Fuelwood as a Renewable Energy Resource

Harry R. Clarke and Ram. M. Shrestha

Industrial Engineering and Management Division
Asian Institute of Technology
Bangkok, Thailand

INTRODUCTION

The problem of increasing fuelwood[1] scarcity in developing countries has emerged as a major concern for energy planners and development economists: for discussion see Earl [1975], Tillman [1978], Eckholm [1980], Gamser [1980], Openshaw [1980]. These studies show that fuelwood is a major energy source in many developing countries with levels of fuelwood dependence often being highest in the poorest of such countries and, in particular, in the rural sector of these countries. With growing population and increasing prices of substitute commercial fuels, the demand for fuelwood is often seen to exceed its sustainable supply thus making problems of scarcity progressively more severe and increasing the hardship of the rural poor. In the words of a recent report, rural populations are facing a "second energy crisis" (World Bank, 1980, p. 38) which stems from the lack of adequate fuelwood supplies.

In fact forest lands are subject to increasing pressure, not only for fuelwood but also for their timber resources and for their use as agricultural land. Clearly, since planning for fuelwood supplies needs to account for these alternative land uses, fuelwood policies cannot be considered in isolation from overall rural development planning. Despite this, most of the literature on fuelwood is descriptive rather than policy-oriented and fails to consider both the issue of alternative land uses and the potential role of substitute commercial fuels.

The present paper considers the problem of increasing fuelwood scarcity as a renewable resource management issue. Appropriate policies for dealing with deforestation are shown to depend on whether fuelwood collection procedures have a market valuation or not. If they do, then pressure on forest resources can be reduced by subsidising the prices of competing commercial fuels. If they do not, then it may be essential to enforce effective property rights on fuelwood resources to maintain desired forest stocks. Section 2 below discusses the fuelwood consumption and supply situation in developing countries with particular reference to the Asian region. Section 3 discusses some policy issues that arise from the fuelwood crisis. Section 4 summarises the role of fuelwood in the formulation of energy plans for developing countries. Section 5 concludes with some final comments.

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(1) There are different approaches to defining "fuelwood". Some authors define fuelwood to include only 'stem and main branch material produced when a tree is felled' (Douglas [1982, p. 670]). Gamser [1980] on the other hand uses the term to indicate any of a number of forms whereby wood raw materials can be used to obtain energy through combustion. The latter broad definition is adopted here.

FUELWOOD CONSUMPTION AND SUPPLY

The level of dependence of countries on fuelwood has historically been associated with the level of economic development achieved. For example, in the United States in 1850, woodfuels constituted about 91% of total national energy consumption. In 1975 the figure had dropped to 1% (Griffen and Steele, 1980, p. 11). As economic development proceeds it is generally observed that fuelwood consumption decreases as it is replaced by more convenient commercial fuels and electricity. Fig. 1 illustrates that developing countries are much more dependent on fuelwood than industrialised countries, with levels of dependency generally, increasing with lower levels of economic development as represented by GNP per capita.

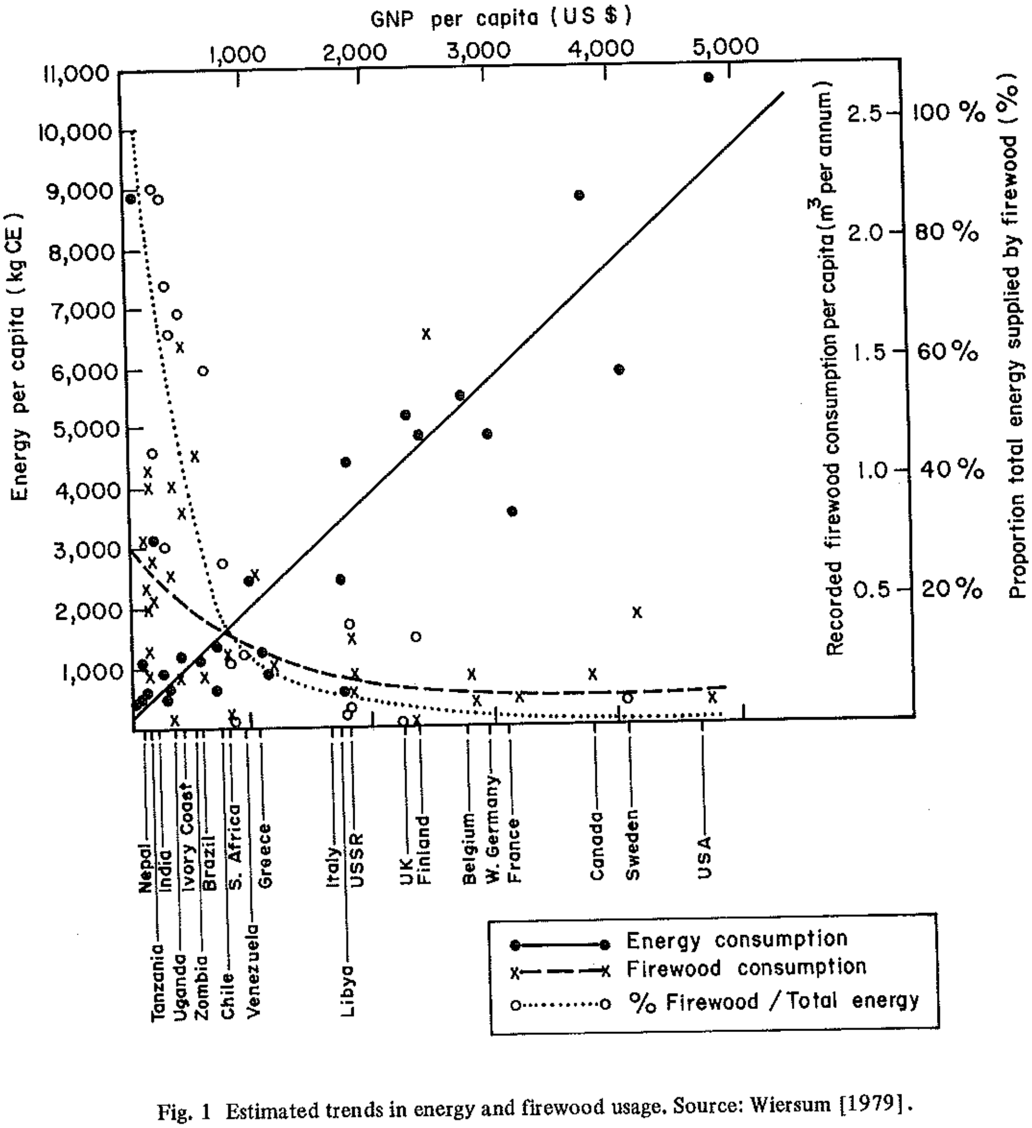

Fig. 1 Estimated trends in energy and firewood usage. Source: Wiersum [1979].

At the global level, woodfuels form only 6% of total world energy consumption, with more than 90% of total energy demands being met by commercial fuels. While this may lead one to doubt the overall significance of woodfuels, it should be noted that in developing countries where absolute levels of energy usage are relatively low, the relative importance of woodfuels is much higher. Fuelwood and charcoal formed about 29% of total energy consumption in developing countries in 1980(2) (United Nations, 1981). Furthermore, according to the World Bank [1981], in terms of household energy usage, fuelwood together with agricultural residues and dung continues to be the major fuel source for more than 2 billion people in developing countries.

There are five major reasons for the widespread use of fuelwood in developing countries: (i) open access to fuelwood resources, (ii) non-availability of substitute fuels, (iii) the low purchasing power of users, (iv) the costs of complementary durable goods, and finally (v) widespread conditions of surplus labor in developing countries. It is worth discussing these issues briefly:

(i) **Open Access.** Traditionally fuelwood supplies in developing countries are collected as free goods by users. Villagers in rural areas may, for example, have free access to a village woodlot. If woodlots do not exist then villagers typically collect fuelwood from neighbouring forests where property rights either do not exist or else are not effectively enforced by the owners of the fuelwood resource.

(ii) **Non-Availability of Substitutes.** The heavy dependence on woodfuels in developing countries, particularly in remote areas of these countries, may simply be due to the fact that commercial fuels are unavailable. For example only about 35% of the total population of the developing countries, and only about 15% of the total rural population of these countries, are connected to an electricity grid (World Bank, 1981, p. 4). Fuels like coal, although available in many developing countries, involve high costs of transportation and distribution which limit their role, particularly in rural areas.

(iii) **Low Purchasing Power.** The rural poor in many cases simply cannot afford to buy more convenient and efficient commercial fuels, even when these are available due to their low purchasing power. It has been estimated that by 1985 about 25% of the rural population in developing countries will have electricity within reach, but that only one half of this group will be able to afford it. Furthermore, if rural electrification continues to increase at the current rate, about 75% of the rural population of developing countries will still not use electricity in their homes by the year 2000 (Brown *et al,* 1981). The purchasing power constraint prevents people from substituting commercial fuels for fuelwood.

(iv) **Cost of Related Durables.** This factor is clearly related to the purchasing power constraint discussed above. As energy-accessing devices, fuelwood stoves are attractive since they are practically costless compared to kerosene, LPG and electricity-using stoves. This provides an incentive to continue using traditional fuels. Furthermore initial costs are relatively high for connecting households to electricity supplies. For example, in Thailand the cost of connecting and metering a household was estimated to be about 1885 Baht (≈U.S.$84). This is a significant percentage of rural per capita incomes, and again provides an incentive for the continued use of non-commercial fuels (for discussion of the Thai electrification program see the Provincial Electricity Authority, 1980).

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(2) Total energy consumption here is defined to be the aggregate of commercial energy, woodfuels and bagasse used.

(v) **Surplus Labor.** Even though fuelwood is frequently collected under conditions of open access (i.e. as a free good) there are still always individual subjective costs in terms of time and effort in actually collecting wood. It might be argued therefore that more convenient, clean and efficient commercial fuels could become competitive with fuelwood as energy sources even if the commercial fuels are not free goods. The idea here is that people collecting fuelwood would compare the opportunity cost of time spent collecting fuelwood with the cost of alternative fuels. The problem here is that although the opportunity cost of collecting fuelwood can be measured in terms of time spent collecting, such time will not have a monetary value unless the individual can convert this time into an income earning activity. In fact, apart from the harvesting season, a significant proportion of the rural population in many developing countries is unemployed for much of the year. This surplus labor has zero opportunity cost in monetary terms. This feature of rural life, together with the open access of individuals to forests, contributes greatly to the use of woodfuels.

The countries of Asia, because of their wide divergencies in levels of economic development and patterns of energy resource endowment, provide an interesting example of the fuelwood problem. As shown in Table 1, the share of woodfuels in energy consumption, although generally substantial, varies widely among the Asian countries: it ranges from 25% in Malaysia to 96% in Nepal. Excluding centrally planned economies, Montalembert [1982] estimates the share of fuelwood in total Asian energy consumption to be 40%. The data on woodfuel usage is highly imperfect since fuelwood is mostly collected by final users, so levels of consumption remain largely unrecorded. The use of Landsat technologies may eventually lead to better data becoming available: until it does we must rely on currently available, although imperfect, information from sample surveys and so on.

Table 1 also makes it clear that, excluding China and the oil exporting countries Indonesia and Malaysia,(3) the countries of Asia have a substantial dependence on imported energy (specifically imported petroleum products). At the same time, while imported commercial energy is absorbing a substantial proportion of these countries' export earnings, many are facing substantial firewood problems. Rates of deforestation are very high in Thailand for example: according to Sirivandhanakul and Tadyu [1982] the percentage of the total land area occupied by forests fell from 53% in 1951 to 25% in 1977. In Nepal, where fuelwood accounts for virtually the entire national energy supply, it has been reported that more than 25% of the total forest area has disappeared between 1950 and 1975 (ESCAP, 1982). In Sri Lanka the forest cover has been reduced from 44% in 1956 to about 20% at present (Revelle, 1980).

With increasing population the pressure on forest land will continue not only as a fuelwood source but also for agriculture and timber. In fact while Montalembert [1982] estimates that fuelwood collection constitutes about 85% of the total round-wood(4) removals in Asia, data on deforestation due to cultivation are difficult to determine. At the global level, the deforestation rate in developing countries is estimated to be 1.3% of the total forest area or 10-15 million hectares of forest per year (World Bank, 1980). Again it is difficult to determine how much of this deforestation is due to fuelwood collection and how much to increased demands for agricul-

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(3) Energy import figures in Table 1 for Malaysia and Indonesia do *not* indicate that these countries are net energy importers. In fact these countries have a policy of exporting "high grade" fuels and meeting their domestic fuel demands by importing low grade fuels.

(4) "Roundwood" is used here to refer to all tree trunks and branches.

Table 1
Fuelwood and Other Energy Consumption in Selected Asian Countries

Country	Rural population as a percentage of total in 1980[1]	Energy Consumption in 10^3 metric tons of coal equivalent in 1980[2]				Fuelwood & charcoal as a percentage of total consumption*	Energy imports as a percentage of merchandise exports in 1978[3]
		Commercial	Fuelwood & Charcoal	Bagasse	Total		
Bangladesh	89	4,059	3,236(+)	148	7,443	43 (+)	35
Burma	73	2,217	7,966	34	10,217	78	N.A.
India	78	126,439	69,001	4,810	200,252	34	27
Indonesia	80	33,341	43,764	1,237	78,342	56	5
Korea, Rep. of	45	54,326	21,908	–	76,234	29	19
Malaysia	71	11,258	3,672	61	14,991	25	9
Nepal	95	160	4,349	13	4,509	96	N.A.
Pakistan	72	17,987	6,066	747	24,800	24	40
Philippines	64	15,856	8,658	2,147	26,661	32	32
Sri Lanka	73	1,544	2,350	23	3,917	60	18
Thailand	86	17,215	11,036	1,168	29,419	38	28

1 Source: Calculated on the basis of data on percentage of urban population provided in World Bank [1981 (a)].
2 Source: United Nations [1980].
3 Source: World Bank [1981 (a)].
* Figures rounded to the nearest integer.
\+ These estimates appear to be rather high. According to the Bangladesh National Planning Commission fuelwood consumption is estimated to be slightly above 1 million metric tons (Rahman, 1982).

tural land. It seems certain however that fuelwood gathering is a major source of deforestation.

Fuelwood scarcity and deforestation have already had serious consequences in many parts of the developing world. In the Asian region, Montalembert [1982] classifies about 31 million people living in northern Afghanistan, India and Nepal as facing an *acute scarcity situation* where existing fuelwood resources have been depleted to the point where people can no longer obtain sufficient fuelwood currently even with excessive rates of fuelwood depletion. A further 288 million people living in the Indo-Gangetic plains of Central Asia (Pakistan, India and Nepal) and 263 million people in South and South-East Asia (Bangladesh, Southern India, Central Thailand, Java etc.) are facing *deficit situations* where fuelwood resources can meet minimum fuel needs only by depleting the resources at rates which exceed their sustainable supply. Finally there are a group of countries (Bhutan, Burma, Laos, Malaysia, Papua, parts of Indonesia and the Philippines) where fuelwood supplies remain in a *satisfactory situation* where there will still be adequate supplies through to the year 2000.

There are thus in Asia wide differences in the extent of the fuelwood problem between countries. The problem is particularly severe in those countries which are energy importers. With

Table 2

Fuelwood Consumption with Estimated Costs of Substitution by Coal

Country	Fuelwood & charcoal consumption in 1980[1] (10^3 m.t.c.e.)	Estimated cost of substituting woodfuels by coal[2] (million US$)	GNP in billion US$ in 1980[3]	Estimated cost of substituting woodfuel, as % of GNP
Bangladesh	3,236	158	11.16*	1.4+
Burma	7,966	391	5.91*	6.6
India	69,001	3,388	159.90	2.08
Indonesia	43,764	2,149	69.00	3.11
Korea, Rep. of	21,908	1,076	56.50	1.90
Malaysia	3,672	180	22.93	0.78
Nepal	4,349	213	1.94*	10.97
Pakistan	6,066	298	25.73	1.15
Philippines	8.658	425	35.27	1.20
Sri Lanka	2,350	115	N.A.	–
Thailand	11,036	541	32.84	1.64
China	50,184	2,646	N.A.	–

1 Source: United Nations [1981], m.t.c.e = metric tons of coal equivalent.
2 Calculated assuming the delivered cost of coal is $10/barrel of oil equivalent.
3 Source: International Monetary Fund [1982]. Conversion from figures in national currencies to US dollars made by the authors.
* GDP values, since GNP figures are not available.
\+ The woodfuel consumption figure seems high here. See also the note to Table 1.

increasing deforestation, levels of energy import dependence will increase. Table 2 shows the estimated cost of substituting fuelwood consumption in selected Asian countries by coal in 1980, assuming the delivered price of coal is $10 per barrel of oil equivalent. As already mentioned, the data on fuelwood consumption in developing countries are generally weak so that the attempt to estimate what such costs would be may also be subject to considerable inaccuracy. Certainly the costs of substituting alternative fuels for fuelwood in many of the countries considered would appear high both in absolute terms and as a proportion of GNP. At the global level, if all developing countries using traditional fuels were to switch to kerosene, their demand for oil would rise by between 15 to 20% (World Bank, 1980, p. 38).

POLICY ASPECTS OF THE FUELWOOD PROBLEM

The major consequences of the demand for fuelwood exceeding its supply are experienced in terms of (i) increased costs of fuelwood, (ii) increased human costs of fuelwood collections, (iii) environmental degradation through soil erosion and flooding, and (iv) reduced land fertility through the diversion of agricultural wastes and animal dung. These are now discussed in turn.

First, with regard to costs, when firewood is sold in a market its increasing scarcity will place an increasing burden on the resources of its users, in particular the rural poor. In some cities of the wood-scarce Sahel it is estimated, for example, that expenditure on wood-fuels constitutes between 1/3-1/4 of the average manual laborer's income (Dunkerley, 1982). Even if fuelwood is not sold in a market, there are substantial human costs in its collection. In many developing countries women and children carry out the task of collecting fuelwood. With increasing scarcity, this work is becoming more difficult: for example in the village Dwing in Garhwal India, women of all ages walk at least 10 km up and down steep Himalayan mountain slopes three days out of four for average periods of seven hours in order to secure fuelwood supplies (Agarwal, 1982).

The environmental and agronomic consequences of fuelwood depletion may also be severe. Accelerated deforestation has led to ecological disasters such as increasing desertification in Sub-Saharan Africa and substantial soil erosion/flooding problems in Nepal and India. Apart from reducing possibilities for agricultural production, erosion also has a host of secondary consequences, such as accelerated siltation problems in reservoirs.

Finally, with increasing fuelwood scarcity the rural poor frequently switch to the use of agricultural wastes and dung as energy sources. Diversion of materials for use as fuels in this way will in the longer term have serious effects on the fertility of soils. In India alone, 60-80 million tons of dry dung are burned annually as a fuel source. According to Eckholm [1980] this is equivalent to about 1/3 of the total chemical fertiliser used in this country. Overall the use of cow dung for fuel by developing countries is estimated to cost these countries about 20 million tons of food grain annually (World Bank, 1981, p. 2).

With the substantial economic, human and environmental costs of deforestation it might appear that the policy problem for planners in developing countries is simply to *restrict* the use of fuelwood resources. This ignores however the benefits that may stem from alternative land uses such as agricultural production or growing energy crops such as sugarcane for the production of liquid fuels.(5) Moreover, choice between these alternative land uses is not a simple issue: for example there may be a complementary relation between agriculture and the use of land for growing forests.(6)

With growing population and limited availability of land, it may not be realistic to rely heavily on fuelwood as an energy source. Apart from the case of marginal agricultural land, the benefits in converting forests to agricultural land may be higher than those yielded by wood production. For example according to Revelle [1980] the annual value of wood production in Thailand was estimated to be $91 per hectare, whereas the corresponding value of rice production on the same land would be $400 per hectare. Under these conditions there is a strong economic incentive to clear land for agricultural production and to use the revenue generated from this production to meet the cost of imported commercial fuels.

Clearing all forests for food cultivation is an extreme policy, however, since it neglects the social costs of deforestation e.g. environmental costs associated with flooding, erosion and desertification. These latter costs although undoubtedly important are difficult to quantify: what is needed is some method for establishing, at the regional level, minimum safe levels of forest re-

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(5) The ethanol program in Brazil and gasohol production schemes in the U.S. are other examples: for discussion see Flaim and Hertzmark [1981].

(6) This complementarity may arise in a number of ways: forest cover helps prevent siltation problems in irrigation schemes. It can also under certain circumstances serve as a windbreak for grain crops.

sources which will offset these environmental problems, and for the division of a country's remaining land resources between forest and agriculture to be decided on the basis of some social cost-benefit analysis which accounts for the differing agronomic characteristics of land in different areas.

A practical problem in implementing a "minimum safe level" type of policy is that while forests are mainly state-owned in developing countries, rural people enjoy virtually "free" or "open" access to these forests because of a failure to adequately *enforce* property rights. This has major implications for fuelwood supplies in the long-run. The accepted economic theory of "open access" resources states that economic agents (firms, households) will continue to exploit such resources until the net economic rent from such resources is completely dissipated.(7) In the context of surplus-labor developing economies, where the economic costs of using labor to collect fuelwood may approach zero, the interesting question arises as to why forests have *not* in fact been completely wiped out. This seems to have been due to three types of factors. First, markets for fuelwood in the proximity of forest land may not exist, so collection of wood will be limited to the level of a household's own energy needs.(8) Second, there seems a quite strict complementary relation between food consumption and fuelwood usage, which means the demand for the latter is bounded whenever food demands are bounded. Finally, even if markets for fuelwood *do* exist so people have an incentive to collect wood not only for their own consumption but also to sell at market, the expected cost of being detected poaching firewood from a state-owned forest increases as the frequency and volume of firewood collection increase.(9)

FUELWOOD AND ENERGY PLANNING

Having discussed the problem of open access to forests, we now wish to focus directly on the issue of desirable management policies. Initially consider a situation where property right *can* be enforced on forest stocks, with these stocks being subject to sole ownership. We are then left with a forest management problem of the type analysed by Clark [1976]. This author considers optimal biomass harvesting mainly in the context of fisheries, but his analysis is general enough to be extended to other renewable resources such as forests. The problem formulated for the sole owner (or decision-maker) is to determine harvesting policies for a forest when the objective is to maximise the discounted net present value of the resource. Clark's analysis determines a *long-run desired forest stock* (LRDFS) and a corresponding stationary wood harvesting rate. The optimal transition to such a desired stock is via a *most rapid approach path,* so as the stock is higher than (less than) the LRDFS, the resource should be exploited at maximum (respectively, minimum) rates until the LRDFS is attained.

The case where the initial forest stock is less than the long-run desired stock is a natural

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(7) The theory of common property resources (or more accurately, "open access" resources) is well documented in the resource economics literature (Gordon, 1954; Scott, 1955).

(8) Note that because of its bulk, fuelwood has a relatively low value per unit volume and weight. This means that, even if markets for fuelwood do exist, they will be localised because of high transport costs. It also suggests that, even where fuelwood is collected for use by final end-users, there will be geographical restrictions on the feasible collection area. For example, according to an Indian study, fuelwood is not generally collected more than 15 km from the end-use site (Hughart, 1979).

(9) Formally one might wish to account here both for the effect of fuelwood demands on desirable levels of property right enforcement and for the effects of increased enforcement on poaching activities.

situation to consider in relation to deforestation issues.[10] The analysis of Clark, however, is strictly dependent on the assumption that property rights *can* be enforced on the forest resources. If property rights cannot be enforced then the form of the appropriate energy policy response can be seen to depend on whether fuelwood collection procedures have a positive market valuation or not. If they do have a positive market valuation (i.e. if the time taken to collect fuelwood can be used to generate income by either selling fuelwood or through other activities) then the optimal policy program suggested by Clark can, with certain reservations, be approached via a tax-subsidy policy which reduces the effective economic cost of substitute commercial fuels such as kerosene, LPG and electricity. In the present case, providing a subsidy for a substitute resource would help reduce the use of renewable fuelwood resources and allow their stocks to attain LRDFS levels more quickly. In fact fuels like kerosene and even electricity *are* subsidised in many parts of the developing world in order to reduce pressure on forest resources.[11] Effectively authorities attempt to reduce user-prices of commercial fuels below the collection, access and detection avoidance costs for gathering non-commercial traditional fuels.[12]

There are three major reservations that can be raised in relation to the feasibility/desirability of such tax-subsidy policies, even if collection times do have a market valuation. First note that as forests regenerate, assuming collection costs are negatively related to the size of forest stocks, the size of necessary subsidies will increase. This seems an implausible policy in the longer term. Second note that if collection costs are low, subsidies and thus taxes may need to be unrealistically high. Finally note that while subsidies for kerosene, for example, might be justifiable in term of forest management objectives, this type of policy has a relatively non-specific impact since non-target groups, such as industries which use kerosene as an industrial input, will in general benefit from subsidies. These groups may *not* be contributing to the fuelwood problem, and subsidies on crucial inputs will only foster allocative inefficiency within such industries.

The major practical problem with tax-subsidy schemes of this type in developing countries, however, is simply their reliance on the assumption that fuelwood collection procedures *do* have a market valuation. In fact, in poor rural areas, fuelwood has a very limited market since it is mainly collected as a free-good. Moreover, since in many developing countries labor is in surplus supply for most of the year (the exceptions being the planting and cropping seasons), the opportunity cost of individual worker labor will often be close to zero. Under these conditions the labor time used in collecting fuelwood has virtually a zero market valuation, so rural communities will tend to continue to use fuelwood *even if* substitute commercial fuels are "cheap". In more direct terms, subsidies will be ineffective now because of purchasing power constraints: these effectively

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(10) The policy implications of *under-utilised* forest stocks in energy planning are also interesting. Where stocks are underutilised, presumably due to accessibility problems or high transport costs, policy alternatives such as power generation from dendrothermal plants, methanol production from wood and charcoal production suggest themselves. The charcoal option has been widely adopted in recent years: for example in Sri Lanka. Dendrothermal plants have been set up in the Philippines and Hawaii. By 1985 Rosario [1980] estimates the total power generated by dendrothermal power schemes in the Philippines as 114 MW.

(11) In many developing countries a major argument in favour of subsidising kerosene and electricity is the effect of such policies in reducing pressure on forest resources: see for example World Bank [1980], Wijarso [1980].

(12) One could also consider here the possibility of subsidising other *non-commercial* fuel producing programs such as biogas plants. A number of countries such as India and Thailand have subsidised such schemes to help reduce the pressure on renewable non-commercial fuels such as forest stocks.

trap people into using non-commercial fuels since, even though collection involves substantial time and effort, this time and effort cannot be converted to a cash-earning activity that would permit the use of more convenient and cheaper commercial fuels.

It remains to suggest useful policy measures when there is both a failure to enforce property rights on a forest resource and conditions of surplus labor, so collection of fuelwood has a zero economic valuation. The direct proposal to establish property rights by, for example, assigning "woodlots" to village communities has proven to be of value in some countries. It is often described as a "community forestry" approach since it ultimately depends on some collective agreement within villages on the proper usage of a common property resource.(13)

Another useful policy can be the widespread distribution of more efficient wood-burning stoves. In fact this type of policy may be useful even if fuel subsidy policies are feasible since, unlike this latter policy, the subsidisation of durables can be directed to the target group of fuelwood users alone. If the fuel efficiency gains are sufficient there may be significant reductions in the consumption of fuelwood without any reduction in per capita final energy usage levels.(14) It must be recognised here that educating and motivating people to use such stoves may demand considerable effort and cost.

CONCLUSIONS AND FINAL COMMENTS

Fuelwood continues to be a major energy source in many developing countries. In some cases these countries will be net commercial energy importers so the use of fuelwood can be viewed as reducing their imported energy dependence. With increasing demands for fuelwood and increasing demands for agricultural land, forest stocks are in some areas being rapidly depleted, leading to acute deforestation and fuelwood scarcity problems. In such countries, planners face the immediate task of providing alternative energy supplies. In many other cases the switch to alternative commercial fuels appears eventually inevitable but fuelwood will serve as a useful "stopgap" until such alternative supplies are developed.

Increasing fuelwood production by extensive afforestation and commercial cropping of fast growing trees is technically feasible. With growing population the important issue in densely populated developing countries is the optimal allocation of land between energy and food production. In particular, is it desirable to convert forest lands into agricultural land and to then substitute the use of fuelwood by other fuels? As there exist a wide variety of land types, in terms of soil fertility and suitability for cultivation, there is no simple either/or solution here. For example food production on marginally fertile land may bring about less social benefits than growing

(13) In Nepal for example, community forestry schemes have been introduced under the management of the *panchayats* which are administrative units covering several villages. For discussion see ESCAP [1982]. One might also consider here the policy of establishing *effective* property rights on state-owned forests by simply selling or leasing such forests to the private sector. The argument here is that private agents will have a vested interest in enforcing property rights and will thus do so more efficiently. This policy is currently being implemented in Thailand to prevent illegal logging and deforestation (*Bangkok Post*, Monday September 18, 1983, p. 2).

(14) In many developing countries many households use conventional (open hearth) wood-burning stoves which have efficiencies in the range 5-10%. Research on the development of more efficient stoves is taking place in many countries. The Indian "Junagadh" stove is reported as having efficiencies of up to 30%, the Indonesian "Singer" stove of 27% etc. (Hughart, 1979).

trees. There are also arguments that increasing deforestation, by increasing levels of imported fuel dependence, will impose permanent balance of payments penalties on energy importing countries. But this is not true so long as the economic yield in terms of export revenues of deforested land is higher due to the higher value of food production. Thus the issue of increasing or decreasing fuelwood supplies is closely interwoven with that of determining desirable patterns of land use.

Optimal forest management policies, including the plantation of fast growing species, are desirable goals, but they are goals which may prove difficult to achieve unless there is adequate enforcement of property rights on forest resources. There are no incentives for commercial cropping, or indeed the use of other non-commercial technologies such as biogas, when there is open access exploitation of forests and surplus labor conditions.

Although fuelwood will continue to be an important energy resource in the short-run, it may have only a limited role to play in long-run energy planning in developing countries, since with land availability as a major constraint, substitute fuels which do not require land and substitute land uses such as food production may rule out the long-run economic viability of substantial areas of fuel-providing forest.

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