows on deep fertile alluvial soils. Prefers river banks and very moist areas (but not marshes). Does not tolerate drought especially when young. The wood has specific gravity of 0.69.
14. *Leucaena leucocephala*	A native of tropical America. Introduced to Indonesia in 1900.	Altitude : 0 - 1000 m above sea level Rainfall : It requires rainfall of at least 1000 mm. Soils : Grows on fertile soils. Its introduction on dry, poor soil is bound to fail. Normally a light demanding species, but is adaptable and tolerates the shade of large trees. The wood has specific gravity of 0.82.

Species	Distribution of tree species	Habitat of tree species	
15. Pterocarpus indica	In Indonesia distributed from Java, to East Nusa Tenggara	Altitude :	0 - 800 m above sea level
		Rainfall :	Mean annual rainfall over 1500 mm. Tolerates a dry season of 6-7 months.
		Soils :	Frequent on lateritic soils but adapts itself to every variety of soils. It belongs to light demanding species and the wood has specific gravity of 0.65.
16. Swietenia macrophylla	A native of Central America. Introduced to Indonesia in 1870.	Altitude :	0 - 1500 m above sea level.
		Rainfall :	Mean annual rainfall over 1500 mm.
		Soils :	Grows on variety of soils type, but with a distinct preference on for well drained, sandy clayey slopes. It belongs to semi light demanding species and the wood has specific gravity of 0.61.
17. Sesbania grandiflora	Plantation distribution from Sumatra, Java, Sumbawa to Timor.	Altitude :	0 - 1000 m above sea level.
		Rainfall :	It requires fertile soil. But it can still grow on poor soils. The wood has specific gravity of 0.42 - 0.52.

Species	Distribution of tree species	Habitat of tree species	
18. Schleichera oleosa	Thailand, East Java and west Nusa Tenggara	Altitude :	0 - 700 m above sea level
		Rainfall :	Mean annual rainfall varying from 1000 to 2000 mm.
		Soils :	Grows on variety of soils. The wood has specific gravity of 1.01.
19. Schima noronhae	From Sumatra, Kalimantan to Java	Altitude :	200 - 2500 m above sea level
		Rainfall :	It requires mean annual rainfall over 1800 mm with a dry season of 4 - 5 months.
		Soils :	It requires well drained soils. The wood has specific gravity of 0.62.
20. Rhizophora mucronata	From Sumatra to Irian Jaya	Altitude :	0 m above sea level
		Rainfall :	Monsoon climate to wet climate with annual rainfall over 1800 mm.
		Soils :	A long of sea coastal on alluvial soils. The wood has specific gravity of 1.05.
21. Trema orientalis	Sumatra, Kalimantan, Java to Sulawesi	Altitude :	0 - 500 m above sea level.
		Rainfall :	Mean annual rainfall over 1500 mm. with a dry season of 3-4 months.
		Soils :	It requires fertile soils. But can still grow on poor soils. The wood has specific gravity of 0.36.

Species	Distribution of tree species	Habitat of tree species
22. *Tamarindus indica*	A native of Afrika Mow found scattered throughout the tropic. In Indonesia it is found in Java, Sumatra, Sumbawa, Sulawesi to Timor.	Altitude: 0 - 300 m above sea level Rainfall: Tamarind is suitable for growing only in region that has extended spells of dry weather. Soils : It requires well drained soils but it can still adapt itself on variety of soils. The wood has specific gravity of 0.90.
23. *Gigantochloa apus*	Especially in Sumatra, Java and West Nusa Tenggara	Altitude: 0 - 800 m above sea level. Rainfall: Mean annual rainfall varying from 1000 mm to over 2500 mm. Soils : Grow well on fertile soils. The sulm has specific gravity of 0.52.

Appendix 3. Mean annual volume increment and regeneration system of Fuelwood Tree Species (Becking, 1944; PPHI, 1955; Letourneux, 1957; Anonymous, 1979)

Species	Felling rotation (years)	Mean Annual increment of volume (m3/ha) per ha	Regeneration System Clear cutting with artificial regeneration	Coppice
Acacia auriculiformis	8	20	X	-
Acacia decurens	8	17	X	-
Albizia falcataria	15	30	X	X
Anthocephalus cadamba	9	15	X	-
Bruguiera sp.	30	5	X	-
Cassia siamea	10	10	X	X
Calliandra calothyrsus	10	32	X	X
Dalbergia latifolia	20	15	X	X
Leucaena leucocephala	5	20	X	X
Gliricidia maculata	8	20	X	X
Eucalyptus urophylla	9	19	X	X
Sesbania grandiflora	7	15	X	X
Swietenia macrophylla	25	17	X	-
Schleichera oleosa	25	10	-	-
Schima noronhae	25	12,5	-	-
Trema orientalis	8	10	X	-
Tamarindus indica	25	5	X	-
Casuarina equisetifolia	20	5	X	X
Lagerstroemia speciosa	15	10	X	X
Pterocarpus indica	15	10	X	-
Gigantochloa apus	5	15 ton	X	-
Acacia leucophloea	20	19	X	-

SOME SOCIO-ECONOMIC ASPECTS OF FUELWOOD PLANTATION IN JAVA

HARTONO WIRJODARMODJO[1/]

ABSTRACT

In its effort to provide fuelwood for rural people near the forest, Perum Perhutani has planted fuelwood plantation in the form of small plantation, hedge crops and interplanting crops. It comprises some 60,000 ha. This program is part of the "forestry for rural community development program of Perum Perhutani."

The species used are those species already familiar and planted in Java. Leucaena leucocephala and Acacia auriculiformis, Glericidia sp for the lowland region, Caliandra calothyrsus for region 500 m - 1,500 m, and Acacia decurrens for regions above 1,000 m. elevation.

The species seem to be most suitable as regard growth, production, as well as socio-economic conditions of the rural community.

* * * * *

It is well known that wood is the dominant domestic fuel for rural people in developing countries. "Wood is the poor man's oil" (Makhijam and Poole, 1975).

Statistical data on fuelwood production and consumption are in general less reliable than for industrial wood. In Indonesia the biggest consumers of fuelwood are households in rural areas, i.e. 39.3 million tons in 1974, while small industries take the second place, i.e. 13.7 million tons (Dept. Pertanian, 1978). The figures for Java are resp. 24.[illegible] million tons for households, 8.5 million tons for industries and 24.9 million tons for transport, total 32.8 million tons. This is an increase of 8.5% yearly during the decade 1964 - 1974, while production was increased only by 4.5% yearly in the same period. In the year 1974 the deficit was already 10 million tons, and it was estimated that this figure will increase yearly by 4%. So there is a firewood crisis. Since more people and poor people use wood for fuel, firewood crisis affects more people and the poor people. The rural people get their fuelwood from their gardens, from plantations, agricultural waste products, and from the forest.

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These gathering of fuelwood is one of the main causes of land deterioration and deforestation which cause further environmental damages, well known dilemmas.

Perum Perhutani, a State Forest Enterprise, who is responsible fo the management of 3 million ha forest on the island of Java, has tried and initiated plantation for fuelwood production.

This program of fuelwood plantation has these purposes:

1) of helping rural people with their energy needs to lessen the pressure of people to the forest.

2) to elevate the welfare of the village people near the forest.

It is one of the "Forestry for Rural Community Development" programs of Perum Perhutani.

VILLAGES NEAR THE FOREST

Perum Perhutani has made a survey of villages which are located near the forest in Central Java. The forest area in Central Java is 650,000 ha. which occupies 19% of the land area of Central Java. The number of villages bordering the forest is 2372 with 6,681,513 inhabitants.

Appendix I gives an account of the social-economic characteristics of those villages. From the table we see that 52.75% of the people are farmers, 20.35% farm labourers, 12.25% forest labourers, 7.85% merchants and 6.80% others.

The land use patterns is as follows: 303,644 ha sawah (wet rice field) and 693,559 ha dryland. In these areas, not only rice fields and mixed gardens on dryland are important, but also livestock breeding. Excessive grazing on foliage contributes also significantly to the large scale destruction of tree cover. Beside fuelwood crisis there is also a fodder crisis in these areas. An off-farm activity that also must be taken into account in connection with firewood are bricks and tiles industries, palm sugar making and other small industries.

Nibbering and Schrevel (1980) recently made a study on the social-economic aspects of firewood situation in several villages in Malang area, East Java. They show that factors such as distance to the forest and social-economic situation play the lead in conditioning fuel use patterns. People from villages close to the forest boundary do enter the forest to gather firewood.

Table 1 below gives an impression to what extent the households in rural areas utilize the wood resources from their own land and from the forest (Nibbering and Schrevel, 1980).

Table 1: Proportion of households using collected wood from the forest, in villages with and without coffee/mixed garden.

With coffee/mixed garden		Without coffee/mixed garden	
Village	Percentage of collectors in forest	Village	Percentage of collectors in forest
Kebonsari	24	Pujon Lor	8 (88) *)
Watu Kidul	45	Manting	76
Gombong	70		
Ngramban	31		
Talasan	58		

*) most households (20) purchase firewoos which is collected (in the forest) by inhabitants of other villages nearest to the forest; if these households as well are considered to obtain the wood from the forest, their proportion becomes 88%.

Firewood collected from the forest are mostly dead wood and sticks, chips and thick branches, while wood obtained from their mixed gardens are mostly wood from Lamtoro (Leucaena leucocephala), Sengon (Albizia falcataria), Waru (Hibiscus sp), Dadap (Erythrina sp) and Bamboo. Prices for one pikul **) of good firewood is Rp.500 - Rp. 1,000 ***) and that of an inferior one is Rp. 100 - Rp. 500. As mentioned before, small industries are also big consumers of firewood. They get their firewood from the sellers. It is clear from many studies that farm labourers (they are landless labourers) and small farmers collect the wood and sell it to the small industries.

**) pikul = a load of about 50-60 kg. or 0.05 m^3

***) 1 US$ - Rp. 615.

FUELWOOD PLANTATION OF PERUM PERHUTANI

The social-economic studies indicate that wood is an important commodity in a rural area. It is used daily as fuel for households as well as small industries whereas the leaves are used as fodder. Therefore, in establishing fuelwood plantation Perum Perhutani considers those social-economic aspects important. In choosing the species the following requirements were used:

- The species must easy to grow and easy to regenerate.
- The species can grow on a wide range of climatic condition.
- The species can grow on shallow and unfertile soils.
- The species gives good firewood and have other uses such as, fodder or gives other minor products.
- The species is fast growing.
- The species has the ability to improve soil condition.

At present, considering the above mentioned requirements, Perum Perhutani has chosen the following species for fuelwood plantation on a large scale namely:

a. Acacia auriculiformis.
b. Calliandra callothyrus.
c. Leucaena leucocephala.
d. Glericidae maculata .
e. Acacia decurrens.

Descriptions of the species:

a. Acacia auriculiformis.

° FAMILY : Leguminosae.

° Geographical distribution : North Australia, Irian, Java and other places in Indonesia.

° Characteristics: No special requirement for soil and climate. It can grow on unfertile soil and in dry climate (type D), altitude 0 - 400 m s.s.l. May reach up to 15 m in height with diameter of 50 cm. Low branching with wide and dense crown. The badly formed bole limits the possibilities for uses as contruction timber.

° Propagation : By seeds and stumps.

° Productivity : With 8 years rotation period the end yield will be 171 m^3/ha. Amount of calory: 4907 cal/gram dry weight.

b. Calliandra callothyrus

- FAMILY : Leguminosae.
- Origin : From Guatemala, Latin America, Introduced in Indonesia 1936.
- Characteristics : Woody shrubs, may reach up to 10 m in height, diameter 20 cm. It grows both on wet and dry climate, till 1500 m a.s.l.; fast growing with dense crown; it has a deep root system with symbiotic nitrogen fixing bacteria, increase the soil fertility.
- Propagation : By seeds and stumps. Easy to regenerate after coppicing.
- Productivity : With 10 years rotation period. After the third year the annual production per Ha is 150 stacking meters. Amount of calory: 4617 cal/gram dry weight.

c. Leucaena leucocephala

- FAMILY : Leguminosae.
- Origin : Tropical America. Introduced in Java a long time ago, and recently, the giant type from the Philippines and Hawaii.
- Characteristics : It grows well on many soils which are not too poor in nutrients, not on deeply eroded lateritic soils and swampy soils.

  Easy to sow and forms a dense growth. the plant improves the soil by fixing nitrogen and taking up nutrients out of the subsoil, has a good root system.

- Propagation : By seeds and stumps. Easy to regenerate after coppicing.

- Productivity : Increment per year not less than 50 m3 per ha.

  Amount of calory: 4464 cal/gram dry weight. Leaves can be used as fodder.

d. Glericidae maculata

- FAMILY : Leguminosae.

- Origin : Brasil. Introduced in Indonesia 1900.

- Characteristics : Tree with rich branching. May reach up to 15 m in height and 25 cm in diameter. Fast growing with deep root system. It grows on unfertile soil, able to increase soil fertility. Has no special requirement for climate up to 1500 m a.s.l.

- Propagation : By seeds and stumps. Easy to regenerate after pruning.

- Productivity : With 10 years rotation period. After the third year the annual production per ha is 80 stacking meters. Leaves can be used as fodder.

e. Acacia decurrens.

- FAMILY : Leguminosae.
- Geographical distribution : Sub-tropic Australia, South Africa. Introduced in Indonesia especially in Java as forest plantation.
- Characteristics: Grows well on altitude 1000-2000 m a.s.l. It needs porous soil, nevertheless it can grow on unfertile soil with dry climate. May reach up to 30 m in height with diameter 40 cm. Has thin canopy which is pyramidal in early stages.
- Productivity : With 8 years rotation period the end yield will be 212 m^3/ha. Amount of calory: 4462 cal/gram dry weight. Leaves can be used as fodder. Bark for tannin production.

Systems of Plantation

At present Perum Perhutani has already established fuelwood plantations of about 60,000 ha. consist of:

Calliandra and Glericidae	42,020 ha
Albizia falcataria	1,050 ha
Acacia decurrens	3,700 ha
Others (Acacia auriculiformis, leucaena leucocephala,)	12,600 ha
	59,370 ha.

The system starts with site preparation. This means besides opening up the area, careful attention should be paid to:

a. Cleaning of vegetation which may cause root and light competition.
b. Tilling the soil in order to improve the physical soil characteristics.
c. Providing soil conservation

The cleaning may best be done by cutting of shrubs, burning, plowing of grasses and weeds or a combination of these techniques.

The tillage of the soil may consist of hoeing, harrowing, plowing, deep plowing and soilripping or subsoiling, depending on the intensity of the site preparation and the soil layer to be affected.

Building terraces sometimes cannot be avoided in order to conserve water and to prevent soil erosion.

Three types of plantation systems are introduced, namely:

a. Pure plantation

In Indonesia, firewood species are planted mainly in Java where population is most dense. Started by Perum Perhutani who manages the forest area on the island of Java, the firewood species were planted in belts on forest borders as pure plantation especially in areas noted for its fuelwood need. Extensions are continually being done, encouraging communities to follow the step.

In regions where there is a sharp market demand for fuelwood, usually for small industries such as brick making, the village people have started to plant the firewood species on their own initiatives with seeds or seedlings provided by Perum Perhutani.

For own household use, firewood is given free of charge as much as the person could carry on their back or shoulders.

b. Cover crops

It is done together with the afforestation activities to establish some measure for soil conservation. By introducing cover crops the soil can be covered in a short time. The vegetation cover is important in soil conservation, but often the cover crops are used for green manure as well. The selected species for firewood supply are legumes.

These legumes act as nitrogen suppliers because of their ability to fix nitrogen from the air.

The system of cover crops needs good sowing or planting techniques, good site preparation and maintenance (pruning). These activities should be done without hindering the growth of the main tree species.

This system provides a way of establishing forest crops in combination with agriculture. The trees are usually species that grow quickly above the crops. They have deep root systems to avoid root damage by the cultivators. The trees have to be able to withstand competition from the crops for light, water and nutrients.

c. Hedge crops

This system is introduced to make more productive use of the space than traditional cultivation. The other aim is, to exclude animals from parts of the forest range.

In many places, quick growing trees for firewood have been planted on vacant land around houses and villages, as well as on roadsides and riverbanks.

SOCIAL-ECONOMIC ASPECTS

From the economic view, there are two interests with different objectives, namely the aspect of personal economies and the aspect of the national economy.

The aspect of personal economies is the various considerations for meeting needs without taking into account the interest of other people, while the aspect of the national economy is how to fulfil needs of a national character. Automatically there are many conflicts between these two different objectives. Recent surveys by FAO (1979) on the domestic fuelwood consumption in several developing countries was about 1.5×10^9 cbm for the year 1979.

It means that fuelwood made the fourth largest contribution to the total wood energy consumption after petroleum, coal and natural gas.

Furthermore, the survey showed that about 90% of the world's fuelwood consumption is in the developing countries. In most developing countries where wood is available, wood is the dominant source of energy for low income families. Although fuelwood is a daily household necessity, its low economic value does not permit it to be transported for longer distances. This localization of the demand for fuelwood frequently results in progressive depletion of the wood resources. Large areas become denudated in this way and erosion settled in. In areas where the forest has degenerated into waste land and where the fuelwood need is acute, efforts in reforestation bring very minimal results since the trees are cut again illegally as soon as they have been planted. In villages where there are extensive activities in the burning of limestone, cooking of coconut sugar and its kinds, hence requiring substantial firewood, trees used for firewood such as Calliandra or Glericidae could be planted. The people should be trained of collecting their own seeds, making their own seed beds and producing their own seedlings. It is in fact from these activities that the people would be able to earn their income, namely from the sales of the seeds of trees, sales of

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firewood from their own "forests". It has been pointed out that firewood are collected by villagers who are mostly landless labourers, some are seasonal labourers. These seasonal labourers earn their income mainly from agricultural activities.

These people could get extra income from the sales of firewood. They also could get payments from Perum Perhutani from its firewood exploitation. As mentioned before the forest area of Perum Perhutani for firewood supply covers about 60,000 ha. located bordering the villages. An estimate of the production can be figured as follows: Area especially planted with Calliandra and Glericidae is 42,000 ha. Harvesting starts at the 4th year. Rotation period is 10 years. The average production per ha. is 150 sm firewood. We expect a production of 7 x 150 x 42,000 sm = 44,100,000 sm firewood. If we assume that the production capacity of each labourer is 2 sm per day, with a payment of Rp. 600 per day, each ha of firewood plantation could give employment to 75 man days. The total opportunity for employment will be 42,000 x 75 mandays = 3,150,000 mandays. If we distribute the harvesting period all over the year in 250 days, it means that 12,600 people will earn extra income from the firewood plantation. Besides there is additional fodder for the livestock.

In conclusion fuelwood plantation of Perum Perhutani fills a part of the fuelwood shortage in Java and also increases the welfare of the rural people. With this effort it will hopefully reduce the entering and damaging of forest by people,

VILLAGES NEAR THE FOREST
IN CENTRAL JAVA

APPENDIX I.

No.	Forest District	Number of Villages	Number of people (x1000)	Profession in Percentage					Agricultural land		Cattle Livestock
				Farmers	Farm labourers	Forest labourers	Merchants	Others	Rice field (ha)	Dry-land (ha)	
1	Telawa	72	214	50	29	11	7	3	6,447	12,743	73,675
2	Blora	75	148	42	22	13	18	5	14,876	16,892	63,710
3	Randublatung	41	143	48	27	11	10	4	8,287	5,228	118,253
4	Gundih	103	536	52	21	19	3	5	16,784	17,194	87,078
5	Pati	173	523	60	20	12	6	2	26,234	20,543	215,741
6	Mantingan	61	89	58	19	12	7	4	7,806	13,337	39,656
7.	Magelang	314	643	49	28	7	12	4	21,919	68,125	265,624
8	Pemalang	61	175	71	11	6	9	3	15,552	34,241	20,506
9	Surakarta	196	593	48	10	26	1	15	19	47,456	224,103
10	Kendal	79	284	50	32	11	4	3	6,557	22,035	50,161
11	Semarang	61	114	39	5	28	2	26	5,421	9,085	57,029
12	Kebonharjo	42	61	42	17	24	8	9	16	2,569	22,175
13	Banyumas Timur	121	336	45	20	14	12	9	19,959	40,877	93,507
14	Pekalongan Timur	156	31	52	19	15	12	2	18,417	21,564	90,207
15	Balapulang	75	366	58	21	10	8	3	17,341	20,892	56,888
16	Pekalongan Barat	137	459	48	39	4	4	5	14,199	198,651	15,030
17	Kedu Selatan	337	679	55	26	7	7	5	36,100	79,401	231,772
18	Purwodadi	54	204	61	17	8	7	7	28,502	10,996	49,964
19	Cepu	94	257	65	15	9	6	5	3,245	10,968	69,503
20	Banyumas Barat	120	826	62	9	8	14	7	35,963	40,762	93,503
	Total	2,372	6,681	52.75	20.35	12.25	7.85	6.80	303,644	693,559	1,938,115

Survey made by Perum Perhutani, 1980.

NEPAL

COUNTRY REPORT ON THE WORKSHOP: "FIXING CRITERIA FOR MASS SELECTION OF FUELWOOD SPECIES"

MAJRUL HAQUE AND
EKRAJ SHARMA[1/]

ABSTRACT

A study of the energy sector conducted in 1976 by the scientists of the Energy Resource and Development Group of the Tribhuvan University, Kathmandu showed that fuelwood accounts for about 87% of all energy consumption. In rural areas, the fuelwood demand alone accounts for over 95% of all wood consumption in Nepal. Hence, fuelwood would remain as the principal source of energy for most of the people especially in the rural areas.

Many years before, forests were plentiful in Nepal when the population pressure was not yet high. However with the increasing population at present, the forest area has shrunk because people are forced to accept what is available, even though the desire for traditional species exists.

It has been estimated that in the year 2000, tree plantation would need to supply about eight million tons of coal equivalent to fill the anticipated future energy gap.

The government has started tackling the problem with an intensified effort towards raising more fuelwood plantations. The current target for planting is about 3,000 ha. annually. Already, "tangya" is being practiced in the Terai on an appreciable scale.

Some of the appropriate criteria for selection of fuelwood species are: easy to cut or split, easy to harvest and handle, low branch wood to stem wood ratio, fast-growing, easy to coppice, high calorific value, not emitting much smoke or sparks, capable of growing in marginal and sub-marginal areas, cheap to produce, should have supplementary uses, and seed availability is not a problem.

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THE BACKGROUND

Nepal is a small under-developed country lying between latitudes 25°N and 30°N and longitudes 80°E and 88°E. It is roughly a rectangular piece of land in the middle Himalayas. It is basically an agricultural country with almost 80% of her people engaged in agriculture. It has a population of about 13 millions with an annual growth rate of 2.1%. Total land area is 54,600 sq. miles. Forests cover 29% of total area, followed by waste land 18.64%, cultivated land 16.49% and land under perpetual snow 14.97%. The remaining portion consists of pasture, water and residential area. Total number of land holding (1977) was 1.49 million with average size per holdings of 1.23 ha. It is one of the poorest countries in the world with majority pf the people living on or around the poverty line.

The country can be roughly divided into seven natural zones which occur in the following order from south to north: (i) Terai (ii) The Siwalik hills (iii) Mahabharat Lekh (iv) Midlands (v) Himalaya (vi) Inner Himalaya (vii) Tibetan-Marginal Mountains.

There are three main classes of rivers, the first river flows down from the Himalaya and the Tibet; the second originates in the midlands and the third are numerous and small and which come from the southern slopes of Siwaliks or Mahabharat Lekh. Fluctuations in the discharge of water from all the three classes of rivers is remarkable; while the mean flow varies between 0.02 and 0.1 cum/sec/sq.km, there are peaks in flow as low as zero and as high as 7 cum/sec/sq.km. Class III rivers exhibit the greatest fluctuation, often being without water during the winter dry season. The Terai is exposed to serious floods at the onset of every monsoon. The small rivers are responsible for most of the damage.

A very wide range of climates are met with, from the summer tropical heat and humidity of the Terai to the colder dry Continental and alpine winter climate of the middle and Northern sections. Annual precipitation varies from more than 6,000 mm in central Nepal (Southern slopes of Annapurna range) to less than 250 mm in the North-Central

portion near the Tibetan border. About 80% of the precipitation is confined to the monsoon period (June-September). The spring months are characterized by windy and stormy weather, increasingly higher humidity and pre-monsoon thunderstorms. Snowfalls are confined to the northern and western mountainous regions, especially at elevations above 3,500 m. Summer and late spring maximum temperatures range from more that 40°C in the Terai to about 28°C in the mid section of the country.

Moving from North to South, there is generally an increase in precipitation; rocks become weaker and the rate of erosion is also more intense. The mountains are young and the entire ecosystem is very fragile.

Natural and partially hidden erosion (from fallow or bare agricultural land or scattered, open or degraded forests) is one of the most serious problems in Nepal. In some areas, spectacular erosion (active land-slides) is very common.

Topography (mainly altitude) and rainfall affect the luxuriance of vegetative growth. The east-west distribution of rainfall generally results in a pattern of number and variety of species decreasing as one moves westwards.

Starting from the south, the forests are subtropical deciduous (or semi-deciduous) in character succeeded by forests of broodleaved trees mixed with Rhododendrons in the Mahabharat Lekh and middle hills, then yielding to temperate evergreen and conifers, later alpine meadows on the southern side of high Himalayas.

The natural forest in the densely populated areas of the Nepal hills has been seriously over-exploited mainly because of excessive cutting for fuelwood, repeated lopping for leaf fodder and by over-grazing.

Only a few decades ago, more that two-thirds of Nepal was under forests, but these have shrunk to only 29% of the area now. Considerable tree-felling has occurred in the recent past. Over the last decade about one million hectares of hill forests (i.e, about 25% of the forest area) have been completely destroyed. According to the assessment made by the World Bank, increasing population pressure and fuelwood and fodder demands could result in the complete disappearance of all the accessible forests in the Hills in the next 15 years and in the Terai in 25 years unless reforestation programs are initiated on a massive scale.

THE ENERGY SITUATION

A study of the energy sector was conducted in 1976 by the scientists of the Energy Research and Development Group of the Tribhuvan University, Kathmandu; they investigated all alternatives for meeting future energy demands to the year 2000, including end-use efficiency, biogas, solar energy, wind, geothermal, hydro-electric, coal, lignite, etc. and concluded that in rural areas, wood fuel will remain the principal source of energy for as long as supplies last. Table given below shows the pattern of energy use. Fuelwood accounts for about 87% of all energy consumption. In fact in rural areas, the fuelwood demand alone accounts for over 95% of all wood consumption.

TABLE - 1

TOTAL COMMERCIAL AND NON-COMMERCIAL ENERGY CONSUMPTION BY TYPES OF FUEL (1974 - 75)

	Fuels	Energy Coal tonne replacement	%	
A	Commercial			10.74
	1. Coal	64,480	0.90	
	2. Petroleum fuels	613,546	8.58	
	3. Electricity	90,331	1.26	
B	Non-Commercial			89,26
	1. Fuelwood	6,204,000	86.78	
	2. Husk	86,000	1.21	
	3. Dung cake	28,800	0.39	
	4. Vegetable wastes etc.	62,757	0.88	
	Total	7,149,114		100

(Source - Energy Sector Study Tribhuvan University, 1976)

Although the potential fo hydro-power in Nepal is enormous and while harnessing of only 4% of t total water resources could provide power, sufficient enough for all the energy needs of the country, the development of this resources cannot afford the desired relief to the general rural masses in the immediate future because of:

(i) a long gestation period involved in the ultimate fruition of the projects (from preliminary hydrological investigations to design stage, then installation and later completion).

(ii) requirement of heavy initial investments, and
(iii) the very small paying capacity of the rural poor. Even if the power becomes available, they cannot buy it due to overall meagre incomes.

Utilization of solar energy also holds bright prospects in several regions of Nepal which have a large number of sunny days but the initial costs of transport and installation of necessary equipment to use solar energy and subsequent maintenance thereof, is beyond the means of ordinary men. So is the case with harnessing wind energy, although in several regions winds are legendary both in terms of velocity and consistency (Kali Gandaki valley).

Exploitation of natural gas involves more exploration and study of socio-religious constraints; the 'Sacred Flame' of Buddhist gompas and other similar sources are greatly revered. People may not like any interference with those sources.

The use of bio-gas, though possible in warmer locations, again has limited applicability; the anaerobic decomposition gets dulled in cooler climates.

Petroleum products too cannot be depended upon, not only because of the rising costs, but also, due to abnormally high transport costs in a mountainous country like Nepal where communications are still difficult.

Hence for many years to come, fuelwood would remain as the principal source of energy for most of the people especially in the rural areas. Because of the renewable nature of this resource and a comparatively low-investments endeavour involved in raising the trees etc, in the near vicinity of households, this resource has the greatest chance of helping the people out of the crisis in which they are placed.

TRADITIONAL USAGE

Only until a few decades ago, forests were plentiful in Nepal. Population pressure was not that high. People in the hills practised shifting cultivation. There was no shortage of fuelwood. People were thus choosy; they selected and cut the trees that gave them the best fuel, which burnt with least smoke and stayed longer, for they not only needed the fire for cooking but also to provide them warmth in cooler situation.

Thus, in the high hills, they b[illegible] Betula spp and junipers; lower down they chose firs, Taxus, Oak, Rhododendron spp, Schima wallachi, Castanopsis spp, Alnus nepalensis, Pines and Michelia spp. In the Terai, which was not much inhabitated then (because of malaria and which got colonized after eradication of the same) Shorea robusta and Acacia catechu were freely cut. Even Albizzias, Terminalia spp were consumed. Fallen dry wood in the forests also provided a considerable resource to depend upon.

Now population pressure is increasing and forest area has shrunk-in fact far receded from the centres of large habitations. That has forced people to accept what is available, even though desire for traditional species exist.

Every tree yields some firewood through lops and tops, even if its main trunk is utilized either for timber or other industrial uses. So also, twigs from leaf-fodder supplement the daily requirement of fuelwood. Lumbering waste in nearby situations is collected and used. Saw milling waste, offcuts and dust are all now used. Even bark taken off from harvested logs is now consumed.

DEMAND AND SUPPLY SITUATION

The demand and supply situation varies very irregularly from one part of the country to another, corresponding to the behavioural pattern of the society in relation to the forests. The warmer slopes which got inhabitated more densely and where cultural ethos towards maintenance of forest crops was lacking, there is complete devastation with acute shortage of fuelwood. In pocket, where people realized (as the Sherpas did in the past at Khumbu) that their survival was linked with the maintenance of forest cover, the situation is not bad.

The question has therefore, to be considered in three situation.

(i) Where forest resources are in abundance and exist in near proximity of habitations. (eg. Bardia distt.) Here there is no shortage and as yet there is no market price for fuelwood. But care is required to ensure that such forest resources do not get dwindled away due to pressure from adjoining deficit areas. It is to be regretted that people here are not aware of the totality of the energy crisis on the national level.

(ii) Where forests are in short supply and human population continues to rise. (eg. Shanusa & Chautara distt.) Costs incurred involve only those of additional time and distance. The inhabitants have had to travel farther

and farther with each passing year to satisfy their firewood needs. Often a journey ranging from 3 to 5 hours is required to reach the area where firewood could be collected.

(iii) Where forests are scanty or non-existent and human as well as cattle population is high. (eg. Midlands) The environment is over-taxed already. Whatever little local control exists is negated on the principle of sheer survival.

Often members of several families now frequently group together to form wood-gathering expeditions lasting from several days to a week or more. Alternatively wood is brought by trucks to established depots or on mules for delivery at households. Already in some villages, households may devote an average of 11 man-days per month to fuel collection alone (besides 15 man-days per month to fodder collection).

Precisely when the demand began to exceed convenient supply is difficult to establish. It is different in each setting. But, generally speaking, deficit has been mounting in the Terai from 1968 while in the hills it has been felt from even earlier than 1964.

Reasons are however linked to:

(i) Population growth.
(ii) historical pressures of transient (pilgrim) populations in and around places of workship.
(iii) historical free exploitation of the forest without regard for the restrictive regenerating powers of plants, especially in high and arid settings.
(iv) Growing tourist traffic

Annually the large number of trekkers and mountaineers require hundreds of tons of wood for cooking and warmth.

An interesting fact is that in 1977, while there was an over-all shortage of fuelwood, yet the country exported 2.5 million cft of fuel-wood, because it was surplus in one part of the country and heavy transport cost precluded it being carried for use in remote areas.

The following table illustrates the trend on mounting deficits.

Year	Fuelwood demand			Million Available yield	Cft. Deficit
	Terai	Hills	Total		
1977	97.6	255.3	352.9	127.5	225.4
1990	135.0	334.4	469.4	83.7	385.7

(Projected figures)

(Source - The Nepal Journal of Forestry, No. 4. 1978)

RURAL ENERGY NEEDS BY 2000

Two thirds of the population lives in the hills. It is there that great denudation has taken place. Migration of people to the Terai is creating scarcity conditions even there. Taken as a whole and on the basis of an annual consumption of 0.91 cum of fuelwood per person, it has been estimated by the Energy Sector Study that tree plantations would need to supply about 8 million tonnes of coal replacement equivalent, to fill the anticipated future energy gap to the year 2000.

PLANTATION REQUIREMENTS

It has been estimated by the World Bank that to fulfill the above requirements, raising of plantations on the following scale would be required.

	Ha
1) Village fuelwood plantations in Hills	640,000
2) Village fuelwood plantations in the Terai	400,000
3) Urban fuelwood plantations in the Terai	113,000
4) Urban fuelwood plantations Kathamandu Valley	20,000
	1,173,000

This is exclusive of plantation activity required to meet the demand of industrial timber.

This is a gigantic challenge not only in terms of trained manpower to handle the work but also in terms of finance initially required. Work has of necessity, to be phased.

CURRENT PLANTATION ACTIVITY

His Majesty's Government has started tackling the problem with an intensified effort towards raising more fuelwood plantations. The current target for planting is about 3000 ha, annually. Further, plantation activity is increasing under Donor Agency aided projects e.g. the Community Forestry project, the Sagarnath Project and the Resources Conservation and Utilization Project. In addition, the industrial set-ups are also helping in raising plantations.

The technical solution to the common problems of competition for land lies in some form of joint production of wood and crops, planting along roadsides, river/canal banks, around houses and other small areas of otherwise unused land. This is the direction in which we intend to move. Already taungya is being practiced in the Terai on an appreciable scale.

CRITERIA FOR SELECTION OF TREE SPECIES

Some of the appropriate criteria for selection of fuelwood species are:

(i) the wood should not be difficult to cut or split,
(ii) it should be easy to harvest and handle,
(iii) should have low branchwood to stemwood ratio,
(iv) be fast growing, permitting planting on close spacing and harvesting at short rotations thus yielding large volume and weight per unit area in a given site situation,
(v) be easy to coppice,
(vi) should have high calorific value,
(vii) whose availability of seed is not a problem,
(viii) should not emit much smoke or sparks,
(ix) be capable of growing in marginal/sub-marginal areas i.e. should possess wide tolerance limits necessary for extensive application,
(x) be cheap to produce i.e. it should have a low energy imput to output ratio,
(xi) species already growing and used in the area are more valuable than introduced species, and
(xii) should have supplementary uses either in providing leaf fodder, poultry feed, food, medicine, etc. or to enhance soil stability.

The quality of multiple uses is of increasing importance since with shrinking forest area and acute firewood crisis, there is also a crisis in other domains e.g. leaf fodder, fruits etc.

In application of these criteria, however, there are great constraints arising out of the environment (site conditions, peoples attitude etc.) limiting the choice of species.

SPECIES SO FAR USED IN RAISING PLANTATIONS

In the Terai, so far large-scale plantations are confined to those of Dalbergia Sissoo, which is very easy to grow from stumps. These are planned to be worked at short rotations (10-15 years).

The other species planted is Teak (Tectona grandis) but this is mainly for poles and timber. Early thinnings and lops and tops at harvesting time would yield firewood.

Other experimental plantings on a very small scale area confined to various provenances of Eucalyptus camaldulensis, E. tereticornis. A few plants of Leucaena leucocephala have also been raised which show considerable promise (attaining over 8 m in height and 10 cm in diamete in two growing seasons).

In the Hills, some experiments were tried with various Eucalyptu spp. but the success had been indifferent. Boron deficiency has been identified and perhaps remedial action may further boost planting of the same. There are many naturalized Eucalyptus trees planted over 50 years back.

Other species tried on a large scale are the pines, which are doing well on degraded sites. Alnus nepalensis is doing well on moiste sites. At other places Schima wallachii has been planted. With protection Castanopsis spp are also coming up.

SOCIO ECONOMIC ASPECTS

Species Selection/Preferences

People want to grow in their areas trees which can provide both leaf fodder as well as fuelwood. During winters, in order to get more sun, they prefer to severely lop the trees or even pollard it; hence selection is limited to such species as would withstand such a treatment.

In some places, people prefer trees that yield a sufficient crop of fruits e.g. those of Choerospondias axilaris (Lapse) which can be sold at a good price (one such nature tree yields fruits worth over Rs 800/-annually) and is therefore prized.

In some regions, bamboos can come up very easily but these are not preferred for use as fuelwood.

Along the margins of the cultivated fields, people prefer trees (e.g. D. Sissoo) which cast a minimum of shade (which otherwise affects crop production) and has a thin crown, not allowing much space for birds to perch (they otherwise sit there and come down repeatedly to eat or destroy the ripening grain). Its timber is also used in making agricultural implements.

In the Terai often people plant mangoes which provide edible fruits (as well as timber at harvesting time). Bassia spp. also provide economic support to villagers in some places and are preferred.

Cottonwood (Pupulus ciliatus) is preferred in Muktinath valley (Mustang distt.) as it is prized for poles for house construction. Betula spp are prized for fuelwood.

Demand, Supply and Consumption

Most of the dwellings, especially in the rural areas are not air tight. Hence fuelwood is required for heating their houses when the mercury falls below desired levels.

The awareness of the people towards maintenance of vegetative cover is often vitiated by need of sheer survival. Even so, the attitudes of various ethnic groups in Nepal towards forest differ widely. People of Western-Central Nepal (Baragaonle) tend to over-exploit the forest resources, whereas Sherpas in Khumbu link maintenance of forest cover to their very survival and hence keep the supply position easy.

The areas where shifting cultivation was, or is still practised (though considerably on the decline), lot of usable materials is often wasted just burnt while other pockets feel starved of fuelwood supplies. Supply situation thus gets greatly distorted.

In the past, among certain groups polyandry was practised for various reasons. Now there is a clear shift to monogamous marriages, resulting in an increase in the population growth rate. This in turn has pushed up the demand of fuelwood.

The majority of the people being poor, cook their meals on open hearths (chulos) made by using two stones or bricks to put their cooking utensil on with fire lit below. Thus a lot of energy is wasted, which affects the over-all consumption. Use of improved designs of chulos has been suggested but not yet gone into wide use.

Some of the hermits burn firewood all day and night perpetually not only to keep themselves warm in open isolated areas but also as an act of religious observance.

Enforcement of existing laws regarding forest conservation is often difficult in remote areas because patrolling becomes difficult. Therefore complacency sets in and use of available resources lack economic appreciation.

The nationalization of all community lands in 1957 led to adverse effects on maintenance of forest cover. Large forest areas where cut over affecting future supplies. In some places local sentiments are high for panchayat-central rather than for the remote State contro in the forest wealth.

The high cost of alternative energy sources has forced greater dependence on firewood and its demand gets accentuated.

Also very important is the factor of inappropriate land-use which tends to intensify erosion and hence reduce productivity forcing more land to be put into agriculture after further deforestation which in turn reduces the over-all yield and availability of fuelwood.

Technologies of Fuelwood Production/Utilization

By and large the population having had a long and continued association with the forests (no matter if it often was to their detriment) is quite aware of the characteristics of the various species which are good for fuelwood. This knowledge has been traditionally passed down from generation to generation. But knowledge about regenerative qualities of such species, though known, was not relatively put to use except incidentally or occasionally, as the pinch for fuelwood has only become acute in recent times. However there is readiness to plant fuel and fodder trees in private or community owned lands. The villagers rate the importance of forestry development next only to the drinking water. They are prepared, in some areas, even to offer voluntary labour for afforestation programme in their villages.

With regard to the economic utilization of available fuelwood, there is little awareness to use it economically nor any attempt is made to improve the design of their hearths.

Depending upon the income, the structure of houses changes. Only the richer class have good masonary houses with proper doors and windows; the poor have hutments which admit plenty of air and thus need larger quantities of fuelwood for heating the rooms.

With rising costs of petroleum products, firewood is being increasingly depended upon as the primary source of energy.

Forest/Plantation Management of Fuelwood Species

Attitudes in different ethnic groups vary. Some panchayats are very well organized and oriented towards effective voluntary management of the forest resource. The panchayat of Thokarpa Sunkosi catchment) is an outstanding example of such endeavour. There, plantations on an appreciably large scale have been raised without any barbed wire fencing. But there are others who are not so understanding or efficient.

In Nebuatar (near Bhimphedi), barbed wire fencing had to be done initially. After a few years protection when benefits started flowing to the villagers (first in the form of larger availability of grass) their attitude has under gone a vast change and now they are interested in lending further cooperation in proper management of the forests. Where new plantations are being raised by the taungya method, protection problems are considerably reduced.

Other Considerations

The pressure of population coupled with lack of education and proper orientation has been responsible for defective land-use practices, resulting in ecological degradation of the site and accumulating losses. While an average agricultural farmer is conscious of using more organic fertilizers in his fields (and actually puts in increasingly more manure every year in his field), the appreciation of increasing soil loss due to bad terracing is often lacking. Washing away of soil or of the farm in retiringly accepted as 'fate' or a natural mishap and not one which can be effectively checked through appropriate skills.

SUMMARY

To sum up therefore, site-specific approach is called for in meeting the challenge of acute fuelwood crisis, owing to the very irregular pattern of the demand-supply situation and equally varying peoples attitude coupled with the difficult transport situation.

In each region, therefore, case studies are required to devise appropriate strategy to deal with the problem of meeting the present and future fuelwood demands.

With regard to the effective implementation of the plantation programme in meeting the crisis in which the nation is now placed, it will be necessary to periodically assess and monitor the growth, notice and remove constraints timely.

Fuelwood/Fodder Trees - suitable for planting or trials

Altitude	Species	Year To Harvest	Nutritive value
0-1,500 m	Artocarpus lakoocha	10-15	good
	Albizzia spp	-	leguminous, fair
	Bauhini variegata	-	leguminous, good
	Ficus benghalensis	15	fair
	Ficus glaberrima	10-15	fair
	Ficus religiosa	15	fair
	Leucaena leucocephala	-	leguminous, good
	Litsea polyantha	5 - 7	fair
	Morus spp	3 - 7	good
	Premna integrifolia	5	good
	Shorea robusta	20	fair
	Sterculia villosa	7-10	-
	Stereospermum tetragonum	7-10	-
1,200-2,000m	Albizzia mollis	7-10	leguminous, fair
over lapping	Bauhini purpurea	4	leguminous, good
	Castanopsis indica	10-15	poor
	Castanopsis tribuloides	10-15	good
	Erythrina arborescens	7	good
	Ficus nemoralis	7	good
	Ficus rexburghii	7	good
	Ficus semicordata	-	-
	Litsea polyantha	5-7	fair
	Machilus gamblei	10	good
	Machilus odoratissima	10	good
	Morus spp	3-5	good
	Prunus cerasoides	7	fair
	Schima wallachii	10-15	fair
	Symplocos crataegoides	5-7	fair
2,000m and	Aesculus indica	20	-
above	Betula utilis	20	-
	Ficus nemoralis	7	good

Ficus rexburghii	7	good
Morus spp	5-7	good
Populus spp	5	-
Quercus spp	20	fair
Salix spp	3-5	good

PHILIPPINES

METHODS OF HARVESTING AND UTILIZATION OF FUELWOOD SPECIES IN PICOP

A. G. VERACION[1/]

ABSTRACT

Anticipating further increase in the price of oil after the oil crisis in 1973, Paper Industries Corporation of the Philippines (PICOP) has started shifting from the traditional use of bunker fuel oil (BFO) to biomass in the form of manufacturing and logging wood residues as alternate source of energy to generate the required power for its wood industrial complex. As result of its wood fuel utilization program, PICOP saved a total of about ₱ 205.6 million from 1977 to 1980 thru the substitution of BFO with wood fuel.

To support the energy requirements of its various processing mills (sawmill, veneer, plywood plants, pulp and paper mills), PICOP has put up four steam generating units with purely wood wastes as fuel and one steam generating unit with combined bunker oil and wood wastes as fuel.

The main sources of the fuelwood of PICOP for its energy generating units using wood are from manufacturing and processing plants such as log ends, trimmings, slabs, center cores, barks, sawdust and waste veneer; logged-over areas (selective and clearcut) such as stumps, top ends, big branches of big trees left after logging, cull logs, dead and damaged trees; and driftwood along shorelines.

Thirty-four (34) predominant species for fuelwood within the logging operational areas were identified.

The harvesting or gathering of fuelwood inside the concessions of PICOP is done under PICOP supervision by private contractors who are given the authority to retrieve or salvage logging residues.

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The contractors who are gathering logging wastes apply manpower, animal power, or machine power or combinations thereof, in bringing the logs to the roadside. All woods used for fuel purposes are reduced into uniform sizes with the use of a klockner machine which chips the wood into small pieces or bits.

The utilization of manufacturing and logging wood residues not only enhances the ecological improvement of the environment but also leads to better conservation . Wood as fuel is abundant and cheap; as an alternate source of fuel to generate energy, the direction is right and the prospect bright.

Introduction

The potential of wood as fuel for energy generation as substitute for bunker fuel oil (BFO) was given great emphasis by Paper Industries Corporation of the Philippines (PICOP) in its operation after the oil crisis in 1973. Anticipating further increases on the price of oil, PICOP has started the shifting from the traditional use of bunker fuel oil (BFO) to biomass in the form of manufacturing and logging wood residues as alternate source of energy to generate the required power for its wood industrial complex.

As a result of its wood fuel utilization program, PICOP saved about ₱33 million in 1977 thru the substitution of BFO with wood fuel; ₱37 million in 1978; and ₱47.9 million in 1979. In 1980 (last year), the savings was estimated to be about ₱87.7 million.

Steam Generating Units

To support the energy requirements of its various processing mills (sawmill, veneer, plywood plants, pulp and paper mills) PICOP has put up within its mill complex the following steam generating units:

	Boiler Unit	Rated Capacity MT/hr.	Power Generated MT/hr.	Type of Fuel Used
a.	PPG Bark Boiler 1	114	99.13 (87%)	Combined bunker oil wood waste
b.	PPG Bark Boiler 2	114	74.56 (65.4%)	Wood waste
c.	TPG Bark Boiler 1	14	12.84	Wood waste
d.	TPG Bark Boiler 2	14	12.80	Wood waste
e.	TPG Bark Boiler 3	20	13.54	Wood waste
f.	Power Boiler	182	163.60	Bunker oil
g.	Recovery Boiler	60	36.15	Bunker oil

Fuelwood Demand and Supply

The projected demand and supply of wood waste for energy generation of the different steam generating units of PICOP for the next 3 years has been estimated to be as follows:

Year	Demand (cu.m.)	Supply	Types of wood wastes
1981	648,000	407,000	Plant wastes (A)
		61,000	Outlogs, hauling wastes (B)
		180,000	Logging wastes (C)
1982	620,000	395,000	(A)
		53,000	(B)
		172,000	(C)
1983	648,000	395,000	(A)
		53,000	(B)
		200,000	(C)

Sources of Fuelwood

Essentially, the main sources of fuelwood of PICOP for its energy generating units using wood are as follows:

a. Manufacturing and processing plants - These are log ends, trimmings, slabs, center cores, barks, sawdust and waste veneer which come in the process of manufacture of logs either into lumber, veneer, and plywood. Manufacturing wastes will yield about 50% of the wood fuel requirements of the steam generating units.

b. Logged-over areas (selective and clearcut) - These are the logging wastes (stumps, top ends, big branches of big trees left after logging), cull logs, dead and damaged trees as a consequence of logging operations and other miscellaneous wood species of no known uses today, or otherwise known as logging residues.

c. Driftwood along shorelines.

Species Identified for Fuelwood

Predominant species identified for fuelwood with their corresponding specific gravity within the logging operational areas are as follows:

Species	Specific Gravity
1. Dipterocarps	
a) Almon (Shorea almon Foxw.)	.289
b) Apitong (Dipterocarpus grandiflorus Blanco)	.553
c) Bagtikan (Parashorea plicata Brandis)	.402
d) Guijo (Shorea guiso Blanco)	.772
e) Kalunti (Shorea Kalunti Merr.)	.348
f) Manggasinoro (Shorea philippinensis Brandis)	.410
g) Mayapis (Shorea squamata Turcz.)	.470
h) Narig (Vatica mangachapoi Blanco)	.563
i) Palosapis (Anisoptera thurifera Blume)	.340
j) Red Lauan (Shorea negrosensis Foxw.)	.535
k) Tangile (Shorea polysperma Blanco)	.324
l) Tiaong (Shorea forma tiaong Foxw.)	.442
m) White Lauan (Pentacme contorta Merr.)	.372
n) Yakal (Shorea astylosa Foxw.)	.748
2. Non-dipterocarps	
a) Alupag (Euphoria didyma Blanco)	.769
b) Bansalagin (Mimusops parvifolia R. Br.)	.578
c) Bok-bok (Xanthophyllum excelsum Blume)	.626
d) Bitanghol (Calophyllum blancoi PL.)	.456
e) Dangula (Teijsmanniodendron ahernianum Merr.)	.967
f) Duguan (Myristica philippinensis Lam.)	.412
g) Kamatog (Erythrophloeum densiflorum Elm.)	.469
h) Lamog (Peanchonia spectabilis Merr.)	.579
i) Loktob (Duabanga moluccana Blume)	.402
j) Marang (Litsea perrottetii Blume)	.600
k) Makaasim (Syzygium nitidum Benth.)	.516
l) Malugai (Pometia pinnata Forst.)	.570
m) Nato (Palaquium luzoniense Vid.)	.410
n) Pagsahingin (Canarium asperum Benth.)	.454
o) Pangnan (Lithocarpus bennettii Rehd.)	.489
p) Tiga(Tristania micrantha Merr.)	.921
q) Malabayabas (Tristania decorticata Merr.)	.866
r) Margapali (Dehaasia triandra Merr.)	.509
s) Terminalia (Spp.)	.535
t) Sudiang (Ctenolophon philippinensis Hallier)	.873

HARVESTING SYSTEMS

The harvesting or gathering of fuelwood inside the concessions of PICOP is done under PICOP supervision by private contractors who are given the authority to retrieve or salvage logging residues. Present logging equipment of PICOP are so big and are not suitable to handle the small logs, thus, the need for the services of the contractors.

Retrievals or salvaging of logs are confined on log landings and cableway routes on selectively-logged areas and on clearcut areas. Wherever contractors are gathering logging wastes, they invariably apply any or combinations of the following in bringing the logs to the roadside:

a. Manpower - is used to retrieve small size logs, top ends, or big branches, the weight of which can be handled by one or two men.

For ease in carrying, the logs are first bucked into log lengths of 2.5 meters with either an ax or a power chainsaw. After determining and clearing their trailway, they then proceed in carrying the logs to the roadside. A pair can carry about 3 cubic meters in a day.

b. Animal power - for the bigger size logs, whether in flat or in more difficult terrains, animal power such as the carabao (water buffalo) are used to skid the logs to the roadside.

The logs are first bucked into manageable lengths before they are hauled. Hauling is done with the use of wooden sleds.

Considering the limitation of the carabao, it can only skid about 3 cubic meters in one day.

c. Machine power - it is used for the bigger-sized logs in the more difficult situation which cannot be handled manually or skidded by carabao.

To recover the logs, rubber-tired skidders are used such as timberjacks and clark rangers. Logs are pulled whole length to the roadside.

Skidding output is about 24 cubic meters/day.

Skidding Trails

Skidding trails used either by carabao or rubber-tired skidders follows mostly cableway or skyline routes. The idea is that cableway routes are already cleared of obstructions like stumps of trees and thus make the pulling of the logs easier.

Bucking

Logs skidded to the roadside more than 2.5 meters long are all bucked into lengths of 2.5 meters. This is to maintain length uniformity and ease of piling and loading on trucks when hauling to the millsite later on.

Piling/Sorting

The bucked logs are piled neatly along the roadside before hauling, piling as much as an equivalent of 1 to 2 truckloads in a setting. In piling, the smaller logs are separated from the bigger ones.

Landings

Abandoned logging landings or the widest section of the road are used as assortment area for the skidded fuel logs.

Loading

This is done manually in the absence of mechanical loader. Logs are placed across the width of the bed of the truck. The bigger logs are loaded first ahead of the smaller ones. To assist in loading, an improvised wooden ramp is place at the end of the truck. Here, logs are rolled and pushed upward.

A loading crew can load a truck in 3 to 4 hours with an approximate load of 14 cubic meters.

Hauling Trucks

Trucks used for hauling are either 6 or 10 wheeler light commercial trucks capable of carrying 8-12 tons weight of load.

Volume measurement

Determination of volume of the individual pieces of logs is done by weight scaling. The whole weight of the truck when fully loaded with wood and when empty are taken by a weighbridge. The difference in weight multiplied by a constant factor gives the approximate volume in cubic meters.

Utilization

All wood used for fuel purposes are reduced into uniform sizes with the use of a klockner machine which chips the wood into small pieces or bits.

Safety

The gathering of fuelwood by contractors is always done with utmost care. This is to prevent any disabling injury which may befall the worker.

PROSPECT

At every stage in the conversion of standing timber into finished wood products, bits and pieces of the wood are left behind; stumps, tops and branches in the forest; and, bark, sawdust, trimmings, and log ends from the manufacturing mills. Scattered in sawmill and plywood compounds, mill wastes constitute a nuisance and even very dangerous to the environment. Sawdust when dumped pollute the river and logging wastes left to rot in the forest invite serious pest infestation. Their utilization therefore does not only enhance the ecological improvement of the environment but their useful utilization leads to better conservation.

Wood as fuel is abundant. They are all around us; they can be grown and regenerated in an endless cycle - so long as there is soil, moisture and the heat and the light of the sun to promote growth.

Wood as fuel is cheap. Based on studies, it is estimated that to produce the same amount of steam, a cubic meter of wood waste is roughly equivalent to about 180 liters of oil considering a medium density wood with a 0.45 specific gravity at a 50% moisture content. Considering the cost of bunker fuel oil (BFO) at ₱1.00/liter, this will amount to ₱180 as the equivalent amount or cost of a cubic meter wood. Compared with a wood recovery cost of about ₱80 per cubic meter, this would mean a saving of ₱100 on a per liter basis of BFO. Wood, therefore is cheaper than BFO.

Faced with diminishing oil and gas reserves and the specter of oil price increases, the use of wood, therefore, as alternate source of fuel to generate energy is in the right direction. The prospect, therefore, is bright.

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PRODUCTION CRITERIA POSSIBLY SUITABLE FOR THE MASS SELECTION OF FUELWOOD SPECIES

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ABSTRACT

Forestry science and practice have developed a number of methods and techniques possibly appropriate for specific set of conditions for definite species or forests. The production criteria possibly suitable for mass selection of fuelwood species are:

1. Species/Site Adaptability

   - determining close correlation of silvical requirements of the "candidate" species to the site conditions obtaining in the areas.

   - trial planting of the species in the different sites intended to be planted.

   - survey of existing "specimen" tree (relics or indicator trees) in the site intended to be planted.

2. Regenerative potential

   - Natural regeneration by either natural fall of seeds or vegetative regrowth (coppice/sprouts).

     a. prolific seeder

     b. bears fruits/seeds at early age

     c. fast growing

   - Artificial regeneration

     d. availability of sufficient quantity of good seeds

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e. ease of producing planting stocks (seedling)

f. needs simple "folk" technology or unsophisticated technological requirements

g. high rates of survival

- Cultural Management

h. capability to compete with host vegetation

i. minimal cultural operations or care and maintenance required

j. resistant to pests and diseases, fire and other destructive agencies.

INTRODUCTION

In considering fuelwood species as alternative sources of energy, there are a number of very important factors to be looked into and one of these is on the aspect of production or the methods and techniques of raising the species found suitable for the purpose. Paraphrasing the stated rationale of this workshop, it is said that a "number of species which are potential sources of fuelwood and/or energy thrive in many upland and estuarine areas. They occur as shrubs or as small and medium-size trees. They grow in various types of soil, climate, topography, etc. Some have wide ranges of distribution while others thrive only in areas with distinct ecological conditions.

The species have varied silvical characteristics or ecological requirements and logically, they may require different cultural or silvicultural management. The topic assigned to me dwells on some of the production components of the whole spectrum of fuelwood technology and these are on species/site adaptability, regeneration and cultural management.

Forestry science and practice have developed a number of methods and techniques possibly appropriate for specific set of conditions for definite species or forest. It was my task to sift through available information and knowledge, select and synthesize those which I consider appropriate and suitable criteria or bases for mass selection of fuelwood species and present them for discussion in this workshop.

POSSIBLE CRITERIA/BASES FOR MASS SELECTION

1. Species/Site Adaptability

Because of the varied conditions under which fuelwood species will be raised, such as different climatic and soil conditions, etc. obtaining in different regions and places, it would be logical to choose a "universal" species capable of adapting to a wide range of conditions. Technically, the classical methods for testing species adaptability are:

a. Correlating the ecological/silvical requirements of a "candidate" species to the environmental factors obtaining in a particular locality intended to be planted. When the correlations are quite close, it is probably possible for the species to thrive in such site. This method however requires of the person doing the job some amount of technical and scientific background.

b. Trial planting of the potential species in the different sites intended for planting and observing their performance. This method, while requiring less technical knowledge and skill, takes some time before conclusive and definite selection of species is made.

c. One other possible technique for determining species adaptability, which I think is quite practical, is to conduct a survey of the range of distribution of the species. In so doing, the geographic distribution, climatic and soil conditions (past and present), altitudinal ranges, etc. under which the potential species thrives will be known. This method is however, possible only where there exists remnants (relics) of the species in the different areas surveyed. Places where the species/trees are found thriving are possible areas for establishing plantations.

2. Regenerative Potential of the Species

Regenerative potential refers to the ability of the species to regenerate itself, usually by natural means. Generally, regeneration is classified into two systems: natural and artificial regeneration systems. The former is dependent on the natural fall of the seeds and/or the development of vegetative parts (coppice or sprouts) once the trees are cut (selection, clearcutting, coppiece, etc.). The later is accomplished by the planting of seeds and/or seedlings (planting stocks) in prepared sites.

For natural regeneration systems, the candidate species must possess certain desirable characteristics, such as: a) prolific seeder and/or capable of producing or developing coppice or sprouts, b) fast-growing, and c) must bear fruits/seeds at an early age, since for fuelwood purposes, the trees are cut when still young (short economic rotation), unless the preferred method of regeneration is by coppice or vegetative growth, although this method too has some limitations, since trees' capability to develop coppice or sprouts decreases with age.

For artificial planting, the important considerations to observe are: a) availability of sufficient quantities of good seeds for planting stock production, b) ease of production of planting stocks, and c) unsophisticated technological requirements

or needs simple "folk" technology for plantation establishment with high rates of survival. These considerations are important in that people in the rural areas are generally of low technical knowledge, not capable of investing large inputs, especially if fuelwood farms are small in size and are established only for household consumption.

3. Cultural Management

The cultural operations involved after planting/establishment are occasional weeding, brushing, release cutting and possibly thinning the stand, especially during the early stages of its development. These operations increase the costs of production, so if possible the frequency of these operations are reduced to the barest minimum but consistent with the production of high quality fuelwood trees. Sometimes if site preparation was properly done, and the species are fast-growing and capable of competing/suppressing the host vegetation early in their development and with the appropriate spacing chosen, a fuelwood plantation needs perhaps only one or two tending operations before the trees are harvested.

In addition to these, the species should be able to withstand pests and diseases, including fire and other destructive agencies such as animals, etc.

Summarizing, the production criteria possibly suitable for mass selection of fuelwood species are:

1. Species/Site adaptability

- determining close correlation of silvical requirements of the "candidate" species to the site conditions obtaining in the areas.

- trial planting of the species in the different sites intended to be planted.

- survey of existing "specimen" trees (relics or indicator trees) in the site intended to be planted.

2. Regenerative potential

2.1. Natural regeneration by either natural fall of seeds or vegetative regrowth (coppice/sprouts).

- prolific seeder
- bears fruits/seeds at early age
- fast growing

2.2. Artificial regeneration

- availability of sufficient quantity of good seeds
- ease of producing planting stocks (seedlings)
- needs simple "folk" technology or unsophisticated technological requirements
- high rates of survival

3. Cultural Management

- capability to complete with host vegetation
- requires minimal cultural operations of care and maintenance
- resistant to pests and diseases, fire and other destructive agencies.

SOME PHILIPPINE TREE SPECIES COMMONLY USED FOR FUELWOOD

Common name	Scientific name	Family
I. Mangrove Species		
Api-api	Avicennia officinalis	Verbenaceae
Bakawan lalaki	Rhizophora apiculata	Rhizophoraceae
Bakawan babae	Rhisophora mucronata	"
Langarai	Bruguiera parviflora	"
Pototan	Bruguiera sexangula	"
Tangal	Ceriops tagal	"
II. Upland Species		
Acacia/Rain Tree	Samanea saman	Leguminosae
Agoho	Casuarina equisetifolia	Casuarinaceae
Akleng parang	Albizia procera	Leguminosae
Alibangbang	Pileostigma malabaricum	"
Anabiong	Treme orientalis	Ulmaceae
Arosip	Antidesma ilocanum	Euphorbiaceae
Bayok	Pterospermum niveum	Sterculiaceae
Binayuyu	Antidesma ghaesembilla	Euphorbiaceae
Ipil-ipil	Leucaena leucocephala	Leguminosae
Kakawati	Glericida sepium	"
Kariskis	Albizia lebbekoides	"
Katurai	Sesbania grandiflora	"
Lagundi	Vitex negundo	Verbenaceae

SOCIO-ECONOMIC FACTORS AND METHODS OF ASSESSMENT OR EVALUATION FOR MASS SELECTION OF FUELWOOD SPECIES

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ABSTRACT

Fuelwood situation in the Philippines was analyzed by the use of current available socio-economic data. The major consumers of fuelwood in the country are the household sector including bakeries, charcoal/firewood-using industries and the government rural electrification program. The fuelwood consumption by the household sector for 1980 was estimated at 31.02 million cu. m; by the tobacco industry the forecasted demands are .63 million cu. m; .72 million cu. m. and .89 million cu. m. for the years 1982, 1985 and 1980 respectively; and for the government rural electrification program the projected annual fuelwood demand after 1986 was estimated at 3.08 million tons.

The author emphasized that socio-economic parameters, such as family income, tastes and preferences, cultural values, product value, resource availability and marketability of the fuelwood species, are very important decision variables not to be ignored whenever mass selection of fuelwood species is under consideration. The economic criteria recommended which can be used for the assessment in the mass selection of fuelwood species are discounted present net worth, rate of return in investment and benefit-cost ratio analysis.

INTRODUCTION

Fuelwood for centuries up to the present time has been the source of energy of mankind particularly in the rural areas of the developing countries where it becomes the principal source of fuel for cooking and at times for maintaining warmth in the home. According to the FAO (as cited by Malmgren, 1980) fuelwood still accounts for nearly one-half for all wood used in the world. In Asia, fuelwood represents two-thirds of the region's wood consumption, while nearly nine-tenths of all wood used in Africa and Latin America is fuelwood.

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The world's consumption of fuelwood was projected by Burgess (1978, as cited by Pollisco and Dalmacio, 1979) to be around 970 million tons by 1980. About half of this, or some 450 million tons will be consumed by people in Asia and the Pacific countries, about 220 million tons by Africa, 180 million tons by Latin America, and the remainder by the rest of the world. Arnold (1979) report on several survey of wood consumption indicate that in various countries in Africa and Southeast Asia, nearly all wood fuel are used for domestic purposes and it is the major fuel for nearly all rural households and about 90 percent of urban households use it in the form of charcoal rather than firewood.

In the Philippines, where massive rural electrification program is being implemented since 1969, it was estimated that only some 3.7 million of a possible 22 million rural population were served by electricity until 1977 (Pollisco and Dalmacio, 1979). In 1980, this number of rural population was preliminarily estimated by the National Census and Statistics Office at 30.4 million. To these people there is no doubt that their main energy source is fuelwood, either as firewood or charcoal.

FUELWOOD SITUATION IN THE PHILIPPINES

Fuelwood in the Philippines is utilized by the households including bakeries, charcoal/firewood using industries and the government rural electrification program. Even the wood-based industries due to the continuous rise in price of fossil oil as a conventional source of energy some of them have shifted to the use of wood residues from sawmilling operation to produce the steam needed in heating lumber, plywood and veneer during the kiln drying process.

Statistics on the current supply and demand of fuelwood is very much insufficient. Projection figures are mostly used on few sample gathered data in several places and in many instances data on consumption and prices found in publications by various authors do not reveal the same figure. One major cause of lack of sufficient and reliable information is that the fuelwood production and distribution system in most areas are not organized and widely dispersed in small scale except in cases like the tobacco growing region of the country where the production of flue cured leaf of virginia tobacco is concentrated in adjacent areas (e.g. Abra, Ilocos Sur, Ilocos Norte and La Union) in the Ilocos Region which is in the northwestern portion in the island of Luzon. In this region, where fuelwood is a basic commodity being used in commercial quantity in the flue curing of tobacco leaf, the quantification of price and the volume consumption of fuelwood may be derived at without great difficulty.

FUELWOOD DEMAND BY THE HOUSEHOLD SECTOR

In 1970, the National Census and Statistics Office (NCSO) included in its population census a nationwide survey on the number of households using different types of fuel for cooking (Pls. see table 1). The survey reveals that in that year, the total number of households in the country was 6.16 million. Out of these households, 4.88 million or on the average 79 percent use wood as their cooking fuel. The data also show that 92 percent and 49 percent of the rural and urban households, respectively, use wood as fuel for cooking. On the other hand, the number of households that use charcoal for fuel in cooking is only a very insignificant of .4 percent of less than one-half percent of the total households in the Philippines. In terms of urban/rural breakdown, it shows that in charcoal use for cooking urban household sector got a bigger share of 0.78 percent while the rural sector got 0.21 percent. If we use the average figure of 5 cubic meters of fuelwood consumption per household per year (Forestry Technical Services PTY, Ltd., 1978, Hyman, 1981), then the total fuelwood consumption in the Philippines in 1970 by the household sector only consuming fuelwood was about 24.42 million cubic meters. Using the above data from 1970 census and applying conservatively the number or urban/rural household using fuelwood for cooking in that year to the 1980 population estimate, the fuelwood consumption by the household sector can be estimated at 31.02 million cubic meters. This represents an increase of 31 percent over a 10-year period or an annual average increase of 2.7 percent. (Revilla, 1979) in his estimate projected that if 70 percent of all households in the country will use wood for cooking by 1985, the fuelwood requirement would be 47.1 million cubic meters while for bakeries is one million cubic meters.

FUELWOOD DEMAND BY THE TOBACCO INDUSTRY

In 1979, the Philippine Government through its Ministry of Natural Resources requested the services of the Forestry Technical Services Pty. Ltd. of Canberra (Australia) to conduct an intensive study on the fuelwood requirement of the tobacco industry in Ilocos region. Its findings reveal that the industry for its flue curing activity consumes an average fuelwood of 16.05 cu. m. in stacked

volume per ton of cured leaf. Assuming an average solid volume of 0.63 cu . m. per 1.0 cu. m. stacked, the average fuelwood consumption per ton is 10.11 cu. m. The same study revealed that in 1976, the region produced 47,000 tons of flue cured leaf tobacco, hence the fuelwood consumption was 475,170 cu.m. Based on this assumption, the study projected a series of forecast demand for fuelwood by the tobacco industry (Pls. see Table 2). It claims that the industry from 1980 to 1990 is expected to consume fuelwood in solid volume of 580,000 to 890,000 cu. meters.

In addition to the flue curing of tobacco leaf in Ilocos Region, the households and bakeries fuelwood demand for domestic cooking was also estimated by the Canberra Consultant Group. Its report indicated that in the Region where there are 216,850 households (1975 estimate), their annual fuelwood requirement was 1.15 million cu. m. with an assumption that each household per year consumes 5.28 cu. m. of fuelwood.

FUELWOOD DEMAND BY THE RURAL ELECTRIFICATION PROGRAM

The current thrust of the government to provide low cost electricity to the rural households has intensified the demand for fuelwood to fire the dendrothermal power plants that are being put up in the various regions in the country. The National Electrification Administration (NEA) in its 1982-1987 rural electrification program, plans to construct 3-megawatt power plants in 72 sites all over the country. Initially in 1982, it would need 55,000 tons of fuelwood and at the end of 1987 and the year thereafter, when all the power plants shall have been fully operational, the total annual requirement would be 3.08 million tons of fuelwood and in terms of area requirements for plantation it would need 56,250 hectares (please see table 3).

SUPPLY OF FUELWOOD IN THE PHILIPPINES

After estimating the fuelwood demand in the country, the next question is on the supply side. With the existing sources of fuelwood mostly originated from the small scattered private lands, the present supply of fuelwood will definitely cannot sustain the demand for fuelwood in the years to come. At present, most of the available fuelwood are gathered from private farm lands or taken from the areas

within the public forests where fuelwood collection is allowed by private individuals with minimal fee. In 1979, the Bureau of Forest Development reported that the quantity of fuelwood which was legally gathered from the public forest land was 198,058 cu. m. consisting of upland and mangrove species. Charcoal production for the same year according to the same source was 42,368 cu. meters.

In order to meet the future fuelwood supply requirement, the government and the private sectors had started several forestry development programs such as dendrothermal plantation, industrial tree plantation, communal tree farms and small farmholders tree farming projects. With this effort and the assistance of the local and foreign financing institutions, it is expected that fuelwood production in this country in the years ahead will significantly increase to sustain the fuelwood requirement of the various sectors especially the consuming households. In terms of area requirement, Revilla (1979), projected that in order to meet the fuelwood demand in the country, the Philippines by the year 1985 should have planted 1.04 million hectares and by the year 2000 about 1.88 million hectares of fuelwood plantations should have been planted.

PRICES OF FUELWOOD IN THE PHILIPPINES

One major factor in the analysis of the demand/supply situation for fuelwood or any commodity is its price. It is an indicator whether such product or resource has become scarce in the market. In the Philippines, according to the Ministry of Energy (as cited by Hyman, 1980, p. 17), market prices of fuelwood directly apply to the 32.99 percent of firewood supply and 65.29 percent of charcoal supply in 1977 that was purchased. There are several studies which reported the prices of fuelwood in the country but there has been difficulty to arrive at a realistic comparison among prices in different regions due to the various units of measurements used in the valuation of fuelwood price and per capita consumption. In 1980 the Philippine Ministry of Energy estimated that the average price of firewood was ₱0.63 per kg. in urban areas and ₱0.67 per kg. in rural areas (Ibid).

The on-going study on marketing and price structure on fuelwood by the Forest Research Institute (FORI) under PCARR-IBRD funding, initial finding reveals that there is a great variation in price of firewood and charcoal in selected provinces. Variation in price is affected by the size of fuelwood bundle including the mode of purchase either pick-up, delivered, retail or wholesale, and to a certain extent the type of season prevailing in the area (e.g., dry or rainy season) and the type of marketing outlets.

SOCIO-ECONOMIC FACTORS RELATED TO FUELWOOD SELECTION AND OR CONSUMPTION

With the rapid advance of technology and the increasing price of fossil oil, what will happen to the fuelwood as a source of energy? The answers could vary but based on particular setting fuelwood will continue to be in demand as long as the consumers would prefer it as a cheap source of energy for cooking and other domestic purposes. However, preference in use is dictated by economic, social and cultural background of an individual or locality. Millions of rural population in the developing countries due to low family income cannot afford the price of expensive sources of energy like electricity, kerosene and liquified gas. Regional differences in people's tastes and preferences and cultural values also play an important role in fuelwood selection and or consumption. For instance, some people prefer charcoal from specific wood species that can add flavor or taste to the cooked food, while others would prefer particular parts of the trees for use as fuelwood. For example, in the Republic of Korea a recent survey on the fuelwood use in the villages reports that 47.1 percent of the household energy demand was met by using twigs, and only 11.9 percent was consumed in the form of cut firewood (wood, et. al., 1980, p. 27). This illustrates the distinct preference for one part of a tree over the other. Local preferences, however, are usually based on the burning qualities of the species, availability and traditional practices relating to the indigenous fuelwood species found within the locality.

ASSESSMENT OF CRITERIA FOR SELECTION OF FUELWOOD SPECIES

As mentioned earlier, the selection and or consumption of fuelwood species is governed by several socio-economic factors such as family income, product value, resource availability and tastes and preferences. Since these indicators are crucial in the mass selection of fuelwood species as a source of energy, an intensive socio-economic survey of rural and urban households including industrial communities as to their species preferences should be conducted. The result of such study could be very valuable input for policy guidelines on what fuelwood species should be recommended for mass production that would suit the tastes and preferences of both the producers and the consumers. The study should also include the range of income that the consumers of fuelwood possess. With these data, we can easily determine the amount of fuelwood required by the various consuming sectors.

Assessment of marketability and potential economic returns from the fuelwood species through its derived product value should be a primary consideration when selecting any species especially when one is embarking on a commercial scale production of fuelwood species. Criteria for economic assessment are available such as the discounted present net worth, rate of return to investment and benefit-cost ratio analysis. If in all cases, the values of the economic criteria

meet the standard feasibility, then using them in the mass selection of fuelwood species should be an important consideration in any investment decision.

RECOMMENDATION AND CONCLUSION

Inasmuch as the social and economic setting of a given locality changes over time, an intensive periodic assessment/evaluation of the key variables affecting social and economic parameters in the selection and or consumption of fuelwood species should be a priority area for investigation. Perhaps every 5 or 10 years assessment whatever it would suit a given country should be undertaken. Results of such assessment should be made conveniently available to the regions/countries where it can be useful in decision-making related to the mass selection of fuelwood species.

Table IA. Number of Households using fuelwood and other types of fuel in the Philippines (1970)

Types of Cooking

Fuel	Urban	% Share	Rural	% Share	No. of Phil. Households	% Share
Wood	929,080	49.31	3,955,789	92.45	4,884,869	79.26
Charcoal	14,714	0.78	8,857	0.21	23,571	0.38
Electricity	155,590	8.26	14,395	0.34	169,985	2.76
Kerosene (gas)	490,237	26.02	182,029	4.25	672,266	10.91
Gas (oil)	283,911	15.07	68,219	1.59	352,130	5.70
Others	10,759	0.57	49,548	1.16	60,307	.99
Total	1,884,291	100.00%	4,278,837	100%	6,163,128	100.00

Source: 1970 Philippine Census of Population and Housing NCSO Manila (summary), from Table 9.

Table IB: Potential households using fuelwood and other types of cooking fuels in the Philippines (1980)

Types of Cooking

Fuel	Urban	% Share	Rural	% Share	No. of Phil. House-holds	% Share
Wood	1,444,867	49.31	4,759,764	92.45	6,204,631	79.26
Charcoal	22,855	0.78	10,812	0.21	33,667	0.38
Electricity	242,032	8.26	17,505	0.34	259,537	2.76
Kerosene	762,430	26.02	218,810	4.25	981.240	10.91
Gas	441,576	15.07	81,861	1.59	523,437	5.70
Others	16,702	.57	59,722	1.16	76,424	.99
Total	2,930,462	100.00	5,148,474	100.00	8,078,936	100.00

Note:

The figures in Table IB are derived from Table IA with an assumption of constant Urban/Rural share of various types of cooking fuel using the preliminary estimate of 1980 population made by the NCSO.

Table 2. Forecast demand for fuelwood by the Tobacco Industry in Ilocos Region: Solid Volume in million cu. m.

	YEAR			
	1980	1982	1985	1990
Barn consumption in cu. m. solid Volume assuming 10.1 cu. m. per ton of cured tobacco leaf	0.58	0.63	0.72	0.89

Source: Proposed for a fuelwood development project: Ilocos Region, Philippine Forestry Technical Services Pty. Ltd, 1978, p. 20.

Table 3. Potential demand for fuelwood by dendrothermal power plant for the year 1982-1987

Year	Power Plant Capacity	Fuelwood Requirement		Area Requirement
		Per day (in tons)	Per year (in tons)	Hectares
1982	3.0 MW	150	54,750	1,000
1983	32.0 MW	1595	582,175	10,633
1984	25.0 MW	1232	449,862	8,217
1985	33.0 MW	1650	602,250	11,000
1986	37.0 MW	1860	678,900	12,400
1987	39.0 MW	1950	711,750	13,000
TOTAL	169.0 MW	8437	3,079,687	56,250

Source: Agro-forestry Division
Dendrothermal Project Office, NEA (Feb. 1980).

Table 4. Prices of fuelwood in selected places in the Philippines (1980)

A. Firewood

Place	Buying		Selling			
			Pick-up		Delivered	
	Pick-up	Delivered	Wholesale	Retail	Wholesale	Retail
Laguna 1/	195/cu.m.	249/cu.m.	247/cu.m.	319/cu.m.	309/cu.m.	339/cu.m.
Davao City				40/cu.m.	50.50/cu.m.	
Davao del Sur				40/cu.m.		
La Carlota City 2/						
(a) farmers	76/cu.m.			88/cu.m.		
(b) middlemen		40/cu.m.	45/cu.m.		170/ton	
San Carlos City	30/cu.m.*	40/cu.m.				
Bacolod City 3/						
(a) farmers		19/cu.m.		20/cu.m.		
(b) middlemen	a) 45/cu.m.			60/cu.m.		
	b) 80/ton			195/ton		
Victoria, Negros Occidental		190/ton				
Bago City, Negros Occidental		170/ton				
Talisay, Negros Occidental		190/ton				

1/ Size of bundle is 6 inches dia. x 18 inches length (15.24 cm. dia. x 45.72 cm. length)

2/ Size of bundle is 8 inches dia. x 14 inches length (20.32 cm. dia. x 60.96 cm. length)

3/ Size of bundle is 2 inches dia. x 12 inches length (5.08 cm. dia x 30.48 cm. length)

* Buyer shoulders the cutting and hauling of ipil-ipil fuelwood.

Source: PCARR-IBRD Sub Project No. 4 Novero et, at., 1981 (Unpublished)

B. Charcoal

	Dry Season				Rainy Season			
	Buying		Selling		Buying		Selling	
Place	Pick-up	Delivered	Pick-up	Delivered	Pick-up	Delivered	Pick-up	Delivered
Batangas	488/ton	688/ton	689/ton	888/ton	666/ton	866/ton	800/ton	1,000/ton
Bacolod								
(a) market		644/ton					711/ton	
(b) dealers					555/ton			
Iligan City		115/ton						

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TIMBER MANAGEMENT AND HARVESTING CRITERIA FOR MASS SELECTION OF FUELWOOD SPECIES

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ABSTRACT

This paper covers timber management and harvesting aspects of pure stands, which may be considered in the mass selection of fuelwood species. Other papers in this workshop are expected to cover other aspects or other cases, e. g. silviculture, nixed stands, and the like.

In timber management, the determination of growth and yield and economic rotation for pure stands of fuelwood species would be the primary aspects to consider in the mass selection of fuelwood species. These aspects together would encompass the overall management considerations such as the various site factors, stand factors, and management regime.

In timber harvesting, wood size and form would be the important considerations in determining the cutting and transport techniques, hence, the harvesting criteria for the mass selection of fuelwood species.

INTRODUCTION

Today, as it ever was, fuelwood is a very important energy source, especially in developing countries. With the increasing cost of fossil fuels, fuelwood will continue to be the poor man's oil. Even for the entire world, wood is the fourth largest energy source, after petroleum, coal and natural gas (FAO, 1977).

Realizing more than ever the importance of this energy source, we are now convened to contribute to studies on improving fuelwood production and utilization efficiencies on a mass basis. The heterogeneity and diversity in all aspects of fuelwood production and utilization, in species, growing sites, growing characteristics, culture, harvesting techniques, uses, wood properties, etc., require that we take steps to fix the various criteria for their mass selection.

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In this paper, fuelwood managed in pure stands will be the main concern. More specifically, this paper covers timber management and harvesting aspects of pure stands, which may be considered in the mass selection of fuelwood species. Other papers in this workshop are expected to cover other aspects or other cases, e. g. silviculture, mixed stands, etc.

2.0 Management Aspects of Fuelwood Plantations

2.1 Objectives of Timber Management

A management plan for the mass growing of fuelwood in pure stands would encompass such aspects as infrastructure development (e. g. roads, bridges, nurseries), nursery and plantation establishment practices, cultural management, protection from fires and infestations, growth and yield monitoring, harvest rotation, and harvesting techniques. Upon establishment of the fuelwood plantation, timber management, as a discipline, would be concerned with growing the fuelwood stands to maturity such that expected yields and benefits are fully attained. Thus, growth and yield levels would have to be monitored and compared to expected values for the given combination of site conditions, stand conditions, and cultural management regimes. Management alternatives should then be considered if possible to correct or narrow down variances between expected and actual yield. Otherwise, the harvest at the end of the rotation would fall short of expectations with adverse implications on sustained yield or product commitments.

Thus, this author believes that growth and yield would be a foremost timber management criteria in the mass selection of fuelwood species. Growth and yield determination for various fuelwood species in various combinations of site, stand, and management conditions, itself, should be a main concern for operators, planners, and growers of fuelwood.

2.2 Basic Concepts of Growth and Yield

Before we touch on stand growth and yield determination, a brief review of the basic concepts of growth and yield would be in order. In forestry, yield is defined as the volume or amount of forest product, however, measured, that may be present in a specified stand at a given time, or attainable from it over a period of time without reference to whether or not it is actually harvested (Davis, 1966). The yield of a forest stand is commonly expressed in terms of volume per unit area.

Yield and growth are closely related. The growth of a forest stand is the amount of increases in volume over a given period of time. Conversely, yield can be defined as the accumulation of growth over time. Thus information on either yield or growth will specify the other.

2.3 Factors Affecting Growth and Yield of a Forest Stand

Growth, or alternatively yield, of a forest stand is affected by such factors as species composition, stand age, site quality, stand density and management activities. Thus for pure stands, yield at a given age will vary at different sites and/or different stand densities.

The species composition of a stand greatly influences the yield that can be expected from such stand. In this paper, however, we deal only with pure stands or stands consisting of only one species.

Stand age greatly affects height and volume growth and is a very important determinant in growth and yield prediction. In even-aged stands, age determination poses no problem assuming that the plantation manager or operator keeps complete records of planting dates of recently-established stands or cutting dates of mature stands. Stand age may therefore be reckoned from the date of planting in the case of new stands or date of cutting in the case of coppiced stands or stand which come out after logging of old stands.

Site quality is a manifestation of the climatic, soil, physical, and biotic components of the acosystem that support plant growth. Site quality varies with locality and time since site conditions change as influenced by natural forces or man's activities. In practice, evaluating site quality by measuring or evaluating the site factors is rather difficult. Thus indirect measures that integrate the influence of site factors on stand growth are commonly employed.

One such measure of site quality is stand height of the given species. This measure is based on the findings that stand height is strongly correlated with site quality, but less influenced by stand density, on a species-to-species basis. Stand height as a measure of site quality is measured by taking the mean total height of the dominant and co-dominant trees in the stand. A site index is then determined by reckoning stand height from a base age. This site Index, as a measure of site quality, is applicable only to the given species. It is possible that a given site would give a high site index for one species and a low site index for another species. But even in theory, site quality influences plant growth of different species differently. Growth of giant ipil-ipil for instance, has been found to be stunted in acidic soils, whereas fast rate of growth has been observed in non-acidic soils. On the other hand, other species such as Mollucan sau grow faster than giant ipil-ipil in acidic soils.

Stand density, as a determinant of stand growth or yield expresses the influence of tree competition for inputs to growth such as sunlight, moisture, and nutrients. Stand density can be expressed as number of trees, basal area, volume, spacing, or any other quantitative criteria on a per unit area basis.

Finally, management activities affect stand growth since they affect site quality or stand density. Thus, for a given species, age, initial site quality, and initial stand density, stand growth would be expected to be greater, for example, when the management regime calls for the application of fertilizer and weeding during the early growing stages of the stand and followed later by thinning (assuming these are done properly) than when no management operations are done.

2.4 Growth and Yield Determination

2.4.1 Measures of Growth Factors

In our growth and yield studies, we normally adopt the following measures for factors influencing growth:

a) Stand Age

Stand age, A is measured in years elapsed from planting or establishment of the stand.

b) Site Quality

Site quality is represented by site index S, which is measured from the mean total height, H, in meters of a group of dominant and co-dominant trees (at least 5) of given age. From the resulting height-age relation is derived the site index function, defined as stand height at a given base age.

c) Stand Density

Stand density, D, is measured as basal area in sq. m. per hectare. When expressed as spacing, P, it is measured as the product of spacing; e.g., a spacing of 2m by 2 m. gives a P-value of 4.

d) Management Regime

Management regime is not explicitly expressed. However, it is understood that the results obtained from statistical analysis are applicable specifically to situations where the management regime is similar to that applied on the data set.

2.4.2 The Data Set and Data Analysis

The data set used for deriving the results given in this paper were taken from temporary plots using the Bitterlich method of point-sampling. Thus the data set can be considered "abstract growth series data" as opposed to "real growth series data" which are taken from a complete chronological record of the stand from establishment onwards. The latter kind of data, while considered to be ideal source of information, can only be had through the accumulation of records over a long period of time. Data analysis consists mainly of regression-fitting by ordinary least squares.

2.5 Yield Prediction Equations for Selected Fast-Growing Species

A few results on growth and yield determination are included in this paper. The species given were selected primarily for their relatively fast growth and not necessary for their high calorific value.

2.5.1 Giant ipil-ipil (Leucaena leucocephala)

From data gathered from 62 temporary plots located in Canlubang and other places over the country (Ilocos, Batangas, Lanao del Norte, Misamis Oriental, Agusan, and Davao) the following equations were derived:

a) Tree-volume equation

$$\log V = -4.230 + 1.978 \log D + 0.899 \log H_t;\ R^2 = 0.99,\ n = 84$$

where: V = tree volume in cu. m.

D = tree diameter at breast height in cm.

H_t = tree merchantable height in m.

b) Site-index guide equation

$$\log H = 0.781 + 0.469 \log A;\ R^2 = 0.69,\ n = 62$$

or, using base age of 5 years the equation becomes:

$$\log H = \log S + 0.469 \log A - 0.328$$

or, $\log S = 0.328 + \log H - 0.469 \log A$

where: S = site index in meters based at age of 5 years

H = mean total height of dominant and co-dominant trees in m.

A = age in years

c) Yield-prediction equation

$$\log Y = 1.588 - 2.797/A - 0.087\ S/A + 0.916/AP + 0.121S - 0.031\ S/P$$

$$R^2 = 0.79,\ n = 62$$

where Y = yield in cu. m. per ha. of 5-cm. and bigger materials

P = planting spacing in sq. m., e.g. 1 m x 2m gives P = 2

S, A as before

Table 1 in the appendix gives the site index, S, as a function of H and A, while Tables 2, 3, and 4 gives the yeild, Y, as a function of S and A spacing of 1m x 1m, 1m x 2m, and 2m x 2m, respectively.

d) Stand growth

Values for stand growth can be calculated by subtrating successive yield values, that is:

$$G_i = Y_i - Y_{i-1}$$

where: G_i = stand growth for year i-1 to i

Y_i, Y_{i-1} = stand yield for years i and i-1, respectively

2.5.2 Bagras (Eucalyptus deglupta)

a) Tree-volume equation

$$\text{Log } V = 0.030 + 2.049 \log D + 0.739 \log H_t;$$

$$R^2 = 0.99,\ n = 143$$

where: V is measured up to 10 cm. diameter outside bark

b) Site-index guide equation

$$H = -18.177 + 50.473 \log A,\ R^2 = 0.94,\ n = 135$$

or $S = H + 50.473 (\log \text{Bage} - \log A)$

where: S = site index in meters at Bage = 6 years

c) Yield-prediction equation

$$\log (Y + 1) = 3.538 - 14.021/A + 0.231\ S/A;\ R^2 = 0.93,\ n = 135$$

For lack of space, the site-index guide table and yield table for bagras and other species will not be given here. However, these tables may be calculated from their respective equations. For bagras, the applicable ranges of values of the independent variables are as follows:

A = 3 to 12

S = 16 to 26

d) Stand growth

Values for stand growth can likewise be calculated from the yield values.

2.5.3 Albizia or Mollucan sau (Albizia falcataria)

a) Tree-volume equation

$$\log V = -3.971 + 1.933 \log D + 0.807 \log H_t;$$
$$R^2 = 0.97, \quad n = 320$$

where: V is measured up to 10 cm. diameter inside bark

b) Site-index guide equation

$$\text{Log } S = -0.192 + \log H + 1 + 0.963/A^{0.7}, \quad n = 310$$

where: S = site index in meters at base age of 10 years

c) Yield-prediction equation

$$\log Y = 3.213 - 1.619/A - 0.205 \log P - 16.237/S;$$
$$R^2 = .69, \quad n = 310$$

The applicable ranges of values of the independent variables are as follows:

A = 2 to 16

S = 16 to 44

P = 2 x 3, 3 x 3, 4 x 4, 6 x 6

2.5.4 Gubas

a) Tree-volume equation

$$\log V = -3.923 + 2.057 \log D + 0.570 \log H_t; \quad R^2 = 0.94, \quad n = 215$$

where: V is measured up to 10 cm. diameter inside bark

b) Site-index guide equation

$$\log H = 0.693 + 0.594 \log A; \quad R^2 = 0.87, \quad n = 166$$

$$\text{or } \log S = 0.699 - 0.594 \log A + \log H$$

where: S = site index in meters at base age of 15 years

c) Yield-prediction equation

$$\log (Y + 1) = -11.158 + 9.488 \log S - 4.227 \log A \log S - 1.014 (\log S)^2 + 7.654 \log A; \; R^2 = 0.90, \; n = 166$$

The applicable ranges of values of the independent variables are as follows:

A = 1 to 27

S = 14 to 32

2.5.5 Yemane

a) Site-index guide equation

$\log H = 1.475 - 0.921/A; \; R^2 = 0.73, \; n = 147$

or $\log S = -0.061 + \log H + 0.921/A$

where: S = site index in meters at base age of 15 years

b) Yield-prediction equation for total pulp timber

$$\log (Y + 1) = 5.777 - 5.105/\log S + 0.885 (\log P \log S) - 0.615 (\log P \log A)$$

$R^2 = 0.92, \; n = 147$

c) Yield-prediction equation for sawtimber

$$\log (Y + 1) = 3.072 + 3.104/\log A - 6.299 (\log S \log A)$$

$R^2 = 0.73, \; n = 147$

The applicable ranges of values of the independent variables are as follows:

A = 3 to 25

S = 18 to 36

2.6 Economic Rotation and Spacing

In determining the economic rotation (harvest age) of a fuelwood plantation, a number of objective-function or goal-attainment criteria exists. For example, if the fuel fuelwood plantation is established to provide fuel to a dendrothermal plant or to a village, meeting adequately the fuelwood requirement of the plant or village would be suitable goal. In many cases, however, fuelwood production is a business activity with the fundamental objective of maximizing profit. Thus, the scheduling and intensity of cultural operations and the timing of harvest would be directed to the attainment of maximum yield or monetary return.

From the economic standpoint, therefore, given a series of cash outlays and proceeds, the harvest age which maximizes net return is considered the age of financial maturity or economic rotation of the stand. Here, the proceeds would include other products from the plantation such as fodder, food, etc. There are several financial maturity models employed in forestry. These can be categorized into three broad classes, namely: the zero-interest models, the net present worth models, and the internal rate of return models. In all these models, the behavior of growth and yield of the stand over time would heavily influence the resulting economic rotation.

Spacing of trees in a stand is another factor that is within the control of the operator or grower. Spacing, of course, interacts with other determinants like site quality, other stand factors, and cultural management. Like economic rotation, the optimum spacing of trees in a stand may be determined on the basis of economic criteria such as net present worth.

2.7 Timber Management Criteria for Mass Selection of Fuelwood Species

The establishment of criteria for the mass selection of fuelwood species from the standpoint of timber management would be a difficult proposition if we consider a whole diverse set of considerations. These would include locational factors such as elevation, soil type, and fertility, topography, slope aspect and climate; stand factors such as species composition, inherent size or growth potential of the species, and type of regeneration; and the management regime. There is a need therefore to select a few measures that would encompass this broad set of consideration.

The factors which affect stand growth and yield presented in this paper would be examples of such measures. The site index, as a single measure, in particular, would already give some indications on the growth or yield potential of a given species under pure or monoculture condition on a site of given elevation, soil type and fertility, topography, slope aspect, or climate. Combined with such other measures as stand age and stand density (e.g. measured by spacing), we could then evaluate the performance of the given species under a set of cultural operations. The growth or yield performance of potential species on the given site, when combined further with other criteria (e.g. use-related criteria like calorific value and economic criteria) would then provide a basis for species selection for fuelwood production.

3.0 Harvesting Aspects of Fuelwood Plantations

3.1 Objectives of Timber Harvesting

Timber or wood harvesting transforms the fuelwood from its standing form to one suitable for transport and brings the fuelwood to the end-user. As in harvesting of other forms of timber like sawlogs or pulpwood, the goal of fuelwood harvesting is to minimize the total cost involved in cutting, transport, and support operations such as planning and road building.

However, the desired characteristics for fuelwood differ from those of sawlogs or pulpwood. Wood properties like color, hardness, grain, and knots are not important for fuelwood. Rather, fuelwood users are more concerned with volume of the combustible matter and, of course, heating value and other related properties. Thus, the minimum-cost harvesting technique for fuelwood could be different from that for larger-sized timber.

3.2 Wood Size and Fuelwood Production

There is a logical tendency to plant trees for fuelwood at very close spacing. The resulting high density would yield high volume at a short rotation. The wood sizes will also be relatively small and this will be a distinct advantage since fuelwood will be easier to harvest even with hand tools and less splitting will be required. The use of hand tools, in turn, being labor-intensive, will promote more employment in the rural areas where fuelwood is grown. In addition, the low level of mechanization will mean less consumption of fossil fuels used in both mechanized cutting and transport equipment.

3.3 Harvesting Methods for Small-sized Timber

For small-sized timber like fuelwood, the harvesting technique would vary considerably from those used in logging operations.

3.3.1 Felling, Debranching, and Crosscutting

Hand tools, like knives and axes will be suitable for felling, debranching, and crosscutting of fuelwood. Power chainsaws will improve productivity per man, but light chainsaws of small horsepower will be more convenient and productive than the heavier (10 hp) kind.

3.3.2 Short-distance Transport

Manual skidding and animal skidding using water buffaloes, cattle, or horses will be more suitable than mechanized skidding using bulldozers and skidders or cable yarding. Mechanized skidding using a chainsaw-engine-powered winch will also be suitable for fuelwood. Skidding distance will be considerably shortened if skidding is done towards loading stations at ridge tops and side hills, and subsequent transport to the truckload in the valley is done by ordinary wire cableway.

3.3.3 Long-distance Transport

In addition to the ordinary wire cableway, as the first leg of the long-distance transport operation, the lasso cableway is also suitable for fuelwood. Subsequent hauling will not require big logging trucks. Stake trucks will be suitable.

3.4 Harvesting Criteria for Mass Selection of Fuelwood Species

The production technology, production resources utilization (e.g. manpower, machines), and production economics for fuelwood vary somewhat from the usual due to the small size and different form that fuelwood takes. Even in the developing countries, mechanization is quite heavy in the harvesting of large-sized timber such as sawlogs and pulpwood, including large-sized fuelwood. The establishment of short-rotation, fast-growing, pure stands of fuelwood affords the use of more labor-intensive harvesting technologies.

Size and form, therefore, are two main determinants of harvesting techniques and their corresponding man/machine utilization and economics. Hence, size and form would be two criteria for the mass selection of fuelwood species.

4.0 Concluding Remarks

This paper covered some aspects of timber management and harvesting of pure stands of fuelwood, which may be considered in the mass selection of fuelwood species. In timber management, growth and yield would be the basic considerations which would encompass the other considerations like the site factors, stand factors, and management regime, as well as relate to management imperatives including rotation, spacing, and cultural operations. In timber harvesting, wood size and form would be the basic considerations

in determining cutting and transport techniques.

It should be clear, however, that these considerations would not be the sole or total criteria for the mass selection of fuelwood species. The entire process of selecting the most appropriate fuelwood species for a given site or a given goal would have to follow sequential decision-making steps, taking into account the ecological silvicultural, socio-economic, use and other considerations or criteria for selection.

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Table 1. Site Index Guide Table for Giant Ipil-ipil.

Age (years)	Site Index, in meters, based at age 5 years													
	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	3.3	3.7	4.2	4.7	5.1	5.6	6.1	6.6	7.0	7.5	8.0	8.5	8.9	9.4
2	4.5	5.2	5.8	6.5	7.1	7.8	8.5	9.1	9.8	10.4	11.1	11.7	12.4	13.0
3	5.5	6.3	7.1	7.9	8.6	9.4	10.2	11.0	11.8	12.6	13.4	14.2	14.9	15.7
4	6.3	7.2	8.1	9.0	9.9	10.8	11.7	12.6	13.5	14.4	15.3	16.2	17.1	18.0
5	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6	7.6	8.7	9.8	10.8	12.0	13.1	14.1	15.2	16.3	17.4	18.5	19.6	20.7	21.8
7	8.2	9.4	10.5	11.7	12.9	14.0	15.2	16.4	17.6	18.7	19.9	21.1	22.2	23.4
8	8.7	10.0	11.2	12.5	13.7	14.9	16.2	17.4	18.7	19.9	21.2	22.4	23.7	24.9
9	9.2	10.5	11.8	13.2	14.5	15.8	17.1	18.4	19.7	21.1	22.4	23.7	25.0	26.3
10	9.7	11.1	12.4	13.8	15.2	16.6	18.0	19.4	20.7	22.1	23.5	24.9	26.3	27.7
11	10.1	11.6	13.0	14.5	15.9	17.4	18.8	20.2	21.7	23.1	24.6	26.0	27.5	28.9
12	10.5	12.0	13.6	15.1	16.6	18.1	19.6	21.1	22.6	24.1	25.6	27.1	28.6	30.1
13	10.9	12.5	14.1	15.6	17.2	18.8	20.3	21.9	23.5	25.0	26.6	28.2	29.7	31.3
14	11.3	13.0	14.6	16.2	17.8	19.4	21.1	22.7	24.3	25.9	27.5	29.2	30.8	32.4
15	11.7	13.4	15.1	16.7	18.4	20.1	21.7	23.4	25.1	26.8	28.4	30.1	32.0	33.5

Table 2. Yield Table for 1 x 1 Spacing

Age	SITE 6	7	8	9	10	11	12	13	14	15	16	17	18
2	8.41	9.36	10.41	11.58	12.89	14.34	15.95	17.75	19.75	21.97	24.44	27.19	30.26
3	21.13	24.31	27.96	32.16	36.99	42.54	48.93	56.28	64.73	74.46	85.64	98.50	113.30
4	33.50	39.18	45.82	53.58	62.66	73.28	85.70	100.23	117.21	137.07	160.30	187.47	219.24
5	44.17	52.17	61.63	72.79	85.98	101.56	119.96	141.69	167.37	197.69	233.51	275.82	325.79
6	53.11	63.15	75.09	89.28	106.16	126.24	150.10	178.48	212.23	252.35	300.06	356.79	
7	60.58	72.38	86.47	103.31	123.42	147.46	176.17	210.47	251.46	300.42	358.92		
8	66.87	80.17	96.12	115.25	138.18	165.68	198.65	238.18	285.57	342.40			
9	72.20	86.81	104.37	125.49	150.88	181.40	218.10	262.22	315.27				
10	76.78	92.51	111.48	134.33	161.86	195.04	235.02	283.19	341.24				
11	80.79	97.46	117.65	142.02	171.44	206.96	249.84	301.59					
12	84.19	101.78	123.05	148.77	179.86	217.45	262.90	317.84					

Table 3. Yield Table for 1 x 2 Spacing

	SITE												
Age	6	7	8	9	10	11	12	13	14	15	16	17	18
2	6.16	7.11	8.20	9.46	10.91	12.58	14.51	16.74	19.30	22.27	25.68	29.62	34.17
3	18.46	22.01	26.25	31.30	37.32	44.50	53.06	63.27	75.45	89.96	107.27	127.91	152.53
4	31.95	38.74	46.97	56.94	69.04	83.70	101.47	123.03	149.16	180.84	219.24	265.81	322.26
5	44.41	54.38	66.59	81.54	99.85	122.27	149.72	183.34	224.51	274.92	336.65	412.25	504.81
6	55.30	68.17	84.04	103.59	127.70	157.42	194.05	239.21	294.87	363.49	448.08	552.35	
7	64.69	80.12	99.24	122.91	152.24	188.56	233.54	289.26	358.27	443.74	549.61		
8	72.76	90.44	112.41	139.73	173.68	215.89	268.35	333.55	414.61	515.35			
9	79.73	99.37	123.86	154.39	192.43	239.86	298.97	372.65	464.48				
10	85.78	107.15	133.85	167.21	208.88	260.94	325.96	407.19	508.67				
11	91.07	113.97	142.63	178.49	223.38	279.55	349.85	437.83					
12	95.72	119.98	150.37	188.47	236.22	296.07	371.09	465.11					

Table 4. Yield Table for 2 x 2 Spacing

Age	SITE 6	7	8	9	10	11	12	13	14	15	16	17	18
2	5.27	6.19	7.28	8.54	10.03	11.78	13.84	16.25	19.09	22.42	26.33	30.92	36.31
3	17.25	20.95	25.43	30.88	37.49	45.51	55.26	67.09	81.45	98.89	120.06	145.77	176.97
4	31.20	38.52	47.55	58.70	72.46	89.45	110.42	136.30	168.26	207.71	256.40	316.51	390.71
5	44.53	55.52	69.22	86.30	107.60	134.16	167.27	208.56	260.03	324.21	404.23	504.00	628.39
6	56.44	70.83	88.91	111.59	140.06	175.79	220.64	276.93	347.58	436.26	547.56	687.26	
7	66.85	84.30	106.31	134.07	169.08	213.22	268.89	339.10	427.64	539.30	680.11		
8	75.90	96.06	121.57	153.86	194.72	246.44	311.89	394.73	499.57	632.26			
9	83.78	106.32	134.93	171.24	217.33	275.81	350.03	444.23	563.78				
10	90.66	115.32	146.67	186.56	237.29	301.81	383.88	488.27	621.04				
11	96.72	123.24	157.04	200.10	254.97	324.90	413.99	527.53					
12	102.07	130.26	166.23	212.13	270.72	345.38	440.89	562.64					

TECHNIQUES OF DETERMINING WOOD CHARACTERISTICS AND PROPERTIES AS BASIS FOR MASS SELECTION OF FUELWOOD SPECIES

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ABSTRACT

Fuelwood demand in the Philippines is conservatively estimated to be 5.9×10^6 bone-dry tons (bdt), equivalent to about 1.79×10^6 barrels of oil or 8.4% of the country's oil import in 1979. Fuelwood is expected to play a bigger part in the country's energy picture with plans to generate electricity from dendrothermal power plants which would consume some 1.492×10^6 bdt a few years hence, saving the equivalent of 2.333×10^6 barrels of oil.

Important characteristics of fuelwood that have to be determined from the strictly fuel point of view are: heating value, volatile matter, fixed carbon, ash content, moisture content and specific gravity. From the economic point of view, however, since heating value range for the different wood species is relatively narrow while plantation fuelwood growth rate range is very wide, growth rates may have a greater effect on fuelwood costs than the other wood properties.

INTRODUCTION

The OPEC countries are at present very unpopular, especially in the developing countries which are the most hard-hit by the ever-escalating oil prices, for precipitating the energy crisis. A more realistic view actually is that with or without the OPEC countries actions, the energy crisis would eventually have arrived. The world could not go on indefinitely consuming a given barrel of oil within a few seconds what nature took millions of years to produce. An oil shortage is inevitable.

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In fact, history will probably judge the OPEC countries less harshly and even give them credit for bringing the world, especially the more profligate and extravagant countries, to its senses. We are all now compelled to conserve the dwindling and finite oil resource and use it more wisely. We hope also that we have now the incentive to develop and exploit alternate energy resources early enough so that when we will have these other resources to fall back upon.

With the benefit of hindsight we now see that we have neglected fuelwood, and at the same time we have cut down our forests, treating them as mines rather than as a renewable resources. Now, many developing countries are ironically suffering from the fuelwood crisis and the problems due to deforestation such as flooding, siltation, erosion, etc. (1).

Fuelwood plays an important, though largely unrecognized, role in the economy of the Philippines as in many other developing and underdeveloped countries. Thus, the consumption of fuelwood for domestic cooking is usually overlooked in the national statistics as it is difficult to measure since the sources of supply are usually localized and close to the consumers due to the expense of hauling and handling it.

Table 1 shows the types of cooking fuels used in the Philippine households in 1970 (2). Wood, the dominant fuel, was used in 79.26% of the households with kerosene in the second position. Fuelwood was used in 92.45% of the rural households and in 49.3% of the urban households. The urban fuelwood users totalled 19% of the total household fuelwood users. This compares with 15, 20 and 25% in Sudan, Lebanon, and Gambia, respectively (3).

Data in the Philippine national fuelwood consumption are scare. A 1976 report indicated that fuelwood consumption totalled some 11.7 million m^3 (4). Table 2 shows the estimated fuelwood consumption in 1980 and 1985. Our present estimates of fuelwood utilization for domestic cooking are based on a study which indicated that it averaged 3.2 m^3/family/year where it was a supplemental fuel and 5.5 m^3 where it was the sole cooking fuel (5). These are equivalent to 0.53 to 0.93 m^3/capita/year for households using fuelwood. These are close to or within the ranges of 0.7 to 0.86 m^3/capita/year cited by Wiersum (6) and 0.5 to over 2 m^3 mentioned by Arnold (3) for other countries. Thus Heyde's data (5) are a realistic basis for a national estimate despite its being based on a small sample. These data were then used with the projected Philippine population (2, 7) to calculate 1980 and 1985 domestic cooking consumption. Consumption for other uses were deduced or calculated from data obtained from various sources (4, 8, 9, 10, 11, 12, 13, 14, 15).

The measurement of fuelwood by volume, while very convenient, is unfortunately, inaccurate as a measure of the energy value. As will be shown later, the specific gravity (s.g.) of wood varies much more than the heating value per unit dry weight. Hence, the wood volume data were converted to bone-dry tonnes (bdt) using the known s.g. of the major species being utilized by a particular consumer. An estimate was also made of the equivalent fuel oil quantity taking into consideration the various conversion efficiencies attainable for the different uses. This amounted to 8.7 to 14.3 million barrels (bbl) in 1980. At current oil costs of US$ 36/bbl, the value of the fuelwood used in 1980 was US$ 314 to US$ 514 million.

Domestic cooking alone in 1980 was the largest fuelwood user, and the corresponding volume was much greater than even the peak volume of 11.584 million m^3 of commercial logs harvested in 1969 (2). It must be noted, however, that at present a great deal of the fuelwood, about 72% in one case (5), actually comes from the existing commercial forests. As the domestic cooking fuelwood requirement grows, there will be an increasing pressure on the existing commercial forests and eventually, the danger may arise, if it has not yet occured, that even young trees or saplings of the valuable commercial Dipterocarp species will be cut for fuelwood. This could further accelerate forest destruction in the country. A major portion of the establishment of plantations of 17,500 ha for fuelwood for other uses is being financially assisted by government agencies (12). The Communal Tree Farm program of the Bureau of Forest Development could produce some of the domestic cooking fuelwood needs (16). However, additional fuelwood plantations need to be established to meet the balance. The total plantation requirement for the expected minimum fuelwood consumption increase for all uses of at least 3.709 million bdt annually by 1985 would be about 230,000 ha if we are to avert the depletion of or damage to existing commercial forests.

A study on Leucaena fuelwood plantations, with growth rates of 16.4 to 50 bdt/ha/yr, for dendro-thermal power plants indicated the benefits shown in Table 3 (17). Disregarding the benefits due to electrification, the other benefits would still be valid even if the plantations were to produce fuelwood for other purposes. Other benefits would be reduction of floods and soil erosion.

FUELWOOD PROPERTIES

Sampling

For long log specimens (i.e., 6 m or more in length), six 2.5-cm thick discs or cross sections are taken, two each from the top, middle and butt positions. For large-diameter logs, the respective quadrants, northern, western, southern and eastern in each disc are marked. For proximate analysis, heating value and other analytical determinations, one each of the butt, middle and

top discs are taken and one corresponding quadrant from each of the three discs is divided into three sectors. One sector from each quadrant is taken to represent a composite sample. The sectors are chipped, air-dried and ground for analysis (18, 19). For smaller logs, i.e., about 15 cm or less in diameter, the whole discs may be used as the composite sample for the above-mentioned tests. Where the log length is limited, the sample may be limited to only one disc.

As a general rule, representative sectors sufficient to provide at least 0.5 kg of wood, air-dry basis, are selected and ground in a Wiley laboratory mill to pass a 0.706 mm (25-mesh) screen and a 0.210 mm (70-mesh) screen. In grinding the samples care must be taken to prevent the Wiley mill from overheating. The fractions retained on the 0.706 mm screen are used for moisture content and proximate analysis while the particles passing through the 0.210 mm screen are used for heating value and other analytical determinations. The samples thus obtained are stored in airtight glass containers.

The remaining butt, middle, and top discs are used for the s.g. tests. Specimens, 2.5 x 2.5 x 2.5 cm in size, are taken along two perpendicular diameters starting from the north-oriented side of the tree, intersecting at the pith. The specimens are soaked in water to maintain their green state. Dry specimens should be soaked for at least one hour before the test. For small-diameter logs the whole discs can be used as the s.g. samples.

Moisture Content

Moisture content (m.c.) is determined by drying a given sample in an oven at 105°C until the weight is constant.

The presence of moisture in fuelwood means that a part of the dry weight of the fuelwood will be consumed to remove the moisture resulting in a lower net or useful heat value.

Freshly-cut wood will usually contain, under Philippine conditions, about 50% m.c., wet basis (wb), or 100% m.c., dry basis (db), which, if allowed enough time, will dry out to about 15% m.c.$_{wb}$ which would be considered "dry" or more accurately "air-dry". The experienced buyer or user may be able to tell, by inspection, whether wood is freshly-cut or already air-dry.

Reporting of m.c. usually causes confusion in the literature. Chemists, in all analyses, and combustion engineers, working with solid, liquid and gaseous fuels, usually calculate m.c. on the "as-fires", actual, total or wet weight basis, hence:

$$\% \text{ m.c.}_{wb} = \frac{(W_1 - W_2) \times 100}{W_1}$$

On the other hand, foresters define m.c. as follows:

$$\% \text{ m.c.}_{db} = \frac{(W_1 - W_2) \times 100}{W_2}$$

Where $\% \text{ m.c.}_{wt}$ = moisture content on the "as-fired", actual wet or total weight basis.

$\% \text{ m.c.}_{db}$ = moisture content on the "bone-dry", absolutely dry or oven-dry basis.

W_1 = weight of sample before m.c. test.

W_2 = weight of sample after oven-drying; oven-dry or bone-dry weight.

Either m.c. value can be converted into the other, thus

$$\% \text{ m.c.}_{db} = \frac{\% \text{ m.c.}_{wb}}{(100 - \% \text{ m.c.}_{wb})}$$

$$\% \text{ m.c.}_{wb} = \frac{\% \text{ m.c.}_{db}}{(100 + \% \text{ m.c.}_{db})}$$

While housewives and even larger purchasers such as bakeries or charcoal makers generally will not bother about the m.c. but will price the fuelwood instinctively depending on whether it is green or "dry", large-scale purchasers such as those operating industrial woodfired boilers or power plants may want to buy on the dry weight basis, if not on the heating value basis. The desired rate of fuel feed to such boilers should be based on an accurate knowledge of the m.c. in order to operate the equipment economically and properly so as to meet the varying demands of the steam-consuming equipment. Also, the allowable amount of maximum m.c. in the fuel feed varies with different designs of boilers.

Knowledge of the m.c. is essential in connection with other fuelwood tests, the results of which are based on the oven-dry (bone-dry or moisture-free) weight of the sample.

Heating Value

The calorific value, heating value, or heat of combustion is measured by burning a weighed sample in oxygen in a bomb calorimeter under controlled conditions. The calorimeter is standardized by burning benzoic acid. The calorific value of the sample is computed from temperature observations made before, during, and after combustion, and making proper allowance for heat contributed by other processes (20, 21).

The result obtained from the bomb calorimeter is the gross or higher heating value, with the resulting water from combustion of the sample condensed to a liquid (22).

A higher-heating value wood is preferable to a low-heating value wood since a lesser quantity of wood, on the dry-weight basis, is required for the same quantity of heat. If a great deal of handling, hauling and processing is required, it is less expensive to use the higher-heating value fuelwood.

The heating values of hardwood barks are lower than that of softwood barks, although hardwood barks, on the whole, are higher in specific gravity than that of softwoods (23). As will be noted later the heating value is affected by the wood components.

The heating values of some Philippine woods are given in Table 4. Some of the samples were analyzed at FORPRIDECOM while most of the others were reported by Aguilar (13). Note that the coniferous species such as *Pinus kesiya* and *Pinus merkusii*, which are highly resinous, had the highest heating values.

Proximate Analysis

However, the burning quality, as distinguished from the heating value of the wood, cannot be determined from the heating value test alone since it cannot tell us whether the wood burns rapidly or slowly and whether is difficult or easy to ignite. This could best be determined by proximate analysis.

The proximate analysis of a fuel is composed of several standard tests (24). Volatile matter refers to the loss in weight of the oven-dried sample when it is subjected to a temperature of 950°C in a furnace according to a specific procedure. The ash is the residue left after heating a given weight of the sample at 700-750°C temperature according to a specified procedure. The fixed carbon is the difference after deducting the percentages of volatile matter and ash from 100%, all on the oven-dry basis. Table 5 shows the proximate analysis of the wood of some fast-growing trees.

A high volatile matter content fuel means that it is easy to ignite and it burns very rapidly. This type of fuel is very useful in circumstances where fuel feed has to be adjusted to meet rapidly fluctuating heat demands such as may exist in wood-fired boilers in an industrial plant.

A low volatile content fuel is relatively difficult to ignite, but once ignited it burns relatively slowly. This type of fuel would be suitable where heat demands change relatively slowly.

A high-fixed-carbon fuel would be advantageous in case of unexpeected or undesired interruptions of fuel feed since the generation of heat energy will not necessarily drop as rapidly as the fuel interruption since the fixed carbon provides a large heat reserve.

For household use, the volatile matter content should be sufficient so as to render the fuel easy to ignite but not too high that the housewife has to feed the stove with wood frequently. The fuelwood should have enough fixed carbon content that the temperature does not fluctuate too greatly.

A high ash content means a lower heating value. Some ashes have a tendency to form clinkers or hard deposits in the furnaces of wood-fired boilers. The clinkers obstruct the flow of combustion air and ashes through the grates and render cleaning of furnaces very difficult (25). Some of the ashes are also carried with the flue gases and, if not removed by gas cleaning equipment, can cause air pollution.

Ash fusion temperature

Ash fusion temperatures are determined by heating ash samples in a furnace (26). The ash first softens and then melts. Several values of temperature from initial deformation to fluid temperature will be obtained. If only one temperature is reported, this will refer to the fluid temperature. Where the fuelwood is to be used as a boiler fuel, the ash fusion temperature may be of interest as it will indicate whether the ash will melt at the furnace operating temperatures and form clinkers or hard deposits. The ash fusion temperatures for North American softwood and hardwood barks range from 1232 to 1577°C (27) which are above the furnace temperatures in wood/bark fired boilers.

Ultimate Analysis

Ultimate analysis consists of the determination of the carbon, hydrogen, oxygen, nitrogen, and ash contents of fuelwood.

The amount of carbon and hydrogen is determined by burning a weighed quantity of sample in a closed system and fixing the products of combustion in an adsorption train after complete oxidation

and purification from interfering substances. This method determines the carbon and hydrogen in one operation. The results include not only the carbon and hydrogen in the organic matter, but also the carbon present in mineral carbonates and the hydrogen present in the free moisture accompanying the sample as well as hydrogen present as water of hydration of silicates (28).

Nitrogen is determined by converting it into ammonium salts by destructive digestion of the sample with a hot, catalyzed mixture of concentrated sulfuric acid and potassium sulfate. These salts are subsequently decomposed in a hot alkaline solution from which the ammonia is recovered by distillation, and finally determined by alkalimetric or acidimetric titration (29).

Sulfur is not recommended to be determined since wood contains a very negligible amount such that it can usually be better detected in the ash.

The percentage of oxygen is calculated as the difference from 100 of carbon, hydrogen, nitrogen and ash.

The ultimate analysis values are used to calculate the chemical balance required to support combustion as well as the combined and excess air requirements for boiler operation (30). Carbon and hydrogen are the combustible elements of wood. The other components are non-combustible. The values of the ultimate analysis of different wood species fall within a relatively very narrow range such that wood may be considered to have a remarkably uniform composition (30, 31). Table 6 shows the average values for North American hardwoods and softwood barks and woods (30).

Proximate Chemical Composition of Wood

Wood is considered to be composed of cellulose and hemicellulose, lignin, extractives and ash. Unlike the ultimate composition, the proximate chemical composition of wood varies widely. E.g., the lignin in 20 non-commercial Philippine woods varied from as low as 20.2% to as high as 39.4% while the alcohol-benzene extractives ranged from 1.4 to 6.6% (32).

The extractives soluble in alcohol-benzene solvent, usually called the alcohol-benzene extractives, is a measure of the resin content. The heating value of extractive or resin-free wood is considered to be constant at 19.31 MJ/kg while resin has a heating value of 30.31 MJ/kg, hence resinous wood will have higher heating value (33).

In a study of the fuel values of bark of 24 hardwood and 18 softwood species, a significant negative correlation was noted between heating value/unit dry weight and ash. A positive correlation between alcohol-benzene extractives and heating value was highly significant for the hardwoods and for all species together, but not for softwoods alone (34). These findings seem to apply not only for bark but also to wood.

Of the major wood components in northern red oak (Quercus rubra), lignin had the highest heating value, 21.18 MJ/kg, and hemicellulose the lowest, with 16.67 MJ/kg, compared with cellulose, with 17.03 MJ/kg, while the extractive-free wood had 19.95 MJ/kg (35).

Older trees will have higher lignin, extractives and ash content (36). The first two items will increase the heating value but the last will decrease heating value. However, the adverse effect of ash is more than compensated for by the other items.

Basic Density

Basic density or bone-dry weight per unit maximum volume may be expressed as g/mL or kg/m^3. It is numerically equal to s.g. Volume is determined by the amount of water or mercury displaced by the wood specimen. The specimen is dried afterwards in an oven at 105°C to determine the bone-dry or oven-dry weight (37). The density of wood chips can be determined with the pycnometer method (38). The basic density is obtained as the ratio of the oven-dry weight in g to the green or maximum swollen volume in mL.

Referring to Table 4, the coefficient of variation of heating value per kg., 6.62%, is much lower than that for s.g., 28.39%. This indicates that measurement of wood volume without considering s.g. leads to a serious error in assessing the value of wood as a fuel. Hence, fuelwood statistics should preferably report the bone-dry weight also rather than volume alone.

In a study of 24 Indonesian wood species with s.g. of 0.32 to 1.04 which were converted into charcoal, as s.g. increased, yield and fixed carbon content of the charcoal tended to increase while volatile matter tended to decrease (39).

High-density woods need lesser space during handling, hauling, storage, and in the combustion area itself. However, low density woods are easy to cut and thus are amenable to manual harvesting and are readily split with relatively simple tools.

High-density woods usually produce hard and heavy charcoal that does not break up badly or develop too much fine powder during handling and shipping. Low-density woods generally produce softer and more friable charcoals that break up easily and produce fine powder (40, 41) that is wasted if they are not briquetted or used in boilers or furnaces designed to use powdered fuel.

An analyses of the data in Table 4 indicates there is no significant correlation between heating value per unit bone-dry weight of wood and its s.g.

Other Fuel Characteristics

Smoke is objectionable to the household user and even to larger-scale users from the aesthetic and environmental points of view. Offensive or even toxic fumes or sparks may be generated by some species. Such properties can be determined qualitatively or by inspection. There are no standard methods to measure quantitatively these fuelwood characteristics.

Acceptable Fuelwood Qualities

Table 7 shows the acceptable fuelwood qualities for three important uses: domestic cooking, charcoal production and boiler fuel. Few wood species have all the ideal characteristics of high heating value, low ash content, low m.c. and no emission of smoke, obnoxious odor or sparks. In addition, requirements for s.g., volatile matter and fixed carbon differ for the various uses.

CONCLUSIONS AND RECOMMENDATIONS

The ideal fuelwood should have high heating value, low ash content, low m.c. with suitable s.g., volatile matter and fixed carbon contents for its intended use. The corresponding ash should have high fusion temperatures if the wood is to be used as boiler fuel. Wood for household cooking should not emit smoke or objectionable odor.

Table 8 lists the fuelwood characteristics which have to be determined in the order of their priority. Ideally all the tests should be determined. However, constraints of time, personnel, and costs usually dictate how much work can be done. The minimum tests that should be done are for specific gravity and moisture content as these are relatively simple and their variation for different species and for different storage times, respectively, are much greater than for the heating value per unit dry weight. Their determinations enable a calculation of the dry weight of the fuelwood. When conditions permit, heating value tests in addition to the two tests mentioned should proved sufficient for most purposes.

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Table 1. Type of Cooking Fuels Used in Philippine Households, 1970 (2)

Type of fuel used	Urban Households		Rural Households		Philippine Households	
	No.	%	No.	%	No.	%
Charcoal	14 714	0.78	8 857	0.21	23 571	0.38
Electricity	155 590	8.26	14 395	0.34	169 985	2.76
Gas	283 911	15.07	68 219	1.59	352 130	5.75
Kerosene	490 237	26.02	182 029	4.25	672 266	10.91
Wood	929 080	49.30	3 955 789	92.45	4 884 869	79.26
Others	10 759	0.57	49 549	1.16	60 307	0.98
Total	1 884 291	100.00	4 278 837	100.00	6 163 128	100.00

Table 2. Estimated Philippine Fuelwood Consumption

Uses	Wood 1000 solid m^3	Wood 1000 bdt	Oil Equivalent 1000 bbl
1980			
Domestic cooking	25 760-44 275[a]	15 198-26 122[b]	7 709-13 250[c]
Tobacco flue curing	580[d]	307[e]	778[f]
Charcoal for industrial purposes	616[e]	326[g]	-
Wood industry steam and power	335[h]	134[i]	242[j]
1980 Total	27 291-45 806	15 965-26 889	8 729-14 270
1985			
Domestic cooking	32 667-56 146[a]	17 313-29 758	8 782-15 694
Tobacco flue curing	449[d]	238[e]	604[f]
Charcoal for industrial purposes	706[e]	474[g]	-
Wood and sugar industry steam	380	158[e]	285[j]
Dendro-thermal power plants	2 815	1 492[e]	2 333[k]
1985 Total	37 017-60 496	19 674-32 120	12 004-18 916

[a]Based on wood consumption per household (5) and population projections (2,7).

[b]Based on s.g. of 0.59 (13), lowest value of fuelwoods used (5).

[c]Based on dry wood heating value at 17 408 MJ/bdt, fuel oil heating value of 6 864 MJ/bbl (15); domestic stove efficiency of 20% that of kerosene stove (3).

[d]Higher tobacco flue-curing efficiency in 1985 (9).

[e]Based on s.g. of 0.53 for giant *Leucaena* fuelwood.

[f]Same basis as (c) but 100% efficiency assumed.

[g]3.4 bdt wood/tonne charcoal.

[h]Based on total wood waste estimates (11) and % utilization for steam (10).

[i]s.g. of 0.40 for Philippine mahogany species, principal raw material.

[j]1.808 bbl oil/bdt wood (14).

[k]Same heating value as in (c) but using wood with 50% moisture content (as-fired basis) so 1 bdt wood = 1.564 bbl for generating electricity (15).

Table 3. Fuelwood Plantation Benefits (17)

	Per ha Plantation area	Per MW capacity if used for generating electricity
Area reforested, ha	1	149-455
Plantation employment, after establishment	0.395 - 0.137	59-62
Employee benefits/year, US% 1000	0.196 - 0.080	29-36
Net foreign exchange savings/year, US% 1000	0.073 - 0.024	109
Benefits to government, US$ 1000	0.076 - 0.068	11-31
Electricity generated, net MWH/year	36 - 12	5 400
Population benefited by electricity	115 - 38	17 100
Wood produced consumed, bdt/year	50 - 16.4	7 459
Oil equivalent of wood, bbl[a]	78.2 - 25.6	11 666
, US$ 1000[b]	0.141 - 0.046	210
, US$ 1000[c]	0.282 - 0.092	420

[a] 1.564 bbl/bdt wood (2)

[b] At 1979 cost of US% 18/bbl

[c] At 1981 cost of US% 36/bbl

Table 4. Fuel Properties of Philippine Woods

	Species	Heating value MJ/kg	s.g.
1.	*Acacia farnesiana*	19.22	0.84
2.	*Albizia falcataria* [a]	18.10	0.25
3.	*A. procera*	19.66	0.66
4.	*Alstonia macrophylla*	19.16	0.56
5.	*Anthocephalus chinensis* [a]	19.27	0.33
6.	*Antidesma ghaessimbilla*	19.14	0.60
7.	*Avicennia officinalis*	18.49	0.63
8.	*Brugiera parviflora*	18.66	0.75
9.	*B. sexangula*	19.43	0.81
10.	*Callophylum blancoi*	19.06	0.59
11.	*Cassia fistula*	18.37	0.52
12.	*Ceriops tagal*	19.60	0.81
13.	*Citrus sp.*	18.21	0.78
14.	*Cordia dichotoma*	18.41	0.36
15.	*Cratoxylum blancoi*	19.06	0.66
16.	*Diospyros philippinensis*	18.61	0.75
17.	*D. philosanthera*	18.11	0.58
18.	*Eucalyptus deglupta* [a]	18.69	0.43
19.	*Excoecaria sp.*	19.22	0.41
20.	*Ficus nota*	18.89	0.50
21.	*Ficus sp.*	18.60	0.34
22.	*Gliricidia sepium*	20.57	0.74
23.	*Grewia multiflora*	18.84	0.45
24.	*Hydnocarpus sp.*	19.71	0.79
25.	*Kleinhovia hospita*	18.63	0.42
26.	*Lagerstroemia speciosa*	19.27	0.59
27.	*Leucaena leucocephala* (common) [a, b]	19.50	0.58
28.	*Leucaena leucocephala* (giant) [a, b]	18.03	0.53
29.	*Litsea leytensis*	20.32	0.63
30.	*L. perrottetii*	19.97	0.36
31.	*Lumnitzera littorea*	19.24	0.73
32.	*Macaranga sp.*	18.47	0.30
33.	*Memecylon ovatum*	19.65	0.72
34.	*Neolitsea vidalii*	18.83	0.67
35.	*Pileostigma malabaricum*	18.37	0.59
36.	*Pinus kesiya*	23.17	0.72
37.	*P. merkusii*	22.88	0.85
38.	*Pongamia pinnata*	18.94	0.52
39.	*Premna nauseosa*	20.27	0.66
40.	*Psidium guajava*	18.56	0.70

Table 4. Fuel Properties of Philippine Woods

	Species	Heating value MJ/kg	s.g.
41.	*Pterospermum diversifolium*	19.82	0.50
42.	*Rhizophora apiculata*	20.09	0.79
43.	*Serialbizia acle*	19.51	0.59
44.	*Sonneratia alba*	19.07	0.62
45.	*Spathodea campanulata*[a]	16.25	0.24
46.	*Streblus asper*	17.84	0.42
47.	*Trema orientalis*	18.85	0.25
48.	*Vitex parviflora*	19.25	0.64
49.	*Xylocarpus granatum*	16.32	0.56
50.	*X. moluccensis*	15.40	0.58
51.	*Zizyphus talanai*	18.34	0.69

[a]Analyzed at FORPRIDECOM. All others from reference (13).

[b]Average of values for 6 samples.

Table 5. Proximate Analysis of Some Fast-growing Woods[a]

Species	Volatile matter %	Fixed carbon %	Ash %
Albizia falcataria	83.2	16.1	0.69
Anthocephalus chinensis	78.8	20.5	0.72
Eucalyptus deglupta	81.0	18.5	0.53
Spathodea campanulata	78.8	19.4	1.80

[a]Oven-dry basis

Table 6. Typical Proximate and Ultimate Analysis of Wood and Bark (30)[a]

	Proximate Analysis			Ultimate Analysis				
	Volatile matter	Fixed carbon	Ash[b]	C	H	N	O	Ash[b]
Hardwoods								
Wood	77.3	19.4	3.4	50.8	6.4	0.4	41.8	0.9
Bark	76.7	18.6	4.6	51.2	6.0	0.4	37.9	5.2
Softwoods								
Wood	77.2	22.0	1.6	52.9	6.3	0.1	39.7	1.0
Bark	73.3	23.7	3.0	53.1	5.9	0.2	37.9	2.3

[a]Oven-dry basis

[b]% differ due to averaging different data sources

Table 7. Acceptable Qualities of Fuelwood for Different Uses

Property	Household cooking	Charcoal production	Boiler fuel
Heating value	High	High	High
Volatile matter	Moderate	Low	a
Fixed carbon	Moderate	High	a
Ash	Allowable[b]	Allowable[b]	Low[c]
Density	Low	High[d]	High[e]
Moisture	Low	Allowable	Allowable[f]
Smoke	None	Allowable[g]	Allowable[g]
Obnoxious odor	None	Allowable[g]	Allowable[g]

[a]Low volatile matter and high fixed carbon content for stable or slowly varying steam demand. High volatile matter and low fixed carbon for rapidly fluctuating steam demand.

[b]Low is ideal but high ash content would not render wood unuseable.

[c]Should also have high fusion temperature.

[d]Low is acceptable if charcoal fines can be briquetted or can be used for boiler fuel.

[e]Low is acceptable if steam demand is reduced from maximum capacity.

[f]Maximum allowable m.c. depends on boiler design.

[g]Depends also on local environmental regulations. Higher operating temperatures may reduce smoke and odor due to volatile matter.

Table 8. Fuelwood Characteristics to be Measured

Priority	Characteristics
1	Specific gravity[a]
	Moisture content[a]
2	Heating value
3	Proximate chemical composition
	Volatile matter[b]
	Fixed carbon[b]
	Ash[b]
4	Ash fusion point[c]
5	Ultimate chemical composition[d]
	Carbon
	Hydrogen
	Oxygen

[a]Minimum tests necessary.

[b]To be done only if one needs to determine the quality of a given fuelwood for a given purpose.

[c]Essential if fuelwood is to be used for boiler fuel or for other large-scale use where clinker formation may cause problems.

[d]To be done only if additional information is needed.

SRI LANKA

FUELWOOD SITUATION IN SRI LANKA
TECHNICAL ASPECTS

M. PUSHPARAJAH[1/]

ABSTRACT

The principal species identified as fuelwood species under Sri Lanka's climatic and edaphic conditions are Eucalyptus camuldulensis, Casuarina equesitifolia, Eucalyptus tereticornia, Sesbania glandiflora, Leucaena leucocephala, Trema orientalis and Calliandra spp.

Based on the FAO Yearbook of Forest Products (1977), the current per capita consumption of fuelwood amounts to an average of 0.33 m^3 which is considered a reasonable estimate. Sanker and Fernando (1977), however, estimate the per capita consumption of 0.51 m^3. Based on the FAO estimate of per capita consumption of 0.33 m^3, the total fuelwood consumption is estimated to be 4,719,000 m^3 per annum. The demand is expected to increase sharply in the future not only due to the rise in population but also to the escalating oil prices and a consequent switch-over from oils to fuelwood as the source of energy for industries.

The factors that determine wood fuel demand are cooking habits, income, family size, population growth, and the relative availability of other fuels. By far, the most important factor limiting the wood fuel supply is physical availability. Fuel wood consumption is higher in the rural than in the urban areas. The total fuelwood consumed for cooking is 84% while 16% is consumed by the industries. The tea industry accounts for an annual consumption of 0.7360 million m^3 and the other industries, such as tile, brick, pottery, account for about 0.0028 million m^3 per annum.

Our present requirements of fuelwood are met from three principal sources: (a) natural forests and plantations (b) rubber wood from area cleared for replanting and (3) other crop residues. The measures taken by the Government of Sri Lanka to increase the supply of fuelwood include the following:

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- establishment of fuelwood plantations.

- establishment of village wood lots through the proposed community Forest Project.

- encouraging people to plant trees in their homesteads and farmlands under the proposed Community Forestry Project.

- compelling major users of fuelwood both in the state and the private sector to establish fuelwood plantations to meet their requirements.

- Tea estates to plant 10% of the total extent of the land with tree species in ravines, valleys and in areas not suitable for tea.

Charcoal production and consumption are in its infancy in Sri Lanka. Commercial production of charcoal by the State Timber Corporation commenced only in 1979, in order to make the maximum utilization of surplus non-commercial wood generated from the massive lands clearing operations under the Mahaweli Development Scheme. The State Timber Corporation produced 1200 tons of charcoal during the year 1980.

INTRODUCTION

Sri Lanka lies between 5°55' and 9°55' North latitude and 79°41' and 81°54' east longitude. The total land area of the island is 6.6 million hectares. The island could be demarcated into two clearly defined climatic zones, the dry zone and the wet zone with an intermediate zone in between. Nearly 66 percent of the island constitutes the dry zone which consists mainly of flat and undulating land. The wet zone is situated in the south and south-western region of the island and consists of the coastal plains and very rugged mountaineous terrain rising up to an elevation of 2750 metres. The mean monthly temperature varies from 30°C in the lowlands to 20°C in the highlands over 2000 meters. The annual rainfall varies from 1250 mm to 1850 mm in the dry zone and 2500 mm to 5000 mm in parts of the wet zone. The total population is 14.7 million.

Of the 6.6 hectares of land in Sri Lanka, 4.2 million hectares fall in the dry zone and 1.5 million hectares in the wet zone, while about 0.9 million hectares fall in the intermediate zone.

The natural forests of Sri Lanka contain more than 100 indigenous timber species. Majority of them are found in the wet zone while the dry zone and the drier parts of the montane zone contain fewer valuable species and the stocking is extremely poor. Although the extent of natural forests in the dry zone is large, nearly 86%, the bulk of this is unproductive or low yielding.

According to the National Forest Inventory of 1961 based on the aerial photographs taken in 1956, out of a total land area of 6.6 million hectares, 44% or 2.9 million hectares were under forests. The present estimate of forest area is only 1.62 million hectares which represents 25% of the total land area. The depletion of nearly 1.3 million hectares of forests over the last two decades had been chiefly due to large scale agricultural development programmes and shifting cultivation.

Another factor that has significantly contributed to the depletion of the forest cover in Sri Lanka is fuelwood cutting. Fuelwood accounts for nearly 64% of the total energy consumption in Sri Lanka. It is estimated nearly 94% of the domestic energy needs of the rural sector is met from fuelwood. The total fuelwood consumption is estimated to be 4.719 million m^3 per annum, based on a per capita consumption of 0.33 m^3, and increasing in direct proportion to the increase in population.

The ever-increasing cost of fossil fuels means that, for the foreceable future, fuelwood will continue to meet the bulk of the energy requirements of the people in Sri Lanka.

One of the options that is available to meet the growing demand for fuelwood is to increase the supply of fuelwood, principally through the establishment of fuelwood plantations. The Forest Department's fuelwood planting programme for the Mahawell Development Scheme, would be settlers, envisages a total target of 28,350 ha over a 10-year period at the rate of 2835 ha per annum.

SPECIES CHARACTERISTICS AND SELECTION

The criteria used for mass selection of fuelwood species are:

1. Rapid growth rate
2. Ability to suppress weed competition
3. Ability to coppice when completely harvested
4. Adaptability to a wide range of sites and soils
5. Copious seed production
6. High calorific value

The principal species identified as fuelwood species under Sri Lanka climatic and edaphic conditions are *Eucalyptus camaldulensis* *Casuarina equesitifolia*, *Eucalyptus tereticornis*, *Sesbania glandiflora*, *Leucaena leucocephala*, *Trema orientalis* and *Calliandra* spp.

Eucalyptus camaldulensis:

Natural range - Australia (Western, South, New South Wales, Queensland and Northern Territory). From 31-229 m

Soil and climate - Grows in wide range of conditions mainly in areas of low rainfall and in high summer temperatures. Rainfall between 1016 and 1778 mm.

M.A.I. - 18 m^3/ha

Rotation age - 10 years

Casuarina equesitifolia:

Natural range - Indigenous on sandy shores and dunes along the coast of Chittagong, Tenasserim and the Andamans; also in the Malayan archipelago, the Malayan peninsula, the Pacific islands, North Australia and the Queensland

Soil and climate - It thrives best in close proximity to the sea on loose sand. Rainfall between 1016 and 1778 mm

M. A. I. - 15 m^3/ha

Rotation age - 10 years

Eucalyptus tereticornis:

Natural range - Australia (New South Wales and Victoria) and Papua New Guinea.
From sea level to 762 m

Soil and climate - Prefers rich alluvial soils, sandy loams, gravel terraces and it does well on deep sandy soil with a moderate amount of moisture. Rainfall between 1016 and 1778 mm. In Algeria, it grows well on low marshy tracts with a deep soil and in Brazil it succeeds on inundated soils

M. A. I. - 10 m^3/ha

Rotation age - 10 years

Sesbania glandiflora:

Natural range - India, Malaysia, Indonesia and the Philippines. It has been widely distributed in southern Florida and the West Indies, as well as from Southern Mexico through most countries of Central America to South America. It has also been cultivated in Mauritius and Northern Australia

Soil and climate - Grows in a wide range of soils but prefers sandy loams and does well on deep sandy soil with a moderate amount of moisture.

M. A. I. - 25 m^3/ha

Rotation age - 5 years

The species can be combined ideally with agriculture in areas where trees are normally not grown. The young leaves, tender pods and giant flowers of this species are used in curries and soups or fried, lightly steamed or boiled.

Leucaena leucocephala:

Natural range - Leucaena is from Central America introduced to Southeast Asia in 1980's. Elevations up to 600 m. Three main types namely, Hawaii, Salvador and Peru types are recognized.

Soil and climate - Does not thrive on highly acidic soils, grows under a wide range of soil and climate. Rainfall requirement between 600 to 1400 mm. Can withstand long, severe dry seasons

M. A. I. - 30 - 40 m^3/ha

Rotation age - 5 - 7 years

Trema orientalis:

A fast-growing tree, 8-10 m. Commonly found in open places and waste ground in Sri Lanka up to 1600 m. Growth figures are not known.

Calliandra callothyrsus:

Natural range - Grown naturally in Central America. Introduced to Indonesia in 1936 from Guatemala. From 100 - 1000 m

Soil and climate - Grows on all types of soils, even very poor ones, and it is able to grow even in heavy clay-type soils that are heavily compacted and where aeration is poor. It grows in areas having an annual minimum rainfall of 1000 mm/year, though it can withstand rather heavy drought periods lasting several months

M.A. I. and rotation age	- After one year's growth Calliandra can be cut at about 50 cm above the ground, yielding 10-15 m^3/ha. Afterwards yearly cuttings are possible producing between 35-65 m^3/ha up to age 15 to 20.

SUPPLY DEMAND AND CONSUMPTION

Statistical data on fuelwood production and consumption are in general less reliable than those for industrial wood. The figures vary greatly between the various sources of information and furthermore a substantial amount of fuelwood which is consumed locally remains unrecorded. A fair amount of coconut husk, trunks and other agricultural residues are also used as sources of fuel but statistics regarding quantity used are scanty.

According to the FAO Yearbook of Forest Products (1977) the production of fuelwood between 1966 and 1977 in Sri Lanka are as follows:

Table 2 :

Fuelwood Production 1966-1977
(X 1000 cubic meters)

1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
3690	3740	3800	3880	3940	4000	4070	4009	4071	4118	4177	4219

The current per capita consumption of fuelwood on the basis of the above data amounts to an average of 0.33 m^3 which is considered a reasonable estimate. Sankar and Fernando (1977), however, estimate the per capita consumption at 0.51 m^3. Based on the FAO estimate of per capita consumption of 0.33 m^3 the total fuelwood consumption is estimated to be 4,719,000 m^3 per annum. The demand is expected to increase sharply in the future not only due to the rise in population but also due to the escalating oil prices and a consequent switch over from oils to fuelwood as the source of energy by industries.

Fuelwood requirements of the domestic and commercial sectors are summarized in the following Table 3.

Table 3:

Estimated Fuelwood Demand-1978

Sector		Population (million)	Percent using firewood for cooking	Total consumption (million m^3/year)
Domestic Sector				
Urban	16%	2.3	75.8)	
Rural	72%	10.3	97.9)	3.9800
Estate	12%	1.7	99.0)	
	Total:	14.3		
Commercial Sector				
Tea Industry				0.7360
Other Industries				0.0028
			Total:	4.7188

The factors that determine wood fuel demand are cooking habits, income, family size, population growth and the relative availability of other fuels. By far the most important factor limiting the wood fuel supply is physical availability. Consumption takes place predominantly in the form of fuelwood with charcoal accounting for a very insignificant part of the total. In localities where wood resources are still quite abundant and conveniently distributed relative to population, average consumption per head of population is normally close to one cubic meter, but in areas where wood is scarce consumption drops to half a cubic meter and below. Wood fuel consumption is higher in the rural areas than in the urban areas. 84% of the total fuelwood consumed is used for cooking whereas the balance 16% is consumed by the industries. The tea industry accounts for an annual consumption of 0.7360 million m^3 and the other industries such as tile, brick, pottery etc. accounts for about 0.0028 million m^3 per annum.

Our present requirements of fuelwood are met from three principal sources:

(a) Natural forests and plantations
(b) Rubber wood from areas cleared for replanting
(c) Other crop residues

According to official data only about 0.1274 million m^3 of firewood is supplied annually by the State Timber Corporation from State Forests. Much of the fuelwood collections made from State Forests in the rural areas are never recorded. The bulk of the firewood consumed in the densely populated south-west part of the island comes from Rubber estate which are due for replanting. The annual replanting of Rubber is 6075 ha and the yield per ha is 172 m^3. However, in 1979 the actual performance was only 2835 ha yielding 487,620 m^3 of fuelwood. Even if the total target is achieved the total production of fuelwood from Rubber plantations cannot exceed 1.044 million m^3.

Assuming all the fuelwood from Rubber estates due for replanting will be available, we still need to develop our forest resources to meet at least 3 million m^3 of fuelwood annually. The renewable nature of fuelwood plantations offers potential for sustained output of wood for fuel. A number of measures has been taken by the Government of Sri Lanka to increase the supply of fuelwood. These include:

1. Establishment of fuelwood plantations
2. Establishment of village wood lots through the proposed community Forestry Project
3. Encouraging people to plant trees in their homesteads and farmlands under the proposed Community Forestry Project
4. Compelling major users of fuelwood both in the State and Private sector to establish fuelwood plantations to meet their requirements
5. Tea estate to plant 10% of the total extent of the land with tree species in ravines, valleys and in areas not suitable for tea

ESTABLISHMENT OF FUELWOOD PLANTATIONS

The sites selected for planting of fuelwood species are forest lands that have been abandoned after shifting cultivation. In most cases, the areas selected for planting carry only a light growth of shrubs and grass with occasional standing trees. Clearing is therefore easy and can be carried out with simple hand tools. The cleared shrubs and grass are burnt before planting and the planting holes 22 cm in diameter and 30 cm deep are made at the time of planting.

All seeds are produced in Sri Lanka and raised in well organized nurseries. Tubed plants are used for planting. The primary transport of plants is carried out by lorries and tractors with secondary distribution being carried out by handcarts and human portage. There are no serious problems of access to the plantation areas.

Planting takes place in the months of October, November and December. To obtain maximum early yields the spacing is usually 2 x 2 m. Fertilizer application is not normally undertaken at the time of planting. The plantations are weeded for two or three years after plant are free from weed competition. The cost of establishment and maintenance for the first three years ranges from Rs 4000 to Rs 8000 per hectare. 1250 ha of fuelwood plantation was raised in 1980, principally with Leucaena, Eucalyptus and Casuarina.

HARVESTING AND COLLECTION OF FUELWOOD

Rubber wood

The trees from Rubber plantations are sold to private agencies on a tender basis. The trees are felled using axe and transported in the form of logs by lorries and tractors to dealers who in turn cut them into smaller sizes using cross cut saws, which are subsequently split to about 6 x 6 x 6 x 45 cm sizes and sold as firewood in depots or delivered at door step by handcarts.

Natural Forest and Plantations

Harvesting of firewood from both natural forest and plantations is carried out by the State Timber Corporation through their contractors. Fuelwood harvesting from natural forests takes place only in the dry zone where the forests are earmarked for development purposes. The preferred species are clear-felled using axe, cross cut into small billets about 1 m in length and delivered to State Timber Corporation depots where the consumers make their purchases. A fair quantity of fuelwood also comes from the departmental Co-operative reforestation areas where the felling and conversion are carried out by the respective lessees and the fuelwood is offered to the State Timber Corporation or sold to public and industries by the lessees themselves. There are no fuelwood plantations in Sri Lanka and the fuelwood that comes from plantations are mostly in the form of thinnings from Eucalyptus plantations in the Mountain Zone and their contribution to the total consumption is insignificant. The thinning operations are handled by the State Timber Corporation.

Rural areas

In rural areas firewood is self collected where one or more members of a household collect firewood for the use of the entire household. In most of the rural areas women are the very visible collectors and transporters of all firewood supplies. Firewood collection is often a social matter, few collectors particularly women going alone. Someone returning home from work may pick up some bits of firewood,but specific excursions to gather wood are rarely made alone. Reasons for this include affinity for company, a fear of enemies or of the bush. Although women go in groups, they usually collect on an individual basis and the only co-operation seen is in helping each other in cording firewood into bundles and in lifting their heavy loads.

UTILIZATION OF FUELWOOD

Cooking

By far the most significant use of firewood in rural and urban households is to cook their food. It is estimated nearly 84% of the total fuelwood consumed in Sri Lanka is used for cooking. Cooking activities are carried out mostly on open hearth in the rural areas and in more efficient hearth in the urban areas. Most rural households use the traditional three-stone open hearth. The use of more efficient covered hearth is getting popular in many households. Generally, the first fire is lit at dawn and burns continuously and is used four times a day for preparation of morning tea and breakfast, lunch, evening tea and dinner. A second separate fire is also lit during the preparation of lunch and dinner to expedite the cooking process.

Heating

Use of fuelwood for heating is confined only to the Up-Country areas where the average temperature is about 15°C. Fires are kept burning all day and into the evening toward off the cold.

Manufacturing

Many industries and traditional manufacturing activities are entirely dependent upon fuelwood as their energy source. They include small local enterprises such as pottery, brick-making, blacksmithing and bakeries and lime burning. Lime burning is very common along the southern and eastern coasts and tile manufacture in the south-western province where wood fires have traditionally been used. Tea industry uses about 15% of the total fuelwood consumption for curing of tea.

Charcoal

Charcoal production and consumption are in its infancy in Sri Lanka. Commercial production of charcoal by the State Timber Corporation commenced only in 1979, in order to make the maximum utilization of surplus non-commercial wood generated from the massive land clearing operations under the Mahaweli Development Scheme. The State Timber Corporation produced 1200 tons of charcoal during the year 1980.

Charcoal represents an extremely viable option for certain sectors of the Sri Lanka economy. If charcoal were available tea drying, brick production, tobacco, steal, ceramics and various small industries that presently utilize fuelwood would utilize this resource.

The chief factors that favour an increased production and consumption of charcoal in Sri Lanka are:

1. Large scale land clearing operations under the Mahaweli Development Scheme - nearly 0.2 million ha of dry zone forests are being cleared under this scheme
2. Low transport costs
3. Labour intensive nature of charcoal production.

The State Timber Corporation is actively promoting the use of charcoal in households by public demonstrations and selling charcoal cookers at subsidized rates. The consumption of charcoal is growing fast and is believed that the use of charcoal will assume major importance in the future in both the domestic and industrial sectors.

Other functions

In addition to the principal firewood consuming activities mentioned above, there are a number of lesser but still significant activities which consume firewood. Firewood has a number of functional roles, as kindling, torches and for making smoke as protection against insects and animal pests. It also plays a central role in many ceremonial and funeral functions. The ritualized use of firewood at cremations is a significant cultural tradition but also a very large consumer of fuelwood.

MANAGEMENT OF FUELWOOD PLANTATIONS AND FORESTS

At present, no natural forest areas are managed purely for fuelwood in Sri Lanka. The firewood that comes from natural forests are from those forests that are earmarked for development or reforestation.

The first fuelwood plantation to be raised in Sri Lanka was only in 1980 under the USAID Reforestation and Watershed Management project. Under this project a total of 28,350 ha will be reforested with fuelwood species in the lower Mahaweli development area over a period of 10 years at the rate of 2835 ha per annum to meet the fuelwood requirement of the would-be settlers. The five major fuelwood species proposed for planting under this project are *Eucalyptus tereticornis*, *Eucalyptus camaldulensis*, *Casuarina equisetifolia*, *Sesbania glandiflora* and *Leucaena leucocephala*. *Trema orientalis* and *Calliandra spp*. will be planted on a trial basis.

A scheme known as Estate Fuel Coupe Scheme was in practice for a long time and has been abandoned recently. Under this scheme natural forest areas were released to tea estates for obtaining their fuelwood and the estates were required to enter into agreement with the Forest Department to the effect that they would satisfactorily plant thse areas with fuelwood species and maintain the areas for three years immediately after harvesting of the fuelwood. The species used under this scheme was mainly Eucalyptus grandis.

SOCIO-ECONOMIC ASPECTS AND OTHER CONSIDERATIONS

A. A. WIJETUNGA[1/]

ABSTRACT

The forest area in Sri Lanka has decreased from 44% of the total land area in 1961 to about 25% during the last two decades chiefly due to -

1. Shifting cultivation
2. Illicit felling of timber
3. Inadequate re-afforestation
4. The preponderant demand for firewood which constitutes 94% of the domestic energy needs of the rural sector, and
5. Construction industry both commercial and domestic.

The increasing population and the spiralling fossil fuel cost are making heavy demand on the Forestry Sector for increased fuelwood supply everyday. Relatively little attention has been made in the past to grow fuelwood species. However, recently more attention has given to this matter due to increased attention being made to rural development and to the fact that the needs of the rural populations for wood fuel are leading to degradation of the environment.

Wood fuel is the rational choice over other available resources of energy due to its renewability and its widespread occurence. The main points in favor of fuelwood plantations are their relatively high increment of usage and their possibility for siting closer to users and on land marginally productive for agriculture. Other important aspects of plantation establishment are their low cost and the generation of employment if established by schemes mobilizing the local populations, the relatively easily acquired techniques, the combined production of fuelwood

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[1/] Director, Forestry and Environment Activity Set III Coordinator for Sri Lanka.

and other minor forest produces (multiple use), savings on fuelwood collection and beneficial effects on the environment, like erosion control and water regulation. Dangers of monoculture exist with large scale plantations. Wood can also contribute more fully as a source of energy by drawing on available supplies as a raw material for charcoal. However, this needs educating the masses to change their traditional belief. It is expected that the importance of charcoal will increase in the household and non-household application.

INTRODUCTION

The forest cover in Sri Lanka has decreased from 44% (2.89 million ha) of the total land area in 1961 to about 25% (1.64 million ha) during the last two decades, chiefly due to:

(i) Shifting cultivation
(ii) Illicit felling of timber
(iii) Inadequate reforestation
(iv) Preponderant demand for firewood which constitutes 94% of the domestic energy needs of the rural sector
(v) Construction industry both commercial and domestic
(vi) Large scale agricultural development programmes

Fuelwood accounts for nearly 64% of the total energy consumption in Sri Lanka. The fast growing population and spiralling fossil for fuel costs are making heavy demand on the Forestry sector for increased fuelwood supply everyday. The total fuelwood consumption is estimated to be 4,719,000 m^3 per annum, based on a per capita consumption of 0.33 m^3 and increasing in direct proportion to the increase in population. Despite the fact that the island is still forested on 25% of its area, there are severe shortages of fuelwood in many localities. The forests are located in sparsely populated areas in the dry zone and on mountain tops in the wet zone and because of the high cost of transportation, fuelwood available from them is economically inaccessible.

Despite the massive use of wood which accounts for 64% of the total energy consumption in Sri Lanka, relatively little attention has been paid in the past to growing fuelwood species. However, more attention has recently been paid to this matter on account of a greater emphasis on rural development, the increase in cost of oil-based fuels and the direct effects of soil degradation and destruction of the vegetative cover caused by fuelwood collection. The Forest Department's fuelwood planting programme for would-be settlers under the Mahaweli Development Scheme envisages a total target of 28,350 ha over a 10-year period at the rate of 2835 ha per annum.

Some basic data about land area, population and gross domestic product (GDP) of Sri Lanka are summarized in Table 1.

Table 1:

Basic data about land area, population and gross domestic product (GDP) of Sri Lanka

1.	Population:	14.7 million
2.	Rate of growth of population:	2.1%('75/'76)
3.	Per capita income:	$175 (US 1971)

		Million ha	%
4.	Land area -		
	(a) Agriculture	3	50
	(b) Forest	2	33
	(c) Other	1	17
		6	100

		Per 100 ha	
		Total Land	Forest Land
5.	Population density	238	477

SPECIES SELECTION AND PREFERENCES

The criteria used for mass selection of fuelwood species in Sri Lanka are:

1. Rapid growth rate
2. Ability to suppress weed competition
3. Adaptability to a wide range of site and soils
4. Ability to coppice when completely harvested
5. Copious seed production
6. High calorific value
7. Easy handling, non-thorny types

The technical aspect of the above criteria have been discussed in the country report on technical considerations.

In addition to the above criteria used in the mass selection of fuelwood species the following factors too are considered in the mass selection with the primary objective of improving the socio-economic situation of the rural communities.

1. Fodder for the local livestock
2. Minor forest products for direct consumption or further processing and marketing by the local population
3. Improvement of soils and food crop growing conditions in Agri-Silvicultural systems.

People in Sri Lanka have a precise evaluation of firewood knowing which species and parts of trees are the best for specific purposes and uses. There is extensive technical knowledge among the local collectors and users concerning the species indigenous to the locality and their cooking, heating, medicinal and other qualities. The preferences are based on the burning qualities, availability and traditional practices relating to the indigenous species found in a particular locality. In general the desirable species are those which are hard, dry rapidly, burn strongly without getting out of control, provides a hot fire, emit little smoke, and give no unpleasant taste to the food. In the dry zone, the most preferred species is Weera (Dyptes sepiaria) and in the wet zone Rubberwood (Hevea brasiliensis).

SUPPLY DEMAND AND CONSUMPTION

Statistical data on fuelwood production and consumption are in general less reliable than those for industrial wood. The figures vary greatly between the various sources of information and furthermore, a substantial amount of fuelwood which is consumed locally remains unrecorded. A fair amount of coconut husk, trunks and other agricultural residues are also used as sources of fuel but statistics regarding quantity used are scanty.

According to the FAO Yearbook of Forest Products (1977) the production of fuelwood between 1966 and 1977 in Sri Lanka are as follows:

Table 2:

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The current per capita consumption of fuelwood on the basis of the above data amounts to an average of 0.33 m^3 which is considered a reasonable estimate. Sankar and Fernando (1977), however, estimate the per capita consumption at 0.51 m^3. Based on the FAO estimate of per capita consumption of 0.33 m^3 the total fuelwood consumption is estimated to be 4,719,000 m^3 per annum. The demand is expected to increase sharply in the future not only due to the rise in population but also due to the escalating oil prices and a consequent switch over by industries from oils to fuelwood as the source of energy.

Fuelwood requirements of the domestic and commercial sectors are summarized in the following Table 3.

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Estimated Fuelwood demand - 1978

Sector		Population (million)	Percent using firewood for Cooking	Total consumption (million m^3/year)
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Tea Industry				0.7360
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The factors that determine wood fuel demand are cooking habits, income, family size, population growth and the relative availability of other fuels. By far the most important factor limiting the wood fuel supply is physical availability. Consumption takes place predominantly in the form of fuelwood with charcoal accounting for a very insignificant part of the total. In localities where wood resources are still quite abundant and conveniently distributed relative to population, average consumption per head of population is normally close to one cubic meter, but in areas where wood is scarce consumption drops to half a cubic meter and below. Wood fuel consumption is higher in the rural areas than in the urban areas. 84% of the total fuelwood consumed is used for cooking, whereas the balance 16% is consumed by the industries. The tea industry accounts for an annual consumption of 0.7360 million m3 and the other industries such as tile, brick, pottery etc. acount for about 0.0028 million m^3 per annum.

Our present requirements of fuelwood are met from three principal sources:

(a) Natural forests and plantations
(b) Rubber wood from areas cleared for replanting
(c) Other crop residue

According to official data only about 0.1274 million m^3 of firewood is supplied annually by the State Timber Corporation from State Forests. Much of the fuelwood collections made from State Forests in the rural areas are never recorded. The bulk of the firewood consumed in the densely populated south-west part of the island comes from Rubber estates which are due for replanting. The annual replanting of Rubber is 6075 ha and the yield per ha is 172 m^3. However, in 1979 the actual performance was only 2835 ha yielding 487,620 m^3 of fuelwood. Even if the total target is achieved, the total production of fuelwood from Rubber plantations cannot exceed 1.044 million m^3.

Assuming all the fuelwood from Rubber estates due for replanting will be available, we still need to develop our forest resources to meet at least 3 million m^3 of fuelwood annually. The renewable nature of fuelwood plantations offers potential for sustained output of wood for fuel. A number of measures has been taken by the Government of Sri Lanka to increase the supply of fuelwood. These include:

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2. Establishment of village wood lots through the proposed Community Foresty Project
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4. Compelling major users of fuelwood both in the State and Private sector to establish fuelwood plantations to meet their requirements
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HARVESTING AND COLLECTION OF FUELWOOD

Rubber wood

The trees from Rubber plantations are sold to private agencies on a tender basis. The trees are felled and transported in the form of logs by lorries and tractors to dealers, who in turn split them into smaller sizes and sell them as firewood at depots or deliver at door step by handcarts.

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preferred species are clear-felled using axe, cross out into small billets about 1 m in length and delivered to State Timber Corporation depots where the consumers make their purchases. A fair quantity of fuelwood also comes from the departmental Co-operative reforestation areas where the felling and conversion are carried out by the respective lessees and the fuelwood is offered to the State Timber Corporation or sold to public and industries by the lessees themselves. There are no fuelwood plantations in Sri Lanka and the fuelwood that comes from plantations are mostly in the form of thinnings from Eucalyptus plantations in the Montane Zone and their contribution to the total consumption is insignificant. The thinning operations are handled by the State Timber Corporation.

Rural areas

In rural areas firewood is self collected where one or more members of a household collect firewood for the use of the entire household. In most of the rural areas, women are largely the visible collectors and transporters of all firewood supplies. Firewood collection also has its aspect of social contact, with collectors, particularly women, going for such collection in small groups. Someone returning home from work may pick up some bits of firewood, but specific attempts to gather wood are rarely made alone. Reasons for this include affinity, a desire for company, a fear of the bush. Although women go in groups, they usually collect on an individual basis and the only co-operation seen is in helping each other in cording firewood into bundles and in lifting their heavy loads.

UTILIZATION OF FUELWOOD

Cooking

By far the most significant use of firewood in rural and urban households is to cook their food. It is estimated that nearly 84% of the total fuelwood consumed in Sri Lanka is used for cooking. Cooking activities are carried out mostly on open hearths in the rural areas and in more efficient hearths in the urban areas. Most rural households use the traditional three-stone open hearth. The use of more efficient covered hearths is getting popular in many households. Generally, the first fire is lit at dawn and often burns continuously and is used many times a day for preparation of morning tea and breakfast, lunch, evening tea and dinner. A second fire is also lit during the preparation of lunch and dinner to expedite the cooking process.

Heating

Use of fuelwood for heating is confined only to the Up-Country areas where the average temperature is about 15°C.

Manufacturing

Many industries and traditional manufacturing activities are entirely dependent upon fuelwood as their energy source. They include small local enterprises such as pottery, brick-making, blacksmithing, tile making, tobacco curing, baking and lime burning. Lime burning is very common along the southern and eastern coasts and tile manufacture in the south-western province where wood fires have traditionally been used. Tea industry uses about 15% of the total fuelwood consumption for curing of tea.

Charcoal

Wood charcoal production and consumption are in its infancy in Sri Lanka. Commercial production of charcoal by the State Timber Corporation commenced only in 1979, in order to make the maximum utilization of surplus non-commercial wood available from the massive land clearing operations under the Mahaweli Development Scheme. The State Timber Corporation produced 1200 tons of charcoal during the year 1980.

Charcoal represents an extremely viable option for certain sectors of the Sri Lanka economy. If charcoal were available, tea drying brick production, tobacco, steel, ceramics and various small industries that presently utilize fuelwood would utilize this resource.

The chief factors that favour an increased production and consumption of charcoal in Sri Lanka are:

1. Large scale land clearing operations under the Mahaweli Development Scheme (nearly 0.2 million ha of dry zone forests are being cleared under this scheme)

2. Low transport costs

3. Labour intensive nature of charcoal production.

The State Timber Corporation is actively promoting the use of charcoal in households by public demonstrations and selling charcoal cookers at subsidized rates. The consumption of charcoal is growing and it is believed that the use of charcoal will assume greater importance in the future in both the domestic and industrial sectors.

Traditional ways of burning wood for cooking and heating are generally not energy efficient. Reduction in the quantity of fuelwood available and the increase in cost of fuelwood have altered the traditional consumption patterns. The traditional three-stone hearths are being substituted slowly by efficient cooking hearth designs requiring much less wood than the former. Mud and clay enclosed hearths are becoming popular in households. Though a larger number of people are using aluminum utensils for cooking, still most people are reluctant to switch over from clay utensils due to their belief that the food cooked in clay utensils are tastier. One of the options available to reduce fuelwood consumption is to use fuelwood more efficiently by simple improvements in wood preparation, in hearth design and the choice of cooking pots and their design.

Firewood harvesting has greatly affected the ecological balance of rural communities, usually detrimentally. The consequence of the localized character of fuelwood supply has been to put increasingly heavy pressure on the tree cover and other woody vegetation close to centres of population and to processing activities using fuelwood. One effect of firewood gathering that has been often noted is the denudation of land in the dry zone and montane zone which results from tree cutting. The destruction of vegetative cover leading to soil degradation due to soil erosion by wind and water is seen distinctly in the hill country areas where fuelwood is collected for tobacco curing. A vast area of mangrove forest in the coastal belts had been cleared for lime burning. Brick burning, too has had its adverse effect on the tree cover in stream and tank reservations as a fair amount of brickburning is done in the tank beds during the dry season. Excessive harvesting of fuelwood, in addition to leading to denudation and diminished future availability of wood and fuelwood also has a detrimental impact on the natural resources and the potential of the land to yield agricultural produce in the future, especially in areas where forests play an essential protecting and water regulating role. The Government of Sri Lanka is taking steps to regulate the transport of fuelwood in and around the ecologically sensitive areas and channel all supplies of fuelwood through the State Timber Corporation.

Other functions

In addition to the principal firewood consuming activities mentioned above, there are a number of leaser, but still significant, activities which consume firewood. Firewood also has a number of functional roles, such as lighting of fires as a protection against wild animals, construction of pyres for the cremation of the dead, and use at religious ceremonies. Firewood is traditionally used at cremation in large quantities.

MANAGEMENT OF FUELWOOD PLANTATIONS AND FORESTS

At present, no natural forest areas are managed purely for fuelwood in Sri Lanka. The firewood that comes from natural forests are from those that are ear-marked for development or reforestation.

The first fuelwood plantation established in Sri Lanka was only in 1980 under the USAID Reforestation and Watershed Management project. Under this project a total of 28,350 ha will be reforested with fuelwood species in the lower Mahaweli development area over a period of 10 years at the rate of 2835 ha per annum to meet the fuelwood requirements of the would-be-settlers. The five major fuelwood species proposed for planting under this project are *Eucalyptus tereticornis*, *Eucalyptus camaldulensis*, *Casuarina equisetifolia*, *Sesbania glandiflora* and *Leucaena leucocephala*. *Trema orientalis* and *Calliandra spp*. will be planted on a trial basis.

A scheme known as Estate Fuel Coupe Scheme was in operation for a long time and has been abandoned recently. Under this scheme natural forest areas were released to the estates for obtaining their fuelwood and the estates were required to enter into agreements with the Forest Department to the effect that they would satisfactorily plant these areas with fuelwood species and maintain the areas for three years immediately after harvesting of the fuelwood. The species used under this scheme was mainly *Eucalyptus grandis*.

TRADITIONS, VALUES AND ECOLOGICAL FACTORS

Wealthier urban families in Sri Lanka use electricity or gas for cooking, for reasons of convenience. In the past, it was considered a matter of prestige by the wealthy people to cremate the dead, using large quantities of fuelwood of preferred species. The cost of fuelwood has significantly reduced the quantity of fuelwood now used at cremations.

THAILAND

FUELWOOD SPECIES ASSESSMENT ACTIVITY IN THAILAND

BOONCHOOB BOONTAWEE[1/]

ABSTRACT

Present activity on fuelwood species assessment in Thailand is described in this paper. At least 4 projects are underway in the implementation phase in various parts of Thailand to determine the best cultural practice for fuelwood plantation. Species screening tests are also being carried out to provide information on suitable species for various geographical areas of the country, which differ markedly from north to south and east to west. Several important criteria are being established so that fuelwood plantation projects can be carefully evaluated. These criteria include rapid seedling growth, ease of establishment and regeneration, resistance to major insects and fungal pests, and good response to intensive management practices.

* * * * *

The current activity on fuelwood species assessment in Thailand is undertaken by the Forest Research Sub-division, Division of Silviculture, Royal Forest Department. This undertaking is essentially on technical aspects of fuelwood production. The initial criteria are broadly classified into 4 aspects as follow:

1. Ease of plantation establishment and regeneration.
2. Rapid seedling growth.
3. Resistance to major insects and fungal pests.
4. Good response to intensive management practices.

At present time, no attempt is made on the harvesting and end-use aspects due to the limitation on available budget as well as the time lag needed to produce usable wood biomass from the plantation. Some data on wood properties and heating value are, however, readily available from past research results.

[1/] Chief of Forest Soil Research Lab. Silvicultural Research Associate Division of Silviculture Royal Forest Department, Bangkhen, Bangkok 9, Thailand.

Criterion I: Ease of plantation establishment and regeneration

This criterion is based on several factors to be considered before any tree species is selected for fuelwood plantation purpose. These factors are as follow:

1. Availability of seed or planting stock.
2. Good to excellent seed germination percentage.
3. High survival rate after the first transplant from seed bed into individual polyethylene bag.
4. Freedom of disese in bagged - seedling stage.
5. High survival rate after second transplant (field transplanting).
6. Coppicing ability.

Criterion II: Rapid seedling growth

The minumum height growth employs in this criterion is at least 1 meter after one year in field conditions. The diameter growth is expected to be at least 2.5 cm at 5 cm above ground.

Criterion III: Resistance to major insects and fungal pests

This criterion is set in order to utilize the diverse genetic base of a particular species to provide one or several resistant strains of the species. Special care, however, must be observed to preserve the diversity of that species so that pest outbreak in a monoclonal plantation can be adequately dealt with.

Criterion IV: Good response to intensive management practices

In establishing a plantation for biomass production, it is necessary to plant with species that give good response to intensive management practices. This is because short-rotation plantation for biomass production costs much more than conventional forest plantation. It is, therefore, imperative to utilize the growth potential of the species as well as utilizing maximum productivity potential of the site so that the highest possible yield is realized as quickly as possible. A good response to intensive management practices will assure that this yield achievement is met within the shortest possible time. A typical yield in this case should be no less than 25 dry ton equivalent of wood biomass per hectare per year.

On-going projects in Thailand

1. Species screening test project

This project is designed to study the adaptability of 20 promising tree species to various site conditions. The experimental plots are distributed from the northern part to the southern part as well as eastern to western part of the country. Site preparation and stand

establishment techniques are standardized in all 23 experimental locations. The species being screen by this project appear in Appendix 1. The result of this project is expected within the next 2 years.

2. Above ground biomass productivty of some forest crops project

This project is formulated to provide some initial data on total above ground biomass of some selected forest tree species. The objectives of the project are to study the effect of various techniques in stand establishment and tending practices on biomass productivity of those species. The project duration is 5 years. There are 11 experimental locations across the country.

3. Agroforestry plantation for rural energy development

This project is set up in collaboration with the aforementioned project. The incentive of this project is on the development of rural energy source by the establishment of plantation specifically for energy source and at the same time provides the rural poor with an appropriate practice in combining cash crops production together with their own energy source. This project will help determine the cost and benefit of the practice. There are 9 experimental locations for this project which covers a wide range of climatic and geographic conditions of the country. The duration of project is 6 years.

4. Demonstration energy plantation

This demonstration project is carried out in order to assess the problems in establishing large scale energy plantation as well as studying the coppicing ability in second and third rotation.

All these projects are being carried out at the same time so that immediate data can be obtained without having to wait for preliminary result. Evaluation of these projects will be based on the criteria mentioned above.

Appendix 1

Tree species used in these projects

1. Acacia auriculiformis
2. Leucaena leucocephala
3. Casuarina equisetifolia
4. Casuarina junghubniana
5. Eucalyptus camaldulensis
6. Cassia siamea
7. Azadirachta siamensis
8. Peltophorum dasyrachis
9. Parkia javanica
10. Anthocephalus chinensis
11. Gmelina arborea
12. Xylia xylocarpa
13. Pterocarpus macrocarpus
14. Anisoptera costata
15. Ailanthus triphysa
16. Chukrasia velutina
17. Dracontomelon mangiferum
18. Afzelia xylocarpa
19. Toona febrifuga
20. Melia azedarach
21. Tectona grandis
22. Tetrameles nudiflora
23. Sesbania grandiflora
24. Combretum quadrangulare
25. Duabanga grandiflora

Appendix 2

Proposed Tree Species for Energy Plantations

For successful adaption to soil and climatic conditions the following tree varieties, will be used for planting:

1. Casuarina junghuhniana is a medium to large size tree, about 25-30 meters high, introduced from Australia or Indonesia. In Thailand it does not produce seed. Thus, propagation is done by means of air layering and currently successful method of cutting is developed by the RFD which is promising for mass production of seedling. The tree is adaptable to all types of topography ranging from a height of below 100 meters to above 1,500 meters. It is highly resistant to drought and capable of growing even in laterite soil which is not suitable to agricultural practice. This tree also does well in sandy loam soil. The RFD has recently imported seed from Indonesia and Forestry Research Section of the RFD has successfully found

an appropriate grafting method by using a chemical to stimulate the rooting. It is expected to be successfully adaptable to the Northeast. Currently, it is very popular among private tree planters who are producing trees for fuel and poles used in construction since it is capable of producing coppice, a need for replanting is minimal.

2. Leucaena leucocephala has been introduced in Thailand over the last 5-7 years. Popularity among tree planting people began a year ago (1977). Additional information in this tree is still required. However, a review of literature regarding its cultivation in the tropics, such as Indonesia and Philippines is very encouraging. From the experiment conducted by the RFD a 5-month old plant has achieved growth of 4 cm (d.b.h.) and height of 5 meters. When considered in terms of altitude, soils and amount of rainfall it can adapt well to the Northeast. In addition, it can be used in agro-forestry practices. To date, the RFD is capable of producing 50-70 kg. of Leucaena seed per year from the stocking plant of Khon Kaen. Regrowth by means of coppice is very good.

3. Acacia auriculiformis is small to medium shrub, about 10-15 meters high. It is widely adaptable to all types of topography, it is easy to propagate and highly resistant to drought and forest fire. Regeneration after cutting by means of coppice is very good. It is suitable for planting in sandy soil laterite soil and even in forests.

4. Casuarina equisetifolia is a medium to large size tree about 20-30-meter high at full maturity. It has more branches than Casuarina junghuhniana and propagates by seed. Suitable for planting in sandy loam at an altitude of 100 - 1,500 meters. It requires moderate moisture and is resistant to drought. The tree have been found to have root nodules containing nitrogen-fixing bacteria. They are, therefore not dependent on soil nitrogen for good growth.

5. Eucalyptus spp. (camaldulensis) are introduced from Australia. Several species are adapted to local conditions and does well almost all types of soil. Some can grow in water-logged land, some are drought resistant. It propagates well by seed. Seed stands also exist in the Northeast and the North. Rapid juvenile growth has been noted from several varieties.

SOCIAL AND ECONOMIC DIMENSIONS OF ENERGY FOREST

BHISANUWAT THAWEEWAT[1/]

ABSTRACT

Generally, energy crisis is usually thought of in terms of oil shortage and price escalation which has many far-reaching adverse economic impacts on the national economy. However, analysis of the energy use structure of Thailand revealed that oil and wood energy accounted for 42% and 49% of the total national energy consumption. While oil is the main energy base of the urban sector, wood plays a very important role in rural living. Rapid depletion of forest resources at the present rate of over 8.5% of total forest land per year has resulted in shortage of fire woods in various areas, especially in the north east. The problem is undoubtedly increasing in severity. Wood energy is clearly becoming a critical problem in the near future. This form of energy crisis will have profound social impacts which in turn will reduce the productivity of the rural sector. It is therefore rational to pave the ground for the systematic and orderly solution of this problem concurrently with the solution of the oil crisis. In this context, reforestation based upon fast growing trees for rural energy supply merits consideration in energy planning. Unfortunately, there has not been any systematic and planned study on this subject. Since energy-oriented reforestation links with rural development more closely than traditional reforestation, its social and economic dimensions are more prominent and requiring careful consideration. From limited secondary data, preliminary financial and economic feasibility of the energy forest concept has been analyzed. Social and economic criteria for the development of energy forest are developed. Results indicate that the concept can be looked on with a fair degree of optimism and further development is fully justified.

INTRODUCTION

At present, oil is the dominant energy base of all economic sectors of Thailand since it represents 82% of the total energy consumption in the economic sectors. In the domestic sector, however, wood energy dominates the scene as clearly shown in Table 1. Considering the increase in population and the rapid depletion of forest resource, supply of wood energy will become increasingly far below the demand, thus creating a new energy problem i.e., the wood

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energy problem. There is a clear trend that if not rectified, this problem will become critical in the near future. It will have adverse socio-economic impact on the rural sector and the low-income urban sector. Therefore, it is rational to give prompt attention to this problem and to begin tackling the problem concurrently with the oil energy problem.

Apparently, one obvious alternative to the solution of the wood energy problem would be to increase the wood supply while reducing the demand through such technical approaches as increasing the stove efficiency, increasing the efficiency in charcoal production, promotion of biogas, etc. The increase in the supply of wood energy calls for a new concept of reforestation in which trees are planted basically for energy purpose. This concept so far has not yet, been systematically tried in Thailand. As defined in the workshop prospectus, the author attempts in this paper to look into the socio-economic aspects of mass selection of fuelwood species for the wood-energy development. Unfortunately, the information on this subject is very scarce thus, compelling this paper to be qualitative and conceptual in nature. It does not provide answers on appropriate socio-economic criteria for mass selection of fuelwood species. Therefore, this paper can at the best, serve as a basis for discussion in the workshop.

REVIEW OF FUELWOOD SITUATION IN THAILAND

The Supply

Being a developing country with an agrarian economy the population increase coupled with low agricultural productivity and rural poverty create an insatiable demand for new agricultural land. This is achieved by deforestation. Within the last two decades the country's forest area had shrunk from 27.4 million hectares in 1961, to only 13.1 million hectares in 1977; corresponding to the decrease from approximately 60% to 25% of the whole country area. The problem is most serious in the northeast region where the remaining forest areas in 1977, were slightly over 15% of the whole regional area. Hence, it is not surprising to see that now Thailand has to import building woods from neighbouring countries. This results in the high price of building woods which adversely affects the physical living standards of the poor.

The depletion of forest resource also has strong impact on the supply of fuelwoods and charcoal. The present price of fuelwood in Bangkok is about US\$20/m^3 compared with only US\$6/m^3 in 1977. Accordingly, the price of charcoal in Bangkok has increased from US \$ 0.14/kg in 1977 to US \$ 0.26/kg at present. The high price of fuelwoods and charcoal would undoubtedly, be an incentive for more deforestation, thus completing the vicious destructive cycle.

At present, legal production of fuelwood is very low compared with the consumption figures in Table 1. In 1979 the total production of fuelwood recorded by the Royal Forestry Department (RFD) was only 825,185 m^3. Using an average heating value of 4,465 k-cal r kg. and an average density of 727 kg/m^3 this volume of production was only 38.6% of that consumed by the industrial sector. Undoubtedly, the rest of the demand in the industrial sector and the domestic sector must have come from illegal deforestation, and from trees and plants growing in farm areas. If there is no serious reforestation efforts the future of forest resources in Thailand will be very dismal. The supply of wood energy will soon reach a critical stage at which collecti fuelwoods in rural areas is excessive time and effort consuming.

The Demand

The extent and structure of present wood energy consumption in Thailand is hard to gauge due to a lack of accurate information. The 1970 FAO study is the only detailed analysis that has been made to date and some of their conclusions are outlined in Tables 2 and 3. It can be seen that in the rural areas, fire wood is more commonly used than charcoal especially in the northeast and the reverse is true in the urban areas. Convenience is the reason why charcoal is more popular than fire wood. The data in Table 3 also show that there was no significant difference in per capita consumption of wood fuel among the various geographical regions and between the urban and rural areas.

It should be noted that the average per capita consumption of woodfuel in Table 2 was 1.79 m^3 per annum. This rate of per capita consumption seems to be rather high. From various observations, it can be safely estimated that a family of 6 members will consume approximately 1 kg, of charcoal per meal. Assuming a 50% conversion efficiency in charcoal production, and a charcoal density of 0.4 kg/m^3, the consumption rate of 1 kg. of charcoal/family/meal will be equal to a per capita consumption of 0.913 m^3 of fuelwood per annum. This rate is considerably less than the FAO's rate. Needless to say, the accuracy of the per capita rate of consumption is very important to the planning of wood energy development since it determines the size of land area required for plantation of energy trees. Based on his experience, the author is of the opinion that the FAO's figures might be too high. At the per capita consumption rate of 0.913 m^3 per annum, a 6-member family will need approximately 0.28 hectare of land for planting fast-growing trees which will have a yield of 20 m^3/hectare /year. This energy plantation plot is only 9% of the average plot of 3.2 hectares per family. At this proportion the concept of wood energy should be acceptable and the conflicting land use for food production should not be too serious.

Table 1 Sectorial Breakdown of Primary Energy Use in 1977 (10^{12} Kcal)

Energy Source \ Consuming sector	Domestic	Industry	Transport	Agriculture	Commercial, Service, Construction, Other	Electric Power Generation	Total
Fuelwood/ charcoal	106.3	8.9			1.3		116.5
Petroleum Products	1.9	18.0	40.4	10.7	7.0	19.9	97.8
Hydroelectric Power						10.2	10.2
Bagasse		9.9					9.9
Agricultural Residues (Paddy husks)	1.6	1.5					3.1
Lignite		0.83				1.2	2.1
Coal		0.2					0.2
Total (10^{12} Kcal) (%)	116.2 (48%)	59.4 (25%)	40.4 (17%)	10.8 (4%)	13.3 (6%)	31.3 -	240 (100%)

Source: Thailand -renewable Nonconventional Energy-Draft Project Paper. USAID, May 1979

Table 2 Percentage of Households using various types of Woodfuel for Cooking (1970)

Region	Total Houses Using-Woodfuel	Type of Woodfuel		
		Wood only	Wood and charcoal	Charcoal only
1. Rural	99	22	12	65
North	100	12	18	70
Northeast	100	45	15	40
Central	98	2	7	89
South	98	10	6	82
2. Urban	87	2	18	67
Bangkok	83	1	22	60
Other	93	2	13	78
3. Country	97	19	13	65

Source: 1972 FAO report: "Timber Trends Study, Thailand, Detailed description of sources and results".

Table 3 Annual Consumption of Wood fuel in Thailand (1970)

Region	Total Consumption, Million M^3			Per Capita Consumption, M^3		
	Total Woodfuel	Wood	Charcoal	Total Woodfuel	Wood	Charcoal
1. Rural	54.6	23.4	15.6	1.78	0.76	0.51
North	13.0	6.0	3.5	1.87	0.79	0.46
Northeast	21.1	11.5	4.8	1.75	0.95	0.40
Central	13.9	2.5	5.7	1.98	0.36	0.81
South	6.5	3.5	1.5	1.62	0.86	0.38
2. Urban	10.0	0.6	4.7	1.89	0.11	0.89
Bangkok	6.1	0.3	2.9	1.90	0.10	0.90
Other	3.9	0.3	1.8	1.88	0.12	0.88
3. Country	64.6	24.0	20.3	1.79	0.67	0.56

Source: 1972 FAO report "Timber Trends Study, Thailand," Detailed description of sources and results."

Note: Total Woodfuel figures are derived by adding wood and charcoal consumption together, assuming that conversion of wood to charcoal yields 0.5 m^3 charcoal per m^3 of wood. This is not the form in which the FAO results were presented.

Reforestation Efforts

Ironically, reforestation in Thailand has been practiced by RFD since 1906. However, the achievement so far is insignificant compared with the forest areas lost each year in various parts of the country. As of 1977, RFD had a total 223 reforestation projects with a total area of only 68,979 hectares*. In addition to RFD, two government owned enterprises; the Forestry Industry Organization and the Thai Plywood Company Limited, have planted 21,465 hectares. Teak and other hardwood species are mainly grown in these reforested areas basically for building woods. Therefore, their contribution to the solution of wood energy problem would be very small.

In addition to the government efforts in reforestation, rising price of wood piles and scaffolders in recent years have instigated a number of private plantation projects based on Casuarina species. This fast growing tree can be harvested after 5 years. So far, plantation of Casuarina trees has proved to be a viable agribusiness with an average net profit reportedly of approximately US $ 2,300/hectare/year. There is no accurate information on the total existing plantation area. However, it has been reported that the demand of wood piles and scaffolders in the next 4-5 years would be about 10 million trees per year, much less than the anticipated annual output of 100 million trees. Therefore, the future of Casuarina plantation does not seem to be bright.

CONCEPT OF WOOD ENERGY DEVELOPMENT

Development Approaches

Broadly speaking, there are two approaches for development of wood energy; namely village woodlots and energy forest. These two approaches require different implementation strategies, level of government involvement, and socio-economic consideration.

To provide for local woodfuel needs, woodlots could be planted in each village, using fast growing tree species. This could be done either on a community or individual basis and would yield a sustainable wood supply sufficient for the local consumption. Any wood surplus could be converted to charcoal and sold in local towns as an additional income source. In this approach the roles of government would be mainly confined to promotion and extension.

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* "Forestation as a profession" Technical paper of Thai Plywood Co. Ltd.

The energy forest approach involves large-scale plantation of fast growing trees in various deforested and marginal areas of the country. This approach could be undertaken by either the government of private entrepreneurs. Since it would take a number of years to harvest the energy tree, agroforestry techniques would have to be employed. In this technique cash crops are grown while the planted trees are young. If properly planned and managed the energy forest could be effectively employed in rural development.

Development Objectives

Theoretically, the development of wood energy if properly planned and managed, can achieve various objectives other than the energy sufficiency. The following objectives are often quoted; environmental improvement, employment opportunities, useful by products such as foliage, barks, gum, etc.; and industrial development. However, the magnitude of the various secondary benefits would very much depend on the scale of development. For the village woodlots, all the secondary benefits would not be outstanding. For the energy forests the secondary benefits would have a greater chance to realize.

Whatever development approach is employed the quantifiable objectives are very important to the acceptability of the concept. As far as the socio-economic aspect of the wood energy development is concerned, three levels of development objectives could be set around the farmers as follows:

Level 1 Domestic energy sufficiency
Level 2 Income supplement
Level 3 Main income

These three levels require different socio-economic considerations and scale of operation. At the first level, small private plots of fuelwood species for individual families are envisaged. The acceptance of the concept by a farmer would depend on his evaluation of the costs and benefits. He is likely to accept the concept if he assesses that the woodlot would be more convenient for him than collecting fuelwood and that the use of land and labour involved would not affect his income and his pattern of living.

Small private individual plots are still in the scene at the second level objective. However, fuelwood trees must now be seen and treated like normal supplementary cash crops. The farmer will have to use more land and labour and the opportunity costs for the two production factors and the risk in investment will gain more importance. This means that fuelwood trees must be able to economically compete with other alternative crops, and that a market for the fuelwood must exist. The farmer will have to seriously learn new agricultural practices specially for fuelwood trees.

The third level objective sees farmers fully engaged in planting fuelwood trees in their own land, government reforestation areas, and private plantation areas. It is likely that at this level, the market for fuelwood must cover the industrial sector and the public sector. The markets would be decentralized since transportation is the constraint. The development of such market will require strong government supports. At this level, if the market price provides enough incentive farmers will be willing to take risks.

Problems in the Development

Problems in the development of wood energy arise out of the fact that it is essentially a conversion of hither to naturally grown non-commercial species into socially and economically viable species. As such, the development is first, confronted with many technical unknowns in trasplanting the species from their natural environment to the new agricultural environment. Since many potential species are abound in the tropics the argument then starts on which species is most appropriate judged from technical, social, economical and ecological points of view.

In addition to the inherent problems of the selection of species the success of wood energy development will not be possible without government assistance. At present, forest management, energy, and rural development are carried out by a number of government agencies, between whom the level of cooperation is generally poor. The development of wood energy clearly, requires an integrated and well orchestrated government effort. A clear national commitment is essential, backed up by effective management at every level. This will range from well thought out planning at the national level, to a large team of well trained forestry experts working in the field. Such a degree of coordinated effort will not occur without imaginative and decisive leadership from the top.

Social and Economic Aspects in Selection of Species

General Consideration

Apparently, the success of the wood energy development depends primarily on the species. Ideally, the species selected should possess the following characteristics:

a) Ability to grow in poor soil.
b) Ability to survive droughts, forest fires and other ecological stresses.
c) Rapid growth.
d) Minimal management requirements.
e) Disease and pest resistance.
f) High heating value.

g) No detriment to soil and environmental quality.
h) The ability to resprout from a stump when cut (coppice growth).
i) Having saleable by products.

All of these listed characterisitcs will never be found in any existing natural species. Therefore, to start with, in reality it will be necessary to compromise and select the species with least weak points. Later or, scientific research and development would hopefully be able to breed new more perfect species.

Social Consideration

In selecting fuelwood species, two social issues should be considered; namely social acceptability and social costs. By social acceptability it means the species must be acceptable to the farmers from the social points of view. This in turn means in practical terms, that the promoted species must not require high knowledge base and intensive, management, involve minimum degree of investment risk, and minimum extent of conversion from the original agricultural practices. The rapid acceptance of cassava and Casuarina by farmers in Thailand serves as a good example to illustrate these points.

It should be emphasized that these social criteria would become more demanding as the objective of wood energy development moves up from Level 1 to Level 2.

As for the social costs, this criteria will have to be considered on macro level. If plantation of the selected species requires heavy investment and has economy of scale, the rich will reap most benefits and will eventually in control of wood energy supply. This will work against social equity and in the long run, will jeopardize the social and economic order in the country.

In addition to the social equity question, some species may have adverse environmental impact. Casuarina species, for example, is known to turn the soil acidic. This will in the long run, deteriorate the soil quality thus, incurring costs to the society.

Economic Consideration

To be accepted by farmers, the selected species must be financially and economically feasible. The farmers will evaluate the costs and benefits of planting the fuelwood species with due consideration given to the opportunity costs of the required land and labours. The depth and the correctness of the evaluation will depend on individual's experience and knowledge base. The wood energy concept will be accepted if the farmers see that the woodlot will be more convenient and economical for him than collecting or buying fuelwood. Also the involvement in the fuelwood plantation will not affect their income and their normal ways of living.

For the energy forest approach undertaken by the government economic consideration may be different. The species selection should give more emphasis on intangible benefits such as the environmental improvement, than the financial benefits. The costs and benefits of the programme will have to be evaluated against the costs and benefits incur by not doing anything on the proposed marginal land or deforested area.

The above discussion implies that from economic consideration some fuelwood species may be appropriate for village woodlots and some for energy forest.

The harvesting period and the yield are two crucial factors dictating the financial feasibility of the fuelwood species. The harvesting period should not be longer than 5 years. Longer harvesting periods will reduce acceptability of the species. As for the yield it must be high enough to yield income comparable to alternative cash crops. Due to a lack of reliable information on the production cost of some fast growing tree species and the market, it is not possible to perform a detailed economic analysis to determine the feasible yield. However, a yield of higher than 20 m^3/hectare/year seems to be desirable.

CONCLUSIONS

The following major conclusions may be drawn:

a) Wood energy is the dominant energy base in the domestic sector in both rural and urban areas.
b) There is a clear indication that the supply of fuelwood will soon reach a critical level at which socio-economic impacts will begin to be felt.
c) Previous reforestation efforts have not been able to catch up with the rate of deforestation. There have not been any reforestation programmes basically for energy purposes.
d) Thai farmers are quickly adapted to new market opportunity species. The development is therefore, faced with technical, social and economic problems.
e) It will be impossible to find fuelwood species which meet all the desirable characteristics. In practice technical criteria for the selection of species will have to be compatible with social and economic criteria.
f) The selected species must be socially acceptable and must not incur any social costs. To be socially acceptable by farmers, the species must not be difficult to grow and manage. They must also involve minimum investment risk and minimum conversion of the old agricultural land and practices.

g) The development of wood energy may be in the form of village woodlots and energy forest. They require different implementation strategies, level of government involvement, and socio-economic consideration.

h) The development of wood energy can have three levels of objectives; i.e. domestic energy sufficiency, income supplement, and main income. These three levels of objectives require different socio-economic considerations and scale of operation.

i. The grass root problem of the wood energy development is the conversion of naturally grown species into socially and economically problems of social equity and damage the environment.

j) The two most important economic criteria are harvesting period and yield. The harvesting period should not be longer than 5 years and the yield should be greater than 20 m^3/hectare/year.

U. S. A

OVERVIEW OF U.S. EXPERIENCE WITH FUELWOOD IN RELATION TO RURAL ENERGY PLANTATION

LAWRENCE S. HAMILTON[1/]

ABSTRACT

The author presents a rapid overview of the fuelwood situation in major regions of the United States and the contribution which these regions make to the subject at hand in the ERD program. Issues of more efficient domestic combustion units, control of fuelwood cutting on public land, reforestation of degraded areas such as strip mines, nursery production and charcoal production seem to be relevant to the ERD in the East-West Region. Most relevant are the shelterbelt and fuel problems on the Great Plains and the current interest in fuelwood plantations in Hawaii for rural industry. New developments in Hawaii are described.

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Does a high-technology, energy-wasteful, fossil-fuel-dependent, urban, and industrialized country have anything applicable to say on the topic of fuelwood production and use to meet Asian rural energy needs? And, even more specifically, on the topic of selecting fuelwood species? I think that it does, and I would like to indicate to you some areas where experience pr research in producing, harvesting or using trees as fuel in the U. S. might provide some information useful to researchers from several Asian countries. I want to approach this by indicating the unique experience from the various regions of a geographically very diverse country.

Eastern Deciduous Forest

The Eastern Deciduous Forest Region of the U. S. exhibits the greatest use of wood as fuel. This use increased as this region was opened up to agricultural settlement by forest removal up until about 1865. At this time coal and newly-discovered oil supplanted wood as the major heating and cooking energy forms, especially in urban areas. Natural gas and hydropower accelerated the shift. By the peak of land clearing in the 1880's, fuelwood had largely been relegated to domestic heating and cooking in rural areas. The

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developing timber and wood pulp industries created large and higher value demands for wood. As rural electrification programs and bottled gas became available, rural wood heating became uncommon, and wood cooking became rare indeed. A limited amount of rural industry converted to wood waste energy from the timber industry.

From the 1880's on, lands in this region were released from agriculture by the opening-up of more fertile lands farther west. This process of land abandonment continues even today, though at a much diminished level. These abandoned lands either returned naturally to forest or were reforested, mainly with Pinus and Picea species. Since fuelwood demand was low and forests were fairly abundant, no planting was, or even today, is done for fuelwood purposes.

During the two World Wars, fuelwood use for residential heating increased temporarily, and this stimulated the development of new, more efficient stoves and furnaces for home heating. Combustion efficiencies up to 50-60 percent have been achieved in these wood-burning units. Research and Development represents one of the important contributions of this region to fuelwood use. With the OPEC oil price increases of this past decade, fuelwood for rural energy has made a dramatic comeback. This is mainly for home heating, not cooking. Electric power generation using wood is on the increase with 50 megawatt plants appearing in rural areas.

This increasing use poses new problems in forest management due to uncontrolled intensive harvesting without concern for site degradation and to upsetting long-term availability of sawtimber for sustaining existing industries.

In obtaining this energy from the natural forest, the main criteria for selecting species and individuals are mainly:

(a) high heating value per unit volume usually rated in terms of specific gravity of wood (though lignin, carbohydrate and extractives composition and content are important also).
(b) trees with stems 3 to 10 inches diameter at breast height to minimize the job of splitting wood for better drying and burning.
(c) species which split easily if over 10" d.b.h.: e.g., those with straight non-interlocking grain, and medullary rays.
(d) species which do not deteriorate when being air-dried (e.g., Betula papyrifera with bark on tends to decay rapidly).
(e) species which do not spark when burned (some resinous woods and those with moisture pockets).
(f) species without objectionale odor or causing allergenic reactions.
(g) species which coppice.
(h) species without thorns.
(i) species easy to ignite.
(j) species which have good "coaling" qualities.

In aggregate, in this region, preferred species were of the genera Acer, Fagus, Fraxinus and Quercus.

This region also has had a considerable experience with charcoal production and use. It began largely in connection with small rural iron furnaces, and reached a peak in the days of large demand for wood alcohol before it was made synthetically. The major market currently in rural areas is as a cooking fuel for outdoor barbequeing of meats. There exists a substantial experience with design and operation of small kilns which have relevance for rural energy use. The portable metal or the small cinder block kilns are possibly the most relevant for Asian adaptation. The main criteria for species selection from the above list are (a), (b), (c), (d), (g), (j).

The relatively low price of wood given its bulky nature and the high cost of labor in this region have led to substantial experience with equipment and methods of harvesting and handling for economic efficiency. While much of the mechanized equipment might be technological overkill for use in rural Asia, there exist a number of low-technology inventions such as strap bundling in the forest, which might be appropriately transferred.

Because of the need and desire to reforest some of the million acres of land abandoned by agriculture in this region, there is a long experience and considerable research with raising tree seedlings of various species and planting them on various kinds of land. For those considering use of temperate zone species, there is a wealth of information on nursery practice, seed sources, site requirements, growth and yield, weed control, pest hazards, and fertilization. Most of this concerns species of Pinus, Picea, Abies, and Larix, but there has been considerable work done with the legume Robinia pseudoacacia and with various species of Populus and popular hybrids.

The Southern Forest

Domestic fuelwood use has been insignificant in this region for a long time because the warm climate reduces the need for home heating, and cooking needs have been met by other fuels almost exclusively. Tree farming of various Pinus species has been relatively intensively practiced however for sawtimber and pulpwood. In some areas, 14-year pulpwood rotations have been instituted, and a marked proficiency in both natural regeneration and reforestation has been achieved. Currently, there is much activity in the area of industrial energy tree farms. Research results from studies of whole tree harvesting with short rorations and its impact on nutrient depletion may have implications for short-rotation fuelwood cropping impacts in Asia. High nutrient drains of nitrogen and phosphorus are reported for pines as rotations are shortened, tree densities are increased, and all of the tree is harvested. Greater use of water is also indicated.

Some work has begun in establishing tests of various eucalyptus for industrial and electrical generating energy plantations. It is felt that for short rotation cropping, eucalyptus might require less fertilization to counteract nutrient drain. Use of fast-growing leguminous trees which might be even better has not been sufficiently tested.

At present there are a few electric-generating facilities operating on wood waste from sawmills. For instance in North Carolina a 10,000 kilowatt plant is maintained by the waste from 24 local sawmills producing annually some 144,000 tons of wood refuse.

This region is also the locale of some of the best forest genetic and tree-breeding research in the U.S. This work carried out not only at universities and government experiment stations, but by private forest industry may have aspects of use to mass selection, seed propagation, and seed source control work in Asia.

The Great Plains

Even the extensive grassland region of the U.S. has some experience which may be of relevance to fuelwood as a rural energy source. The absolute tree scarcity that prevailed naturally on the Great Plains is not unlike the situation in some parts of Asia today. Up until cheap coal, oil, and bottled gas became available, generations of rural residents used buffalo and cow dung, compressed grass, corn cobs and sunflower stalks, for cooking and heating.

It was in this region, beginning in 1934, during the Great Depression, and during an era of drought and dust storms, that a rather amazing programs of tree planting was initiated. The concept was to establish long strips of shelterbelts at intervals across this region to break the wind (thus reducing soil erosion), conserve moisture between strips, and to provide shelter for livestock, a supply of fuelwood for the farm and habitat for birds. Note how similar in scope this is to the present day programs in Asia of developing agro-forestry which will help to stabilize agriculture, provide wood for fuel, and develop a more pleasant living environment.

Typically a shelterbelt on a farm consisted of ten to twenty rows of trees in a width of about 120 feet and a length of one-half mile at right angles to the prevailing wind. It was a row-wise mixture of species for variable growth rate, longevity, density of foliage and uses. For example, there was often fast-growing cottonwood (Populus) in the center, flanked by nitrogen-fixing leguminous trees (Gleditsia), good fuelwood (Fraxinus and Celtis), a dense living fince (Maclura) plus shrubs for aesthetics, wildlife food and cover, and the lower part of the wind barrier.

The Prairie States Forestry Shelterbelt Program was initiated as a special Presidential Program, but it never received real support from Congress. Before it slowly unwound as an official government program however, some 220 million trees did get planted on 30,000 farms. During it we learned a lot about afforestation in semi-arid, continental climates where forest micorrhizae were lacking. Would some of this experience be relevant in certain situations in the Asian subcontinent?

Rocky Mountain Forest

Even though there has always been some rural home heating with fuelwood throughout this region, since coal, oil, natural gas and hydropower came upon the scene, wood energy has been relatively unimportant. No fuelwood plantation programs have been instituted in the past, or today. High energy prices have resulted in much more home heating with wood, and fuel gathering by pick-up truck has become a common activity for many families. Considerable distances may be invovled and considerable time budgeted for this activity, as in parts of Asia but it is viewed partly as a form of exercise and outdoor recreation. The wood fuel is almost exclusively coniferous, especially Pinus with some Pseudotsuga and some Picea.

There is little experience with reforestation from this region.

Pacific Forest

The major relevant experience with wood energy in rural development from this essentially coniferous forest region (home of the large conifers--coastal redwood, Douglas fir, western cedar, sitka spruce, western hemlock) has to do with waste wood fuel and tree nursery and planting techniques. A high degree of expertise in the development of wood waste combustion units has been achieved. Most of this is for small scale industrial use, but some also in domestic home heating with sawdust, shaving and chips. Because of the need for reforestation after fires, and use of artificial forest regeneration, there is also a great deal of available experience and research in such aspects of nursery practice as containerization, plantation fertilization, direct seeding (especially by aircraft), and bird and rodent control in seeding areas.

Subtropical and Tropical Islands

Of perhaps more direct relevance to this group is work underway of fairly recent origin on plantations of fast-growing trees in warm climates for energy production. Best known is the work on Leucaena, especially on the Hawaiian giant Leucaena. This will be reported on

by my colleague, Mr. Van Den Beldt, who works with Dr. James Brewbaker of the University of Hawaii (the developer of this strain). I shall briefly indicate some other work mainly in Hawaii but also in Puerto Rico at the Institute of Tropical Forestry.

At this latter institute there have been provenance trials of various eucalypts carried out as part of international trials organized by FAO and the Australian Forest Research Institute. Five-year results have recently been reported for Eucalyptus deglupta, E. urophylla, and E. alba. The attempt here is to find successful fast-growing trees for short rotation wood production, for tropical/subtropical moist-to-wet life zones. One site with heavy clay, poor drainage and soil compaction from grazing proved totally unacceptable. On three other soil types in moist and wet life zones, E. deglupta and E. urophylla did well (mean heights averaged from 10.3 m. to 17.9 m. and d.b.h. averaged from 9.2 cm. to 16.8 cm.), E. alba growth, though acceptable, was generally less impressive.

Some interesting work with Eucalyptus (mainly E. grandis and E. saligna) is being conducted on the island of Hawaii by Bio Energy Development Corporation in cooperation with the U.S. Forest Service with funding from the Department of Energy. This is a research pilot-plant test of the financial and biological practicability of growing wood fiber on a 5-to 7-year rotation to replace oil as boiler fuel at two sugar plantation power plants. Their program is based on producing an average of 20 tons green weight/acre/year, or 120 tons over a 6-year period. This is roughly equivalent to 120 barrels of oil. They are using marginal cane land and degraded pasture or forest. The program is two years on line and has already produced useful results on: site preparation methods and costs; size of seedling containers; outplanting size; spacing; fertilizer application mixes (at least up to 2 years); effects of using row mixtures with Albizia; methods and costs of early weed control; which herbicides are most useful for weed control. Future results will yield information on: provenances; costs and returns; cutting cycles; effectiveness of coppicing over cycles; necessity of continuous fertilization; equipment and methods of harvesting and handling. The harvesting will be machinery intensive, with perhaps limited application to Asia's needs. It is proposed to harvest the 10"-12" d.b.h. trees with hydraulic shearing machines, moving down the rows and passing the whole tree along to a tandem chipper and chip transporters. The criteria for selecting these two species has to do with them having a wide range of sites in the subtropics, having sprouting ability, their fast growth, and their thin bark (so that they could be chipped for paper pulp as an alternative). The project size is ultimately around 850 to 900 acres (350 ha).

Also the State of Hawaii on lands under its jurisdiction has some relevant information on planting fast-growing species for wood energy as an alternative to fuels which all must be imported into the islands. Most of the sites available for planting are acid soils, high elevation and with high rainfall. Using proven, fast-growing E. saligna and E. grandis, they propose a coppice 7-8 year rotation for 4 rotations before replanting is required. A major activity is selection of the available lands which will produce at least 300 cu. ft./acre/year within economic hauling distance of the fifteen steam boilers in the islands. At some higher elevation sites E. globulus will be tried. At lower elevations, with less acid soils and warmer temperatures and less rainfall, Leucaena leucocephala (the Giant) is being tested and in mixture with eucalyptus to take advantage of the nitrogen fixation.

Hawaii is the locale for a large screening of tree species from the warm temperate, subtropic and tropic zones. During the 1960's the U.S. Forest Service established 16 planting sites representing a range of soils, elevations and rainfall zones (e.g., 0-1940 meters elevation, 500-5,000 mm. rainfall, thin mucks over lava rock to deep, highly leached latosols). Seeds from 144 provenances representing 90 species were grown and outplanted. Ten conifers and 32 hardwoods were rated as having promise, though only a few of these would be suitable as short rotation fuelwood species. Eucalypts in general outperformed other species in these subtropical islands.

Finally it should be noted, that as elsewhere in the tropics/subtropics there is Hawaiian interest in trees that directly yield hydrocarbons. Though not fuelwood, they might provide a source of alternate energy. Bio Energy has obtained seeds of one of the Copaifera to test its performance under Hawaiian site conditions. This is the tree that is tapped to yield almost pure diesel fuel--supposedly 20-25 gallons per tree per year.

This overview has been very general in nature, but it is hoped that it will indicate some sources of information in the United States which might be probed more deeply for specifics. I would be glad to assist Asian researchers in this task and have brought some materials, including a selected bibliography, to this workshop.

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MASS SELECTION FOR LEUCAENA: THE HAWAIIAN EXPERIENCE

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ABSTRACT

Mass selection procedures used successfully over a 15-year period in Hawaii for the genus Leucaena are described. Experimental designs for testing superior varieties in different locations are discussed. Conclusions include suggestion for seed dissemination and certification, integration of mass selection practices with international development priorities and use of the Hawaiian leucaena model in other nations and for other species.

INTRODUCTION

When considering species of trees for use in fuelwood plantations, a fairly consistent range of parameters is examined. These usually include (NAS, 1980):

1) multiple purpose
2) adaptability
3) rapid growth
4) ability to coppice
5) high caloric value
6) short rotation period

Rarely do such lists include genetic factors like adequate supply of uniform seed, wide germplasm base collected from centers of origin, potential for genetic improvement, etc. That these genetic parameters are rarely considered is not surprising: so little is known of the amount and patterns of variation and of the reproductive biology of tropical trees (Bawa, 1976), that there is little on which to base such considerations. Neglect of genetic parameters is not limited to the consideration of selection of fuelwood species; it extends into plantations established for pulpwood and lumber production as well. The results can be rather disappointing.

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A few examples of the result of such neglect come readily to mind. The first involves the use of Eucalyptus saligna in Hawaii. E. saligna was introduced into Hawaii in the 1880's as a single seedlot from Australia (Skolmen, 1974). Seed was collected over the years from the original stands and widely planted on all islands in the state. These stands in turn became the seed source for post World War II plantings (Walters, 1973). Recently, it has been noticed that new plantings of E. saligna in Hawaii have become extremely variable due to accumulated inbreeding despression (Rober Merriam, personal communication). Seed from Hawaii can no longer be used in reforestation projects.

Another example involves the use of Acacia mangium in Sabah. Originally, seed was imported as extremely small seedlots from Queensland (Keong, 1979). Initial trials proved so exciting that F_2 seed was used to plant 6,500 ha (Norman Jones, personal communication). Quoting Jones, "the expansion of this population, especially in F_2 and succeeding generations has degraded the form and increased variability significantly."

In both of these cases, a desired trait of the two species, uniformity, of the breeding system, inadequate determination of species variability and the absence of a backup germplasm collection and testing program. Recent concern over this issue has generated a great deal of literature (e.g. Burley and Styles, 1976), and tropical tree breeders are starting to take a closer look at the rather unique breeding systems in tropical trees. This paper describes the Hawaiian leucaena program which has been quite successful in providing adequate quantities of uniform seed for reforestation efforts around the world.

HISTORICAL PERSPECTIVE

Leucaena leucocephala was traditinally used in Hawaii as a pasture species prior to World War II. Post-war research centered on the agronomic domestication of leucaena (Takahashi and Ripperton, 1949) and its usefulness as a cattle, swine, and chicken feed. Complimentary work followed in Australia, and by 1959 three general types had been identified by Hutton and Gray (1959); a) relatively short and bushy, low yielding; b) tall, high yielding, non-branchy; and c) tall, high yielding, branchy. In 1962, seeds of the latter were sent to Hawaii as the first accessions in the Hawaiian worldwide germplasm collection. Over the next 5 years, some 125 accessions were received from around the world and studied in provenance trials (Brewbaker, Plucknett and Gonzales, 1972). Later field collections brought the number of accessions to nearly 700. Simultaneously, cytological (Gonzales, 1966), quantitative genetic (Gray, 1967) and electriphoretic zymogram (Brewbaker and Hamill, unpublished)on inter-and intra-species variations were conducted in Hawaii and Australia. These studies would later provide much of the ground work in determining breeding and selection methods and population variability.

Interest in leucaena as a fuelwood crop goes back to Matthews (1914), who evaluated the use of common leucaena in the Philippines during the American occupation. More recently, interest was sparked by publications such as that of Brewbaker (1975), which proposed the use of leucaena to a wide international audience. Economic analysis of the production of leucaena as a fuelwood on a large scale basis have been done by Brewbaker (1980) in Hawaii and by Semana (1979) in the Philippines.

REPRODUCTION AND BREEDING SYSTEMS

The success of advanced breeding programs in temperate conifers is due largely to the high degree of self-incompatibility and simple manipulation of reproductive systems in these species (Nienstaedt and Snyder, 1974). No tropical species has been studied to the extent of many of the temperate pines, and the few studies that were conducted usually involved analysis of morphological segregation based on limited sample size and isolated localities (Bawa, 1976). Generally, however, it has been postulated that tropical trees are self-pollinated to a degree not found in temperate trees (Wright, 1976). Reports that tend to bear this out have been made for Eucalyptus obliqua with 25% selfing (Brown et. al., 1975), Acacia confusa with 75% selfing (Li, 1977) and Acacia lommisima with 26% selfing (Moffett, 1956)

A high degree of self-pollination in Leucaena leucocephala was suspected by Hutton and Gray (1959), who reported a high level of homogeniety within the shrubby ("Peru" and "Salvador") strains in forage trials. These morphological variations were verified in 1964 by Brewbaker, Gonzalez and Plucknett (1972) in similar trials in Hawaii Studies by Gonzalez (1966) of the genus Leucaena showed a chromosomal count of 2n = 104 in L. leucocephala (n = 13), indicative of polyploidy and therefore a possible high degree of self fertilization (Grant, 1975). Although the rate of self-pollination has not been quantified, unpublished electrophoretic studies by Hamill and Brewbaker (1967) demonstrated remarkable homogeniety in seedling and seed enzyme systems suggesting rather high levels of selfing.

In addition to L. leucocephala, Hawaiian germplasm collections include all 10 verified species of the genus. Several of these, notably L. diversifolia and several L. pulverulenta x L. leucocephala hybrids show excellent potential as fuelwood species. Field trials of L. diversifolia demonstrate similar shrubby/arboreal variation as in L leucocephala, but the boundary between "common" and "giant" types is much less defined. Moreover, segregation in F_2 seed has been noted in the Philippines and in Hawaii. This would seem to indicate a higher level of outcrossing, reflecting unknown levels of heterozygosity. Such variable rates of inbreeding may well limit the wide seed dispersal of superior L. diversifolia cultivars from limited seed banks for fear of repeating the mistakes encountered with Acacia mangium. Further, it appears that open-pollinated seed increase and genetic advancement techniques may be unsuitable for these cultivars. This certainly has been the case in species like Prosopis sp., where variable inbreeding rates have affected height growth by a factor of 3 in F_2 seed (Felker, 1979).

GERMPLASM COLLECTION AND PROGENY TESTING

Defining population variability and proceeding with the task of effectively collecting germplasm assumes critical proportions in the tropics when one contemplates the dwindling genetic resources of many species suitable for fuelwood use (Brewbaker, Van Den Beldt and MacDicken, 1981). Wood (1976) points out that the erosion of genetic bases in ancestral homes takes its toll even with mild human pressures when the "outliers", which are often the most important genotypes, are destroyed.

Population variability is well documented for temperate species, most notably the conifers. This knowledge contributes heavily to the success of temperate tree improvement programs, which invariably begin with the selection of an appropriate number of plus trees from wild populations based on a thorough understanding of variation within and between populations for the various species (Wright, 1976).

Little is known of variation between and within populations for tropical tree species, although it appears that inter-population variation is greater for tropical trees than for temperate trees. If this is true, one would select small numbers of individuals from large numbers of populations, instead of selecting heavily from a small number of populations as with temperate conifers (Bawa, 1976).

The Hawaiian leucaena germplasm collection started in 1962 with the importation of the erect arboreal types ("Peru" cultivar) being studied by Hutton and Gray (1959) in Australia. Approximately 120 accessions representing 7 species were acquired over the next 5 years. Most of these accessions, particularly those naturalized outside the host range, were of the "common" variety and found to be surprisingly uniform (Brewbaker, Plucknett, and Gonzales, 1972).

Field collections by Brewbaker in 1967, 1978 and 1979 from the center of origin in Meso-America demonstrated a large range of scattered native populations of this common variety extending from Central Mexico to South America. Few native arboreal stands were found, they being possible victims of severe deforestation pressures (Brewbaker and Hutton, 1979). Seed collection was done by bulking samples from a few individual in the scattered populations or families, a procedure justified by the high degree of homogeniety within types observed earlier, and by the belief that most variability would be between families. At present, the Hawaiian leucaena germplasm collection contains approximately 700 accessions representing the 10 verified species of the genus, as shown in Table 1.

Table 1. The ten major species of Leucaena.

Leucaena species	Locale	Elev.	Tree Ht.	Fuelwood Potential
leucocephala	Mex./C. Am.	low	22m	exc.
esculenta	Mexico	high	25	exc.
tricodes	So. Am.	low	22	good
macrophylla	W. Mexico	low	18	good
collinsii	So. Mexico	mid	13	good
diversifolia	Mex./C. Am.	high	18	good
pulverulenta	No. Mexico	low	20	fair
shannoni	C. Am.	low	9	poor
lanceolata	E. Mexico	low	9	poor
retusa	Texas	low	8	poor

Source: Brewbaker and Hutton (1979).

Provenance testing of seed collections is done at Waimanalo by planting accessions in 2-row plots at an approximate spacing of 1m x 1m with 8 - 10 trees per plot. Due to the sheer number of accessions, the need for replication may be avoided by using the running check design developed by Hawaii's sugar industry, wherein plots of cultivars of known performance (e.g. K-8) are replicated regularly throughout the experiment. The design allows for simple between/within analysis and for comparisons of means, adjusted for environmental differences detected in the check plots. Superior arboreal types of L. leucocephala are selected from the progeny trials for further tests and/or seed increases, taking full advantage of the high rate of self-pollination inherent in the species.

A great deal of international interest in the Hawaii collection was sparked as a result of the 1976 international consultation for Ipil-ipil research in Los Baños. Since then, innumerable requests from over 100 countries have been received. International sale of Leucaena seed has become a lucrative trade, with inexpensive good quality seed being produced in Taiwan, Haiti, Hawaii and the Philippines.

The high degree of homozygosity in the giant leucaena, particularly the K-8 variety provides an advantage for simple, efficient transfer of germplasm not found in most other tropical species. F_4 seed ultimately originating from Hawaiian orchards has shown little segregation in plantings in Taiwan. Other giant varieties (e.g. K-29) have been observed to express variability in Mindanao whether this variation is due to phenotypic variability, contaminated seedlots, or unexpected outcrossing in seed orchards.

Seed from promising L. diversifolia cultivars (e.g. K-156) is being handled with a bit more care, due to the suspected presence of outcrossing. Plantings of F_2 seed in Hawaii have demonstrated variable levels of segregation of giant and shrubby phenotypes, suggesting a danger of inbreeding depression. F_3 seed of K-156 (which attains heights of 10 m in 2 years) are being observed at several locations in Hawaii and abroad to study this problem. Development of clonal seed orchards to increase the supply of F_2 seed may be the answer to dispersal of suitable K-156 germplasm.

BREEDING

Breeding of the leucaenas for genetic gain in wood biomass seems to have a bright future. Crossing varieties of L. Leucocephala was successfully accomplished by Gray in 1960 after emasculation with .1% Gardinol K, a sulfonated lauryl alcohol (Gray, 1968). Superior yielding forage hybrids (e.g. K-500 or "Cunningham" variety) have been developed by Hutton and Beattie (1976), by crossing different L. leucocephala strains. Similarly, mechanical emasculation techniques described by Gonzalez (1966) were used to breed low mimosine lines of L. leucocephala utilizing within-species crosses and backcrosses (Gonzalez, Brewbaker and Hamill, 1967).

Another possibility for gains in woody biomass production exists in the highly variable, suspected heterozygote L. diversifolia. Inbred lines of two superior types, K-145 and K-156 are being developed for eventual crossing. Preliminary trials on Maui indicate the presence of slight segregation of phenotypes that may eventually be selected and exploited to produce superior hybrid lines.

A third method of obtaining hybrid vigor involves interspecies crosses, particularly L. leucocephala (2n = 104) x L. pulverulenta (2n = 56) with L. leucocephala as the male parent. The 80-chromosome hybrid (i.e. K-340) demonstrates remarkable vigor and has good potential as a fuelwood source, although partial sterility may preclude sexual seed increase.

Vegetative propagation may well be the key to exploiting superior Leucaena germplasm via clonal seed orchards or in the establishment of actual plantations. Success with a number of techniques for vegetative propagation including use of coppice cuttings (Blankert, 1933 and Van Den Beldt, unpublished), seedling cuttings (Hu, personal communication), grafting (Blankert, 1933 and Zabala, 1977), and woody cutting (Zabala, 1977) have been reported without use of growth hormones. Preliminary work with tissue culture seems quite promising (Peasley and Collins, 1980), and may eventually prove quite beneficial in increasing hybrid or sterile germplasm.

YIELD AND VARIETAL STUDIES

Publication of the National Academy of Science report (1977) on Leucaena prompted the establishment of a network of trials to determine the effects of varieties, spacing and environment on wood yields of Leucaena. Sites on four major inslands in Hawaii were selected, as well as sites in Taiwan, Sri Lanka and Malaysia. A basic spacing trial was installed at all sites using K-8 seed from original Waimanalo plantings in order to insure uniform germplasm at all sites. Spacing x variety trials were established at two sites in Hawaii for five varieties identified by earlier forage trials as superior woody types.

The basic spacing trial, shown in Appendix I, is the Augmented Block Design of Federer and Raghavarao (1975). The 4 rep trial consts of 4 replicated spacings ranging from 5000 to 40,000/ha and 8 unreplicated (augmented) spacing ranging from 2500 to 80,000/ha. These populations represent extremes that would be considered by both the small fuelwood farmer interested in short rotations and easily handled material, and by the conventional forester interested in pulpwood production. The augmented treatments allow a great deal of flexibility in the selection of treatments for different locations. At several locations in our network, the closer spacings have been dropped and fertility, liming, thinning and species treatments added. Replicated treatments provide the generation of pooled error terms for age and location combined analysis. The small plot size, 4 x 12 m, takes advantage of the high degree of within-variety homozygosity of the giant leucaena and eliminates intra-plot variability usually associated with larger plot experiments (Tamimi, 1979).

Initial results of the trials have been quite satisfactory. Appendix II demonstrates coefficients of variation at various ages and locations in Hawaii for height data. The rather low C.V. values adequately demonstrate the precision of the design. We are currently examining 18 other nitrogen-fixing trees (NFT; see Appendix III) under a USDA grant, utilizing the same design and even smaller plots (minimally 28 m^2) to determine the limits of small-plot testing and the response of the various species to the design. A cooperative international study involving these 18 species is being established under the newly incorporated Nitrogen Fixing Tree Association.

CONCLUSIONS

1) Greater emphasis must be placed on genetic parameters--germplasm collection, investigation of breeding systems, and systematic production of high quality seed--when selecting fuelwood species.

2) Use of agronomic designs like the Augmented Block Design and the Running Check Design can lower the high costs of provenance and progeny testing, while increasing precision.

3) Future genetic gains of Leucaena spp. for woodfuel use will probably center more on breeding and less on further selection of superior types from provenance trials.

4) International trials involving identical germplasm can be highly beneficial, particularly when compared to locally favored species.

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APPENDIX I. Augmented Block Design, Waimanalo, Hawaii.

12m

1 X .25	1 X 2.5	1 X 2	1 X .75	1 X .5	1 X 1	1 X 1	1 X .375	1 X .25	1 X .25	1 X 2	1 X .5
406	405	404	403	402	401	306	305	304	303	302	301
1 X .25	1 X 2	1 X 1.5	1 X 1	1 X .5	1 X 3	1 X 1	1 X 2	1 X .25	.5 X .375	1 X 4	1 X .5
101	102	103	104	105	106	201	202	203	204	205	206

24 m

plot number

Replicated Spacings: 1 x .25
1 x .5
1 x 1
1 x 2

Augmented Spacings: 1 x 2.5, 1 x .75, 1 x .375, .5 x .25, 1 x 1.5, 1 x 3, 1 x 4, .5 x .375

APPENDIX II. Analysis of Variance and C. V. S. for Leucaena Spacing Trials, Hawaii

AGE IN MONTHS

SOURCE	DF	3	6	9	12	16	21	24	30
Treatment	3	.059**	2.931**	7.599**	11.500**	16.285**	17.037**	19.235**	51.863**
Reps	3	.018**	.319+	.533**	2.648**	3.593**	4.949*	4.936*	2.200
Trt x Reps	9	.0020	.098	.026	.293	.480	.850	.880	.864
Samples	144	.0097	.0673	.0876	.218	.369	.477	.600	.788
C. V. (%)		4.2	6.2	5.8	8.0	9.2	9.4	10.0	8.9

SOURCE		KAUAI			MOLOKAI		MAUI
Treatment	3	.092	5.306**	17.101**	.577+	7.520**	4.582*
Reps	3	8.318+	3.271+	1.625	.429	1.653	1.603
Trt x Reps	9	2.194**	.927+	1.194	.194*	1.517**	.849**
Samples	144	.186	.491	.965	.077	.384	.071
C. V. (%)		13.7	12.4	9.3	9.8	11.4	11.5

+ 10% on F dist. * 5% ** 1%

APPENDIX III

Properties of NFT in U. Hawaii International network trials.

PROPERTIES	Acacia auriculiformis	Acacia mangium	Acacia mearnsii	Acrocarpus fraxinifolius	Albizia falcataria	Albizia lebbek	Calliandra calothyrsus	Casuarina equisitifolia	Dalbergia sissoo	Enterolobium cyclocarpum	Gliricidia sepium	Leucaena diversifolia	Leucaena leucocephala	Mimosa scabrella	Prosopis pallida	Samanea saman	Schizolobium parahyba	Sesbania grandiflora
Specific gravity	.68	.65e*	-	.63	.33	.58	.65	1.00	.68	.50	.75e	.55e	.54	-	.80	.52	.32	.42
Wood yield m^3/ha/yr.	15	30	20e	-	40	5	50	15	-	8e	8e	25e	45	-	8e	15e	20	22
Average caloric value (Kcal/kg)	4850	-	-	-	-	5200	4600	5050	5000	-	4900	-	4600	-	-	-	-	-
Average annual height growth(m)	2.6	2.5	4e	2.0	5.0	1.4	6.0	2.1	2e	2e	25e	4.0e	4.5	4.5	2.5e	4.6	1.9	3.3
Height at maturity(m)	30	30	25	60	45	30	10	35	30	30	10	20	20	15	20	45	30	10
DBH at maturity(m)	60	25	50e	300	200	200	20	30	200	200	20e	20e	35	30	60	180	70	30

* e = estimated values

Source: Brewbaker, Van Den Beldt and MacDicken (1981)

GROUP REPORTS

A. PRODUCTION

The workshop adopted the following criteria on "Production" identified by the participants:

1. Germplasm

   a. Adequate supply of good-quality germplasm

      This refers both to vegetative and sexual germplasm, and includes advance-generation seed from public seed dealers and the potential for clonal increase of seed (through tissue culture, vegetative propagation and the like) of species that demonstrate marked inbreeding depression.

   b. Native usually preferred over exotic

      Use of indigenous species usually is preferable to the introduced exotics. Exotics should be introduced when they demonstrate a significant gain in production and site adaptability and only when they have shown no tendency to become hard to control plant opportunists (weeds). Effort should be made to collect seed of a variety of populations of fuelwood species from centers of origin for screening and selection purposes.

   c. High potential for genetic improvement

      Potential for genetic advance, in immediate practical terms, refers to a species responsive to phenotypic selection and implies a well-thought out screening and selection program. Long-term genetic advance implies breeding; therefore, it is desirable that the plant have no known unusual morphological or reproductive features that would preclude advancement by breeding.

      1) Techniques:

         a) Collection, preservation and screening of local sources of germplasm.

         b) Identification of foreign sources of "developed" seed.

         c) Wide testing of exotics before release.

2. Site Adaptability of Species

a. Depending on purpose, species should either:

- thrive in a wide range of site conditions such as soils, climate or elevation;

- perform superbly on known, limited sites.

b. Species should be able to compete with host vegetation.

c. Species should be free from or resistant to insect and disease problems.

d. Species should be resistant to animal browsing or other animal damage (low palatability)

e. Species should be resistant to damage from environmental factors such as strong wind, fire or salt spray.

1) Techniques:

a) Provenance trials on many different sites are the single most important test of these criteria.

b) Laboratory techniques of measuring seed and seedling vigor may be further developed to assess the ability to compete and thrive under a variety of conditions.

c) Avoidance of misleading "wonder tree" propaganda.

d) Laboratory tests may contribute to the identification of resistance to pests or diseases of a given species.

e) Existence of unpalatable chemical substances or plant parts such as thorns or phyllodes are good indicators of resistance to grazing.

3. Cultural Management

a. The group considered seed and seedling vigor as important criteria in mass selection of fuelwood species. The seeds should have a favorable germinative percentage. Nursery techniques should be efficient and simple, and designed to take advantage of vigor. Seedling vigor is important at early stages to overcome weed competition, drought and other adverse conditions.

b. The management requirement of the species from time of establishment to harvesting should be minimal in order to avoid incurring excessive cost. However, the species should be able to respond to intensive management practices, such as irrigation, fertilization, or land cultivation. Fertilizers, if used, should not be necessary after the establishment.

c. The group considered that the species should be able to respond to coppice management as this is the most inexpensive and easy way to raise second and subsequent rotation crops.

d. Preferably, the species should be able to fix nitrogen, but should not pose a threat to levels of other soil nutrients.

1) Techniques:

a) Replicated trials quantifying optimum rates of inputs for a specific use.

b) Determination of benefit-cost analysis to determine best management method.

c) The best technique (general) for detecting capability for nitrogen fixation is observation on the presence of nodules.

4. Growth and Yield

a. Rapid Growth

Species selected for fuelwood production must exhibit rapid growth. Here, growth is measured more in terms of biomass rather than simply in terms of diameter or height growth considering that energy utilization of wood includes all combustible wood components. Diameter or height growth affects bole-volume growth, but this is only one component of biomass growth. It is recognized, however, that the volume of the bole constitutes the greatest component of biomass. In less branchy species especially, rapid bole-volume growth will almost entirely explain rapid biomass growth.

For a specific site, various factors explain the rate of biomass growth. These include the site characteristics themselves including the soil physical characteristics as well as climate; the stand characteristics including spacing and type of regeneration; and the set of cultural management operations. Species selected for fuelwood production in the given site must therefore promise adaptability and rapid biomass growth for the given set of site factors, stand factors, and management regime.

b. Short Rotation

Short rotation is another desirable characteristic of species selected for fuelwood production. Short rotation means shorter waiting time for the utilization of the fuelwood plantation and more production cycles in the life span of the fuelwood project or the land owner. Rotation is related to growth and yield as output value indicators (calculating the value of yield in terms of some measurable units) compared to the cost of inputs. Ideally, the chosen rotation must maximize the net benefit of land utilization while meeting demand or use requirements.

c. Desirable Growth Form

Species selected for fuelwood production must also exhibit desirable growth form in terms of the bole, branches and crown. The desirable growth form in one which is consistent with maximum biomass growth, intended use of the biomass, and mode of transport and processing. While the mode of transport and processing can be designed to conform with the form of the species, it is better to choose the species form that also accounts for the needs, technology, and even culture of the wood end-user (e.g., for interplanting on rice bunds, a narrow crown, excurrent axis may be desirable, whereas in rural fuelwood plantation, lower branchy types are desirable for easy collection of branches or seeds).

1) Techniques:

a) Replicated experiments measuring growth and yield on a variety of sites and management inputs.

b) Correspondence with other workers.

c) Surveys of land owners as to form of trees desired.

5. Environmental Effects

a. Species should have a low risk potential to become a noxious weed.

b. Species should not have adverse effects on soil characteristics, such as pH, relative to future intended use of the land.

c. Species should have maximum erosion control characteristics (root systems, litter).

Techniques: Replicated experiments on a variety of sites with measurement and monitoring of environmental effects over time, prior to widespread adoption.

B. UTILIZATION CRITERIA AND TECHNIQUES OF DETERMINATION

The recommended utilization criteria for the mass selection of fuelwood species are the following:

1. Ease of harvesting

Certain tree characteristics affect the ease with which the various harvesting operations, such as felling, bucking, transporting or splitting, may be carried out. A relatively straight trunk, minimum branching and/or relatively small branches (though this may also be affected by cultural management practices), and absence of thorns make the fuelwood relatively easy to harvest.

In rural situations, the fuelwood can be harvested manually with the aid of simple handtools or with the use of work animals. As tree population density decreases or rotation age increases, tree diameter may increase to a point where it is difficult for manual labor to fell and handle the stand. When these or other conditions render manual labor expensive or difficult, a certain degree of mechanization may be applied.

Time-and-motion measurements and equipment and manual energy consumptions could be correlated with the wood density (1, 2), size, and form of the various species to measure "ease of handling".

2. High Utilization Potential

In addition to fuelwood, the species should preferably yield secondary or co-products, such as fruit, medicine, fodder, tannins, or resins. The ability to enhance soil stability and/or fertility would also be desirable. Harvesting of the additional products should be such as to minimize adverse effects on the primary product-fuelwood.

3. High Calorific or Heating Value

A high-heating value wood is preferable to a low-heating value wood since a lesser quantity of wood, on the dry-weight equivalent basis, is required for the same quantity of heat. If

a great deal of handling, hauling and processing is required, it is less expensive to use the higher-heating value fuelwood.

The calorific value, heating value, or heat of combustion is measured by burning a weighed sample in oxygen under controlled conditions in a bomb calorimeter (3, 4).

4. Suitable Density for Specific Use

High-density woods need less space during handling, hauling, storage, and in the combustion area itself. However, low density woods are easier to cut and may be easier to split and thus are amenable to manual harvesting.

High-density woods usually produce hard and heavy charcoal that does not break up badly nor develop too much fine powder during handling and shipping. Low-density woods generally produce softer and more friable charcoals that break up easily and produce fine powder.

Density values for wood vary with moisture content. Hence, it is best to determine the basic density using green wood or wood soaked in water to attain the maximum volume. Basic density or bone-dry weight per unit maximum volume may be expressed as g/ml or kg/m^3. Volume is determined by the amount of water or mercury displaced by the wood specimen. The specimen is dried afterwards in an oven at 105°C to determine the bone-dry or oven-dry weight (1, 2).

5. Suitable Burning Qualities for Specific Use

The burning qualities are related to the amount of volatile matter, fixed carbon, and ash; the emission of smoke or sparks, and obnoxious and/or toxic odors; or other characteristics during combustion.

A high volatile matter content fuelwood is easy to ignite and burns very rapidly. This type of fuel is very useful where fuel feed has to be adjusted to meet rapidly fluctuating heat demands such as may exist in wood-fired boilers in an industrial plant.

A fuelwood with a low volatile matter content is relatively difficult to ignite, but once ignited it burns relatively slowly. This type of fuel would be suitable where heat demands change relatively slowly.

For household use, the volatile matter content should be sufficient so as to render the fuel easy to ignite but not so high that the housewife has to feed the stove frequently. The fuelwood should have enough fixed carbon content that the temperature does not fluctuate too greatly.

A high-fixed-carbon fuel would be advantageous in case of unexpected or undesired interruptions of fuel feed since the generation of heat energy will not necessarily drop as rapidly as the fuel interruption since the fixed carbon provides a large heat reserve.

A high ash content means a low heating value. In boilers, some of the ashes are carried with the flue gases and if not removed by gas cleaning equipment can cause air pollution.

Where the fuelwood is to be used as a boiler fuel, a low ash fusion temperature is undesirable. The ash may melt at the furnace operating temperatures and form clinkers or hard deposits which obstruct the flow of combustion air and ashes through the grates and render cleaning of furnaces very difficult.

Smoke as a source of air pollution is objectionable to the household user, for whom it may present health hazards, and may also be objectionable to larger-scale users from environmental and aesthetic points of view. However, smoke may be useful in keeping insect and animal pests away.

The tests for volatile matter, fixed carbon and ash are collectively known as proximate analysis (5) Volatile matter refers to the loss in weight of the oven-dried sample when it is subjected to a temperature of 950°C in a furnace according to a specific procedure. The ash is the residue left after heating a given weight of the sample at 700-750°C temperature according to a specified procedure. The fixed carbon is the difference after deducting the percentage of volatile matter and ash from 100%, all on the oven-dry basis.

Ash fusion temperatures are determined by heating ash samples in a furnace (6). Several values of temperature from initial deformation to fluid temperature are obtained.

There are no specific laboratory methods for measuring the smoke, obnoxious or toxic fumes, or sparks from fuelwood. However, methods being used in other fields could be adapted for fuelwood for measuring smoke and odors and their toxicity. The sparking tendency of fuelwood could be determined indirectly by the dichloromethane extraction method (7, 8) for measuring the quantity of resins which are thought to be directly responsible.

6. Ease of Drying

Fuelwood has to be dried, artificially or naturally, before it will burn satisfactorily. When wet or high-moisture content wood is burned, part of the heat generated by the fuelwood itself is consumed to evaporate the moisture, resulting in lower combustion efficiency. Fuelwood species which air-dry rapidly are less susceptible to deterioration and require less inventory for air-drying.

Moisture content is determined by drying the sample at 105°C in an oven to constant weight. "Ease of drying" can be expressed either as: (1) the time needed to attain a desired moisture content or (2) as the moisture content obtained after a specified drying period.

The basis of moisture content calculation should be defined as to whether it is on the dry weight basis or the actual (as-fired, wet, total weight) basis.

Unfortunately, no single specie possesses all the desirable characteristics, even if only the strictly fuel properties are considered. The requirements for different uses are not necessarily compatible. Thus, e.g., a low density wood is easily handled by the housewife but would give low charcoal yield. Therefore, an acceptable fuelwood species would meet many, if not all, of the desirable criteria. Table 1 sets forth the criteria for three important fuelwood uses.

For criteria for which standard methods for fuelwood are not yet available, the proposed methods should be standardized so that there will be a valid basis for comparison.

Table 1. Acceptable Qualities of Fuelwood for Different Uses

Property	Household Cooking	Charcoal Production	Boiler Fuel
Heating value	High	High	High
Volatile matter	Moderate	Low	a
Fixed carbon	Moderate	High	a
Ash	Allowable[b]	Allowable[b]	Low[c]
Density	Low	High[d]	High[e]
Smoke	None	Allowable[f]	Allowable[f]
Obnoxious odor	None	Allowable	Allowable
Ease of drying	High	High[g]	High[g]

[a] Low volatile matter and high fixed carbon content for stable or slowly varying steam demand. High volatile matter and low fixed carbon for rapidly fluctuating steam demand.

[b] Low is ideal but high ash content would not render wood unusable.

[c] Should also have high fusion temperature.

[d] Low is acceptable if charcoal fines can be briquetted or can be used for boiler fuel.

[e] Low is acceptable if steam demand is reduced from maximum capacity. Maximum allowable m.c. depends on boiler design.

[f] Depends also on local environmental regulations. Higher operating temperatures may reduce smoke and odor due to volatile matter.

[g] Slow-drying wood can be accepted at the expense of low combustion efficiency.

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C. SOCIO-ECONOMIC CRITERIA

The prime technical criterion for mass selection of forest species will no doubt be the suitability of the species to grow on given climatic and site conditions. However, socio-economic considerations are equally important criteria for selection. The recommended socio-economic considerations are:

1. Cost

Paramount to estimating fuelwood plantation costs and maintaining the estimated project cost is the procurement of seed varieties of known genetic stock and the ease by which such stock can be obtained. Costs will obviously depend on:

a. Regeneration Methods

In raising fuelwood plantations from seedlings, the techniques to be adopted particularly in the preparation of the land will depend on site conditions. The cost of different techniques will therefore vary for each technique. For instance, felling of secondary jungle or uprooting of grasses or loosening of soil by plowing will have different costs. The cost/benefit ratio of each technique has to be worked out to arrive at the most profitable technique to be adopted.

If the aim is to obtain maximum yield of fuelwood per unit area, the following reforestation techniques will need consideration.

1) Adopt closer spacing, say 1 meter x 1 meter

2) Application of fertilizer

These operations are bound to increase the cost per unit area. If a wider spacing, say 3m x 3m, is adopted, the cost per unit area will be much less but the ultimate yield per unit area will naturally be reduced. Weed problems will also be greater. However, if inter-cultivation with food crops (cereals, vegetables, chillies, bananas, or mustard) or grazing are permitted in the area, the income from the sale of such food crops or animal products may not only compensate for the reduced yield of fuelwood at rotation but will also provide an early income and contribute to the production of food and animal products in the region.

The options on the regeneration techniques should be subjected to an economic analysis prior to the selection of the regeneration technique for the seedling regeneration.

If species with high coppicing potential are selected, the subsequent regeneration (at least 3 rotations) could be achieved at very minimal costs in relation to the original establishment of the seedlings.

b. Cultural Techniques

The main cultural treatments envisaged are: weeding, particularly during the first three years; protection against fire and domestic or wild animal damage; and treatment for nutrient deficiency and the like. The intensity of these treatments would affect both the survival and growth - but at what cost? This has to be examined in the context of each site condition. However, reliance should be placed on relatively simple techniques. In this context, the criteria for selection of species should be fire resistance, resistance to browsing, and fast growing to overtop and suppress the rank vegetation within the shortest possible time.

c. Harvesting Techniques

The ease of harvesting will reduce the cost considerably. For instance, crooked or thorny species will cost more to harvest. Such species should not be selected.

It is common knowledge that harvesting costs per unit volume of timber are inversely proportional to the volume of timber harvested per unit area. Therefore, more productive species will not only need less land for the same yield than less productive species but also result in cheaper harvesting cost per unit volume of timber.

If the girth of timber of fuelwood species to be harvested is relatively small, hand tools like bow-saws could be utilized for felling of the trees by the local population. This will not only reduce the cost of felling (by contractors) but will also generate employment to the rural population.

Cost of harvesting can also be reduced by locating plantations near consumption centers as much as possible to minimize the transportation costs.

d. Land and Site Requirements

These costs include the cost of purchasing land or the opportunity costs of using land that would otherwise be available for different uses, and the cost of site preparation.

2. Benefits

The rural farmers targeted as the beneficiaries for fuelwood should play an early role in determining whether species will be planted in the project area. In other words, the immature period of the fuelwood plantation should be very short. In this context the three criteria for mass selection of fuelwood species are:

a. Fast-growing Species with Short Rotation

These species should have the following characteristics:

- Adaptability to climatic and edaphic conditions
- Resistance to pests
- Availability of seed material
- Simple techniques of establishment and regeneration
- Absence of adverse effects on environment
- High-yield
- Early returns

b. Multiple-use Species

Species producing other products such as livestock fodder, edible fruit, nuts or leaves, medicinal extracts and wood useful in making small household items would provide added benefit and could entail some net benefit in spite of diminished fuel characteristics.

c. Multiple-use of Land

The concept of growing a multiplicity of species as against monoculture requires serious consideration. The fuelwood species could be planted, say 5m x 5m, and in-between food crops, fodder grasses for stall feeding, pine trees for oleo-resins tapping or food trees, in order to provide a multiplicity of essential products in addition to fuelwood, as well as early income to the villagers.

3. Environmental Improvement

Forest denudation has caused serious environmental degradation during the last two decades, including soil erosion, siltation of reservoirs, and loss of agricultural lands. Effective species selection not only can result in increase fuelwood production but can also be integrated in programs that seek to achieve environmental improvements.

The environmental improvements for consideration would consist of:

a. Shelterbelts

The selection of species for shelterbelts wherever required to protect adjoining agricultural lands in arid regions should be on the basis of their ability to withstand persistent dry winds, drought and high temperatures.

b. Sand Dune Fixation

The species for this programme should primarily be adopted to the macro and micro environments of the region. It is preferred that species so selected should be capable of producing firewood and poles.

c. Soil Conservation and Slope Stabilization

Species reducing erodibility of denuded lands, improving water regimes of soil and conducive to the establishment of a beneficial soil flora are to be considered.

d. Roadside and Riverside Reservations

One general set of criteria cannot be used for the choice of species in this regard in view of the diversity of situations. The selected species should have very strong dense and widespread root systems to resist scouring, undercutting and overland flow.

e. Watershed Protection

The selection criteria for this purpose will be:

- Good survival and fast growth on degraded sites.
- Ability to produce a large amount of litter.
- Strong and widespread root systems.
- Capacity to form a dense canopy and have foliage during the rainy season. Dry season dropping of foliage would be desirable to increase water yield.
- Improvement of soil by fixing nitrogen, as by legumes.

4. Social Upliftment

Forestry is labor intensive. Selecting species that would permit inter-cropping at least during the first two years will allow employment generation and also provide income from the sale of inter-cultivated crops.

Fuelwood species with other uses, such as leaf fodder, food, fruits, or medicinal properties, should be a main criterion in this regard. The varied utilization characteristics of the species should be given due consideration.

Species with a high calorific value would result in the use of less volume of firewood.

5. Social Preferences

People in the area or community should be involved in the selection of species as they know the local conditions best.

The species selected should easily be harvested and have a ready market in the vicinity.

People will not sacrifice good sites for fuelwood plantations. They would use such sites for raising agricultural crops. Hence, species that would tolerate conditions in lands marginal for agriculture should be one of the criteria for selection of species.

D. OTHER PROPOSED ACTIVITIES

Aside from identification of criteria for selection of fuelwood species, the workshop participants proposed the following activities for the ERD-Activity Set III:

1. Validation of criteria and techniques developed at the Los Baños workshop:

   a. Organization of working groups to do the validation (Production, Utilization and Socio-economics).

   b. Produce a manual on the techniques of determination of the various criteria for the selection of fuelwood species.

2. Development of Programs (short term and long term for energy development through fuelwood)

   Preparation of project reports by each country to cover all marginal and sub-marginal lands in a five-year period and present them to the internal agencies for support.

3. Gene Bank Establishment and Coordinated International Trials of Fuelwood Species.

   Select persons from the participating countries to draw plans for the operationalization of a gene bank, identify species to be tested, collect germplasm of these species, and perform international comparative trials of them.

4. Data Bank and Information Exchange

   Selection of people to draw-up plans for the operationalization of a Data Bank and Information Exchange.

5. Selection of persons to study and develop effective techniques of information transfer to the various end-users.

6. Training

Develop a system of training personnel among all levels of fuelwood technology, such as establishment of schools or training centers.

7. Financial Pool

a. Contributions from donor countries

b. Organization of a foundation for fuelwood development (international financing agencies such as World Bank, ADB, SIDA, USAID) with the ultimate objective of establishing an International Institute of Social Forestry.

RECOMMENDATIONS FOR CONSIDERATION BY THE ERD STEERING COMMITTEE/RESEARCH COMMITTEE

1. That the Report on Criteria for Mass Selection of Fuelwood Species developed by the Los Baños Workshop be adopted as an official document of the ERD Program and that this report be widely distributed.

2. That the provision for researcher exhange for the year April 1, 1981 - March 30, 1982 (ERD Year III) be modified for AS III (Fuelwood) to allow a coordinated development of a follow-up validation of fuelwood species selection criteria as applied in each country.

3. That the aforementioned proposed activity of AS III for "Validation of Criteria and Techniques for Mass Selection of Fuelwood Species" be adopted in principle by the ERD Program; that the proposal be refined and that the entire portion of the fuelwood Activity Set budget earmarked for exchange researchers in ERD Year III be applied to this proposal.

4. That the workshop approve in principle the RSI initiative, "Site Selection and Assessment Methodologies for Fuelwood Cropping" (see attached), if its funding does not compete with the activity outlined in 3 above. The proposal is reproduced below *in toto*.

SITE SELECTION AND ASSESSMENT METHODOLOGIES FOR FUELWOOD CROPPING

While considerable interest has been shown in the expansion of fuelwood resources by the systematic cultivation of tree crops in developing countries, implementation has been hampered by a lack of basic knowledge of the biological requirements - - soil, moisture, topography - - of candidate species. Even when these characteristics are fairly well understood, a further obstacle has been the lack of extensive field trials in biologically appropriate locations. Field trials are a necessary preliminary step before serious implementation effort can begin. This is a partly because critical factors in the natural environment may have been over-looked, but even more because the resource management requirements of fuelwood plantations are as yet largely undeveloped for likely tree species. The problem here is similar to one which frequently arises with other renewable energy technologies: the device may be technically adequate but may nevertheless fail if there is too great a mis-match with its socio-economic environment.

Considerable interest and expertise in the biological and managerial aspects of energy forestry based on Leucaena leucocephala exist in Hawaii, both at the University of Hawaii and the Environment and Policy Institute of the East-West Center. This subproject proposes RSI collaboration with colleagues in Honolulu and in selected Asian countries to undertake a program of research to fill some of the major information gaps outlined above.

The RSI contribution would be principally in 2 areas. First, preliminary atlas of priority zones for firewood crop species would be developed. Using the resources of the Benchmark Soils Classification Project at the University of Hawaii, LANDSAT imagery and other information, several variables critical to the successful cultivation of fuelwood plant species would be mapped as a first step in indentifying likely sites for field trials. Conditions suitable for Leucaena cultivation would receive first priority attention, but other candidate species would also be considered as appropriate.

Secondly, RSI would contribute in the development and testing of methodologies for identifying social and economic constraints which might affect implementation of fuelwood crop cultivation in rural Asia. In particular, farming and cropping systems research methodologies will be adapted to deal with some of the managerial and related problems of fuelwood cultivation. If such potential problems can be anticipated, it may be possible to select tree species or management alternatives which yield the highest probability of successfully implementing a program of fuelwood cultivation.

ABSTRACT OF PAPERS SUBMITTED BY WORKSHOP OBSERVERS

DESIGN OF THE FUELPRO MODEL

ERIC L. HYMAN[1/]

This project will lead to the development of a model for selection of woodfuels policy alternatives (FUELPRO) which will consist of two parts. In the first part, the present value of net benefits for each alternative will be calculated using the techniques of extended benefit-cost analysis. These benefits and costs will be grouped under a set of objectives.

In the second part, I will incorporate in a linear programming model a set of general weights previously derived in the Philippines for multiple-objectives evaluation. This model will be used to select an optimal mix of the policy options. It will state whether an option should be implemented and the proper scale of its implementation.

In other words, I will be considering a hypothetical forest/noncommercial energy management case for a single region on the assumption that the benefit and cost coefficients taken from actual projects in various locations can be generalized. Since a linear programming model is a static tool, I will also assume that the foresters, planners, economists, and engineers who designed the projects accounted for the dynamic nature of resource utilization in the project formulation stage. Thus, for example, the optimal rotation for plantation harvesting already would have been identified.

The linear programming model will contain constraints to ensure that certain energy supply and environmental quality goals are met within the resource limitation. There will be extensive use of shadow pricing to account for market prices which do not exist or do not reflect social values adequately. The computerized model will be flexible because the assumptions, constraints, shadow prices, and benefit-cost data can be varied in sensitivity analyses.

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Description of the Weighting and Scaling Procedure

The National Economic Development Authority of the Philippines (1976) devised a methodology for project ranking in conjunction with U.S. AID, an interagency team, the Development Academy of the Philippines, the Project and Planning Development Office, the Presidental Economic Staff, and public opinion surveys. The methodology is based on five social welfare objectives and relative importance weights (WT) for comparing effects (Table 1).

Table 1: Methodology for Project Ranking

Objectives	Relative Social Welfare Weight (%)
1. Promotion of Social Development	28.00
2. More Equitable Distribution of Income and Wealth	26.00
3. Maximum Feasible Economic Growth	19.00
4. Maximum Use of the Labor Force	19.00
5. Preservation of Environmental Stability	8.00
TOTAL	100.00

The next step is to define specific indicators for the evaluation of each objective. Then, relative importance coefficients (RIC) must be assigned to each indicator within an objective.

POLICY OPTIONS FOR SOLVING WOODFUEL ENERGY PROBLEMS

ERIC L. HYMAN[1/]

The woodfuels problem has two components: (1) the supply of energy basic needs for social welfare at acceptable cost, and (2) the maintenance of environmental quality and the sustained yield of natural resources. Additional objectives that should be considered include transfer of appropriate technology and education in resource use; equity in the distribution of personal and regional income;

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public health and safety; and institution building to improve the capacity to solve future problems. Conventional economic analysis must be modified because much traditional energy collectiong takes place outside of the market processes. A shadow price for woodfuels may be imputed by (1) travel and time costs in collection, (2) the alternative cost of the next cheapest energy substitute, or (3) expressed will ingness-to-pay for energy.

Four categories of policy options for solving both types of woodfuels problems are discussed in this paper. First, demand-side approaches reduce the shortage or the social costs of private consumption by decreasing the quantity demanded at each price (actual or imputed). For example, governments can modify the (1) availability and cost of substitute energy forms, (2) amount of energy consumed by changing lifestyles, and (3) technology of energy use including improved woodstoves and charcoal kilns. Two other factors, personal tastes and cultural preferences and the size and location of demander populations are less amenable to public policy. Demand can also be managed by increasing the price of woodfuels or internalizing environmental impacts.

Second, fiscal policies can be used. Instead of changing the supply or demand for woodfuels, these try to case the burden imposed on individuals by high energy prices.

Third, supply-side approaches augment woodfuel energy availability through increased production from natural or manmade sources. Increased output may be obtained by adding silvicultural inputs or by bringing more land under management through reforestation, private agroforestry, community woodlots, and commercial energy plantations.

Fourth, it may be necessary to deal with institutional arrangements such as the creation of property rights, regulation of activities that generate externalities, securing of social cooperation, and the establishment of user fees or development of markets. The paper concludes by discussing the constraints affecting the implementation of programs dealing with wood and charcoal energy.

WOOD AS AN ENERGY SOURCE FOR LESS DEVELOPED COUNTRIES

ERIC L. HYMAN[1/]

This paper begins by listing the characteristics of wood and charcoal and how they affect their convenience and heat value for combustion. It discusses domestic, commercial and industrial uses of

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woodfuels and the quantities used for each purpose in various countries. The next section treats the economic analysis of fuelwood as a marketed good including average prices in the Philippines and also as an extramarket good collected by users. Woodfuels consumption estimates worldwide are presented with special emphasis on Southeast Asia and the Philippines. Changes in the consumption of woodfuels and errors in the estimation of such data are discussed. The paper concludes by evaluating the potential for substitution of alternative forms of energy including biomass.

MEETING THE RURAL ENERGY DEMAND THROUGH FUELWOOD PLANTATION

BOEN MUCHTAR PURNAMA[1/]

Fuelwood has long been used traditionally as a prominent source of energy in the rural area. The present increase in fuelwood consumption is considered as one of several factors of environmental destruction.

The policy of the Indonesian government for the Energy sector comprises the saving of fossil fuel and the energy diversification through developing renewable energy sources. That energy policy will make the fuelwood play an important role as source of energy in the future.

Fuelwood plantation is a leading priority to solve the rural energy problems. The first step to be done is to pick out a suitable fuelwood specie. Several aspects, namely, technical as well as socio-economic aspects, must be taken into consideration in the selection of those species.

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SOCIO-ECONOMIC CRITERIA (A FOLLOW-UP PROPOSAL)

ERIC L. HYMAN

Socio-economic variables depend more on management strategies than on the seed and seedlings. Despite the evailability of good trees species, the fuelwood crisis persists because 1) forests are common property resources and people do not have incentives to conserve them, and 2) suitable incentives or institutions to encourage tree growing are absent.

The appropriate degree of management intensicification and labor versus capital-intensiveness will vary with the objectives and available resources.

1. The basic economic criterion is that the present value of net social benefits (gross benefits minus costs) should be maximized. Costs and benefits should be defined broadly to include environmental spillovers imposed by producers or consumers on those individuals or groups. The financial returns to private enterpreneurs must be attractive enough to induce sufficient investment and operation, maintenance, and replacement expenditures. If prices for competitive uses such as pulpwood and sawtimber are higher than firewood and charcoal, most trees probably will not end up being used for fuel. Marketability of woodfuels may require the establishment of new institutions,

   These economic costs include the cost of:

   a) purchasing land or the opportunity costs of using land that would otherwise be available for different uses
   b) site preparation,
   c) site maintenance.
   d) tree protection
   e) harvesting, and
   f) extraction and transportation

   The economic benefits include the value and transportation of fuelwood, charcoal, and other associated products. The benefits and cost will change over time with the demand and supply for woodfuel, which varies with cost and availability of substitutes and complements, income, population growth and urban-rural shifts, economics of scale and technology. Sensitivity analyses should be conducted varying the assumptions and

parameters. Related to the economic benefits and costs is the generation of supplementary or integral income for individuals, groups, and regions at the lower ranges of the distribution of income.

2. There may be other benefits and costs in social development. For example, the generation of productive employment and the ability to settle slash-and-burn farmers may lead to other benefits in education, health, self-sufficiency, and community welfare. Religious and ceremonial uses or taboos for certain tree species may be important social constraint in some areas.

3. It is also important to consider the technology of use in addition to production. In some cases, improved wood-stoves and charcoal kilns may be more cost-effective than production of more trees in providing wood energy and decreasing the drain on local forests. The technology of use must be evaluated together with cultural acceptability. Cultural preferences relate to the method of burning, requirements for auxiliary equipment, real and perceived safety and convenience, skill requirements and complexity, storability of wood energy and compatability with existing practices.

COMPOSITION OF VARIOUS GROUPS

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