Chapter 8

Technologies to Reduce Overcutting Wing

Contents

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HIGHLIGHTS

Industrial Wood

- If the world demand for wood is to be met without eventually depleting all the accessible tropical forests, practical alternatives to cutting extensive areas must be developed.
- To implement alternative approaches, profitable technologies to harvest, process, and market a wider range of tree species and sizes must be developed. The U.S. Forest Products Laboratory has made and can continue to make significant contributions in developing such technologies.
- Intensive harvesting schemes, such as harvesting all merchantable-size trees from a narrow band of forest, need experimentation and evaluation for economic and silvicultural feasibility and environmental effect.

Wood Fuels

- Overexploitation of forests for firewood and charcoal is increasing. This could be alleviated by enhancing the efficiency of wood use and by substituting alternative energy sources.
- Improved stoves and more efficient charcoal production can conserve wood supplies, but effective technology diffusion requires extensive field testing and careful consideration of social and economic factors.
- Efforts to develop and apply nonwood renewable energy sources are uncoordinated and generally underfunded, but have considerable potential to reduce fuelwood demand.
- Widespread implementation of fuelwood plantation techniques is constrained by sociocultural and economic factors.
- Actions that reduce demand for fuelwood can also reduce incentives to invest in future wood supply. Thus, such actions must be planned carefully with respect to efforts to increase supply through fuelwood plantations.

INTRODUCTION

Exponentially increasing demand for wood for both commercial and fuel uses is contributing to deforestation and resource degradation in both undisturbed and secondary tropical forests. Industrial wood users will buy only a few of the many species that grow in tropical forests. As a result, extensive areas must be "selectively cut," causing severe damage to the unharvested trees and to the soil. The practice also opens extensive areas to inappropriate settlement by farmers. More species *are* used for fuelwood, but fuelwood is being cut much faster than it is grown.

Technical solutions to these problems include methods to increase the efficiency and intensity of harvesting industrial wood so that less extensive areas need to be cut and methods to make wood use more efficient so as to reduce demand.

INDUSTRIAL WOOD: EXPANDING NUMBRR OF SPECIES AND SIZES HARVESTESTED

Background

If the world demand for wood is to be met without eventually depleting or degrading all the accessible tropical forests, alternatives to extensive selective cutting must be found. Tree harvesting and management on small areas can reduce the need to cut wood on other sites. This requires profitable technologies to harvest, process, and market a wider range of tree species and sizes than is the case today. Using a wider range of tree species could lead to destruction of tropical forests and the depletion of soil fertility.

Harvesting, Transporting, and Handling

Improvements in harvesting methods, transportation, and handling can make substantial contributions to the improved use and management of tropical forests. Likewise, the availability of technologies, the amount of planning, and the commitment to management all can reduce the logging damage to residual forests.

The residual vegetation left in a tropical forest after logging is often severely damaged—usually about 50 percent of the remaining forest is adversely affected. Considerable loss occurs during felling and extraction. Furthermore, about one-third of the logged area typically suffers erosion as a result of soil compaction by heavy equipment (6). A major improvement in harvesting practices is possible simply by matching the appropriate practice to particular site conditions to minimize environmental damage.

Intensive harvesting (clearcutting) of small areas reduces the number of roads built, and so reduces road-induced erosion and access by agriculturalists. If fewer roads are built, more capital could be available to improve existing roads and to purchase suitable trucks and hauling vehicles.

Clearcutting, on the other hand, could increase nutrient depletion and reduce biological diversity. Erosion is likely to be severe on clearcut sites during and immediately after logging, and if logging is followed by fire, erosion is even greater (6). In addition, the quality of secondary forests and their suitability for both economic use and as habitat capable of maintaining biological diversity are largely unknown. Intensive logging of tropical forests has significant adverse impact on animal life that is sensitive to microclimate and food supply changes. Other animals, however, can survive in logged forests (12).

Opportunities exist to experiment with various practices that would minimize negative impacts of intensive harvesting. A technique that warrants field testing is the harvesting of all merchantable size trees from narrow bands of forest followed by natural and/or artificial regeneration. If harvested strips are oriented along contours and kept quite narrow (approximately 100 meters), many of the disadvantages of clearcutting may be avoided, Animals still would have access to a large forest habitat, recolonization of plants from surrounding forest would be enhanced, and the soil microorganism populations, which play a crucial role in the physical-chemical properties of tropical soils, probably would be quickly reestablished after logging. This method, however, has economic and engineering drawbacks that limit its commercial appeal (7).

Harvesting technologies that can reduce forest damage include the use of improved cable logging systems, hand tools, self-loading trucks, and large skidder vehicles to reduce the need for crawler tractors. Efficiency in handling can be improved if equipment is selected to match the character of the particular site.

Simply applying existing knowledge about the transport and storage of logs and lumber could reduce losses from mold, stains, insects,

Photo credit: Dr. Miedler, FAO

Selective logging to remove only the most commercially valuable trees can lead to resource degradation because the remaining trees are typically damaged by felling and extraction operations. Also, as more roads are built, erosion problems increase and new areas are opened to shifting agriculturalists

splitting, decay, improper drying, and damage from poor handling practices (32). At present, large quantities of logs deteriorate at roadsides. This occurs in Burma, South India, Bangladesh, and other places where roads are impassable during the rainy season (11).

To encourage responsible management, tropical countries could institute longer term licensing agreements with logging concessions, together with tax incentives. With longer agreements, for instance, operators would have incentive to build roads to a higher standard because they could amortize the costs over two logging cycles (11).

Use of More Tree Species and Sizes

Markets

A variety of factors—some biological, some commercial, and some logistical—interact to determine how intensely a forest is exploited, including the composition of the forest, the form of the trees, and character of their wood (11). Selective logging is common in closed tropical hardwood forests in part because use of such forests has been export-oriented. Export markets require large quantities of a uniform product, preferably a single species of good appearance. Thus, very few species and only large logs were acceptable.

When only select individuals of a few tree species are logged in most tropical forests, forest resources are degraded. This damage could be reduced if more species were used and if the size and form criteria were less limiting.

Considerable research has been conducted on lesser known tropical tree species. The physical and chemical properties of tropical timbers are assessed according to their wood processing use. However, the results of this work are scattered and frequently unknown to wood users (26).

Many lesser known tree species have disadvantages that are difficult to overcome, such as poor form, extreme hardness or abrasiveness, unacceptable loss of quality in drying, and lack of durability (11). The rectification of these features can be costly. Thus, importing countries are reluctant to take such species when well-known tropical woods and temperate softwoods are available at acceptable prices.

Standardized descriptions of wood properties and units of measurement, together with some classification system that distinguishes degrees of suitability for specific purposes, are basic marketing requirements. Standardization and grading are complicated because wood products have a great degree of variability and versatility. Inadequate lumber standards contribute to inefficient tropical lumber marketing and use in both producing and importing countries. Without a grading system directed toward efficiency of use and without prices that correspond to quality, the tendency is for local wood users to demand higher quality material than the end use requires. This puts added demand on forests for high-quality material and often unnecessarily removes tropical forest products from export markets. It also limits local markets from fully using lower grade lumber and contributes to high prices (26). Thus, improved standardization of dimensions and grades could minimize waste, reduce product cost, and increase the profitability of intensive forest management.

A prospect for increasing the use of lesser known species and smaller trees is to group species according to their capacity to meet specific end use requirements—e.g., group all species suitable for construction material together (11). Species could then be marketed by group instead of by species name. But first, performance requirements for various end uses must be identified and systems of matching properties to those requirements must be developed.

Firms in Australia and Great Britain are experimenting with end-use grouping of timber. The Australians devised 12 general end-use categories, each referenced to a well known and widely used wood species to compare new species or species groups with the reference wood (14). The British classification system is more elaborate. It identifies the specific wood properties required for each major wood use and identifies the available timbers with required properties at acceptable and preferred levels. Flexibility is provided by indicating special processing technologies that can be applied to species rated below the preferred level. Timber lists can be expanded as available timbers with established properties become available (4).

In the short term, the end-use approach may be better for local timber markets in tropical countries, particularly in those countries where the forest resources are small or have been depleted. Demand from the export market will come when other sources cannot meet the price, quantity, and quality specifications (11).

Preservatives

Some tropical woods with generally satisfactory physical properties are not used, or they give poor service, because they are susceptible to attack by termites, other insects, or fungi. For example, the sapwood of many durable species is perishable and usually is cut away. With smaller size trees, the portion of sapwood is greater and the waste in conversion is often so large that they are not used.

Many wood preservatives are available, together with a range of techniques for applying them, to counter different degrees of hazards. Some of these technologies—e.g., impregnation with creosote through pressure cylinders—are effective for timber in contact with the ground. But they require considerable expenditure on equipment and chemicals, and creosote is now difficult to obtain. Other techniques, such as pressure treatment with water soluble copper-chrome-arsenic compounds, though less costly and suitable for wood in some forms of construction, are still considered expensive (11). This confines their application to public works and to higher cost construction.

Simple and inexpensive preservative treatments for wood used at the village level and in low-cost urban housing need to be developed and promoted. At the village level, the social and economic benefits of wood treatment could be considerable. In the hot, wet Tropics, a treatment that increases the life of a simple wooden house from 5 to 10 years could reduce by half a villager's time spent on building and rebuilding (17). For simple techniques that already exist, information is needed on the performance of wood so that cost effectiveness can be evaluated (18).

Processing

The use of smaller sizes of both currently desirable tree species and of lesser known tree species raises some problems. For example, sawmills in tropical countries are often designed to deal with large logs. Output and profits from existing facilities would be reduced if small logs were used.

Investments are needed in equipment for small log sawmills and for separate, small log lines in the mills normally used for large logs. Machines for sawing small logs are available and could be manufactured locally in many tropical countries. Existing machines and mill designs need to be appraised, tested, and demonstrated. A further contribution could be made by installing small sawing and planing machines that convert defective material into small dimension stock for furniture, joinery, and flooring, thus reducing waste (11). In the philippines and Sri Lanka, low-cost solar heated kilns designed by the U.S. Forest Service Forest Products Laboratory have demonstrated the ability to reduce waste in drying.

The percentage of high-density wood in tropical forests exceeds that from temperate forests. However, most processing technologies were developed in the temperate countries. Thus, processing technology will need to be modified to accommodate high density timbers as a wider range of tropical tree species is used.

Milling close to the harvesting site is another way to reduce waste. Portable sawmills are relatively inexpensive compared with equipment for permanent mills. However, existing portable machines include heavy components that are difficult to handle. Also, by reducing the inaccessibility of forests to processing centers, it could allow deforestation in areas now untouched by commercial leggings.

An important development would be the use of a small unit set up to mill logs at the stump. Milling at the stump, and transporting the timbers to roadside manually, could be more profitable and cause less environmental damage than hauling logs to mills. Such mills for use at the stump are still in the research and development stage.

Great progress toward making intensive harvesting profitable has occurred where multi-species wood chips are produced for wood pulp or fuel. The market for wood chips from tropical hardwood forests has been limited because softwood chips, which come mostly from temperate forests, make better paper. However, a new papermaking process promises to increase greatly the world markets for hardwood chips. This is the "press-dry paper process" developed at the U.S. Forest Products Laboratory. The process is successful on a pilot-scale, and U.S. firms are working to develop it on an industrial scale. When that is done, a decade or more should still remain before markets for tropical wood chips are greatly affected because of the long investment lag in paper mills.

If in the meantime forest departments can develop management and enforcement technologies to complement the opportunities for clearcutting, the impact on tropical forest resources could be beneficial. Otherwise, this technological breakthrough could result in increased deforestation.

Conclusion

Fuller use of the tropical forests can lead to increased revenues per unit area of forest cut and to development of a wide range of rural industries, including construction and manufacture of furniture and agricultural tools. Use of many tree species and sizes can supply growing domestic markets without reducing foreign exchange earnings from export.

Current logging practices are often environmentally destructive and wasteful. Yet existing technologies for harvesting, transportation, and handling methods could substantially improve management of tropical forests. Some of these have been developed in the United States, and U.S. expertise could play a significant role in the continued development and promotion of these technologies.

Intensive harvesting that would accompany fuller use of tropical forest trees could result in reducing the areas degraded by extensive logging. Enforcement of strict regulations regarding road building, site protection, and forest restoration would be more feasible if the amount of land to be regulated were reduced. However, without strict enforcement of such regulations, intensive harvesting could prove far more destructive than current practices.

Efforts to market a greater variety of tropical timbers are increasing. Much, however, remains to be done. Some species have characteristics that make them difficult and costly to harvest and process and that severely limit their end-uses. For such species and for forest residues, improved technologies and markets are needed for products for which species, size, and shape are not critical (e.g., charcoal, wood chips for pulp, and reconstituted wood panels). For poorly known but potentially marketable lumber species, the emphasis should be on more efficient technologies for processing and for improving use characteristics (preservation and drying) at an acceptable cost, and on marketing techniques, such as grouping of species by end-use requirements.

Although preservative treatment can and does expand international marketability, it is particularly important in moist tropical nations where wood deterioration is greatest and where wood substitutes are often used because of this problem. More consideration needs to be given to preservation technologies that are cheap, technologically simple, but effective.

WOOD FUELS

Background

Although wood is the fourth largest source of fuel in the world (after petroleum, coal, and natural gas), knowledge regarding its production and consumption is very imprecise. Most fuelwood is used in tropical nations, and for many it is in short supply. This is a hidden energy crisis. It does not enter GNP accounts and statistics on it are poor for several reasons. Wood often is gathered locally by users rather than being marketed. Even where it is marketed, it is often collected, without payment to landowners, from trees and shrubs near roads, around houses, on farms, or in poorly policed public forests. Fuelwood gatherers often take limbs rather than felling whole trees, so quantities taken are difficult to estimate.

Thus, much of the wood fuels data available for country-level planning and policymaking come not from actual measurements but rather from multiplying the population size times per capita consumption figures derived from small sample studies. In some cases, the source of the consumption figures cannot be found, much less checked for accuracy.

The ability to design and implement effective policies and projects for solving the wood fuels problem requires a thorough understanding of local consumption patterns and production possibilities. Many wood fuel projects of development assistance agencies and national governments have been unsuccessful because insufficient effort was devoted to studying these factors in advance (22]. Fortunately, interest in wood fuels has increased greatly in the past decade. More studies are being done and the estimates of wood fuel use are improving. FAO'S Forestry for Local Community Development Programs has recently published a useful collection of such studies (9).

Approximately 80 percent of the estimated 1 billion cubic meters (m^3) of wood removed annually from tropical forests is used for fuel (27). Thus, the sustainability of wood fuel production is inseparable from the sustainability of tropical forests. Whereas in the past fuelwood has been gathered mostly from natural stands, in the future it must come increasingly from tree plantations (30). The rate of tree plantings for firewood production throughout the world will have to be increased at least fivefold if fuelwood shortages are to be eased (8).

Three categories of actions could affect the imbalance between the demand and supply of wood fuel products:

1. Actions that directly influence the present and future demand for wood fuels (e.g., introduction of improved wood use or conversion technologies and substitution of nonwood-based energy sources).
2. Actions that affect the production of wood for fuel and, thus, reduce the pressure on natural stands (e. g., woodlots, plantations, and integrated land-use management).
3. Actions that do not directly affect production or use of woodfuel products but that have an impact on the socioeconomic conditions of the population drawing on forest resources (e.g., population, land tenure, etc.).

The third category influences the wood fuel situation only indirectly and is beyond the scope of this assessment, even though in the long run it may be the most important.

Technologies

Fuelwood and Charcoal Conservation Technologies

Four-fifths of the fuelwood consumed in developing countries is used for domestic purposes: cooking, space heating, and hot water (27). The form of fuel chosen, and method of use, can affect the total amount of wood consumed. For instance, many traditional cooking stoves and open fires use wood inefficiently because they focus the flames poorly on the cooking surface or give relatively incomplete combustion. Most stoves or open fires in tropical areas deliver only 5 to 15 percent of the fuel's energy content to the food being cooked (15).

Charcoal production is also energy inefficient. Traditional earth-covered pit or mound kilns can require 10 tons of air dried wood (15 percent moisture) to make 1 ton of charcoal

Photo credit' OTA staff

The three-stone fireplace—shown here in the Philippines—wastes much of the heat from the wood, but has esthetic and cultural appeal that inhibit acceptance of enclosed stoves

(24). Because a ton of charcoal has roughly three times the energy content of a ton of wood, this equals about 30 percent energy conversion efficiency (27). However, this loss is offset somewhat because traditional charcoal stoves tend to be more efficient than traditional wood stoves.

Reducing heat losses during conversion of wood to energy, including during conversion to charcoal, can conserve wood supplies. In other cases, simply changing from open fires to stoves increases efficiency. In many cases, fuelwood savings can be realized simply by drying (seasoning) wood before burning (27). Moist wood produces only half as much heat as air dried wood. However, this seemingly simple change may not be feasible where termites and fungi infest wood rapidly; or where there are heavy, frequent rains; or where people cannot afford to purchase or store an inventory of wood.

Improvements in **stove** design could reduce wood requirements fivefold to tenfold by increasing stove conversion efficiency from the 5 to 10 percent achieved now to an efficiency of 20 to 30 percent (20). Improved stoves typically are designed to provide better draft and more complete combustion and to concentrate heat on the cooking surface. Most improved stove designs use various insulating materials—for instance, a ceramic or clay-vermiculite lining–to reduce heat loss through the stove walls. In addition to increasing the efficiency of wood use, the wide dissemination of such stoves, if properly maintained and used, could reduce the time, energy, and money that tropical country women now spend collecting fuel (20).

More than 100 stove models, both traditional and experimental, are described in a recent compendium of stove designs (5). These stoves represent a broad spectrum of candidates for improving fuel-use efficiency. For example, the Lorena stove used in Guatemala can cut fuelwood consumption in half. It is molded from mud and sand, fitted with a metal damper and pipe, and costs the equivalent of only US$5. The Indian Junagadh stove is also simple and cheap and is reportedly 30 percent efficient. It is made with bricks or mud to absorb more heat, is designed with a tighter fitting hole for the pot to reduce heat loss, and in some cases is equipped with a metal damper to control combustion (22).

Few such stoves, however, have been readily accepted by local populations. Acceptance is determined not only by fuel efficiency but by cost, simplicity of operation and maintenance, availability of materials, cultural preferences and patterns, and the mechanisms chosen to promote the new stoves. These factors vary from region to region, so a stove designed in one place may not be accepted or used efficiently elsewhere (20).

Obtaining the widespread use of an improved stove design is more important than design details if the improvements are expected to have a significant impact on fuelwood demand. Many programs to design improved stoves have failed to meet expectations because they underestimated the economic and social constraints involved. Further, claims about efficient stoves have seldom been adequately documented. Thus, it is especially important to field test (onsite) a design before promoting its widespread use (19). A strategy to design and promote any new stove should include:

1. a survey of traditional cooking practices to ascertain sociocultural criteria that the stoves must meet,
2. field testing of existing stoves,
3. assessment of alternative designs,
4. laboratory testing of alternative designs,
5. design work or modification of existing stoves,
6. limited, followed by extended, field testing of the improvements, and
7. national or regional extension programs and support (13).

Introduction efforts have focused on low-cost, owner-built stoves. Two models that have achieved some acceptance are the Louga stove (Senegal) and the Lorena stove (Central America and various African countries). Because a relatively lengthy period is needed for the initial promotion and for household training to build, use, and maintain the stoves, the extensiordtraining cost per stove is high and the dissemination rate is slow (limited by availability, skills, and mobility of extension staff'). Consequently, more attention is being given to using existing artisans and their marketing network to speed the dissemination process.

Charcoal production can be improved on a large or small scale. As traditional earth-covered kilns give way to improved designs, including kilns built of brick, concrete, or metal, there is better carbonization control, higher conversion efficiencies, and production of a cleaner end product. The conversion efficiency of a traditional earth kiln can be improved 50 percent at low cost simply through improved kiln operation: use of only dense, dry wood chopped into relatively uniform pieces; assuring that the wood is packed as tightly as possible; assuring the earth covering the kiln is sufficiently thick to prevent complete combustion; proper spacing of initial air vents; and careful monitoring of combustion and later carbonization conditions **(27).**

At minimal cost, flattened metal cans or other scrap sheet metal can be inserted between the stacked wood and the insulating earth layer, reducing dirt contamination (which in some kilns reduces the efficiency of 20 to 30 percent of the charcoal produced) **(27).** More sophisticated designs and building materials (brick, concrete, or metal) can be even more efficient but may require substantially higher capital investment.

A relatively expensive alternative is the portable steel charcoal kiln, which consists of two cylindrical steel shells, a conical lid, and four chimneys. It has been used throughout the world for many years. The chief advantages of such kilns are ease of operation, increased rates of recovery (15 to 20 percent), relatively short production cycle (72 hours), and relative portability (by truck or animal-drawn cart). The high capital cost makes it prohibitively expensive for traditional producers who do not reap much economic benefit from improved conversion.

However, these kilns have been used successfully in conjunction with large-scale agricultural land clearing and on large plantations where periodic portability is desired. For example, the "Char-Lanka" project in Sri ***Lanka*** takes advantage of an expanding market for charcoal to make beneficial use of the timber cleared from a large agricultural development project area. A major U.S. bank helped finance both small-scale artisans to fabricate portable metal kilns and small-scale charcoal producers to lease such kilns. Eventually over 200 kilns will be built locally (27).

In some tropical countries, charcoal already accounts for a significant fraction of total wood fuel use and it is increasing its market share, particularly in urban centers. Given the low conversion efficiency of most charcoal production, the increasing substitution of charcoal for wood with its attendant energy losses will exacerbate problems of wood supply/demand imbalance.

Because most charcoal is produced part-time by small cottage industry laborers, many or most of whom operate illegally or extralegally, it is particularly difficult to launch national or regional campaigns to improve charcoal production efficiency. Char-Lanka is one potentially promising model that could help small-scale kiln producers function more effectively. The peace Corps and others sponsor many local efforts to improve traditional charcoal producers' operating efficiencies, but so far substantial improvements in forest resource depletion rates have not been demonstrated.

Resource Substitution

Resource substitution can be used to protect forests in two ways: by substituting alternative energy sources for fuelwood, or by substituting fuelwood cultivated in plantations for fuelwood collected from natural forests. Nonwood energy substitutes can be conventional (kerosene, electricity, or natural gas) or innovative (solar, wind, small hydro, or biogas). Detailed

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analysis of these technologies is outside the scope of this assessment.

Substituting Nonwood Fuels. Through the 1950's, 1960's, and early 1970's, large-scale shifts occurred from traditional fuels (wood and charcoal) to petroleum fuels—primarily kerosene. It is unlikely, however, that substitutions will usurp the primary place of fuelwood in developing countries while wood resources still exist. Further, it is unlikely that financial subsidies of such fuels can continue indefinitely. However, such subsidies can be a way to achieve important temporary reductions in wood demand, while the productivity of natural forests is recovering or while fuelwood plantations are being established.

Many efforts to develop and apply alternative energy sources are under way worldwide, but they seem to be widely scattered, uncoordinated, and generally underfunded (32). Actual adoption of these technologies is constrained by their financial and managerial feasibility and by the enormous logistical difficulty in changing the habits of millions of dispersed and often isolated villagers. The substitution of various forms of energy for fuelwood by these people probably will be influenced largely by changes in their lifestyle, standard of living, the location of their settlements, and access to available technologies. Conscious policy decisions to affect fuelwood consumption, production, or substitution will have a much greater prospect for success if the policies build on the energy and economic changes already occurring throughout the rural areas of the Tropics (27).

Still, the energy demand/supply imbalance must be met mainly through improving the supply, distribution, and use of fuelwood and charcoal. A preparatory committee for the U.N. Conference on New and Renewable Sources of Energy concluded that there is "no alternative source of energy that could provide a viable substitute for fuelwood on a scale which could permit a major reduction in dependence on it by the world's poor in the next quarter century. Their poverty, and the remoteness of many of them, will inescapably remove other energy sources from their range of possibilities" (31).

Fuelwood Plantations. The idea of growing fuelwood in plantations is not new. But there is not extensive technical experience growing trees for firewood because foresters traditionally have planted trees primarily for timber and pulpwood (19). Most fuelwood produced from plantations is used for cooking, with some for heating and charcoal manufacture. Some large-scale plantations do, however, supply fuelwood for industry and transportation.

Three different types of plantations can be envisioned: plantings by individual farmers, more concentrated village woodlots, and large-scale plantations for concentrated demand.

Individual plantings—increasing emphasis in forestry development programs has been focused on technologies aimed at bringing rural populations into direct participation in forestry and fuelwood production projects. This can include farm forestry, where individual farmers grow just enough trees for their own fuel needs or for a cash crop, and agroforestry, where trees are combined with food-producing systems in the form of shelterbelts, windbreaks, or more complex mixtures.

Individual tree planting can make use of otherwise little-used areas. Because wood for fuel need not be large, fast-growing and coppicing shrubs can be used along roads and field edges. Multipurpose trees that provide fuelwood as a byproduct of food or forage production may be accepted even by rural people with little land. Where water is adequate and a market for fuelwood exists, closely spaced plantings of fast-growing, coppicing shrubs or trees can be grown on relatively small areas to both provide domestic needs and generate income.

In many countries, fuelwood is becoming part of the market economy providing farmers with income that offsets the costs associated with establishing or maintaining tree cover for environmental stability or rehabilitation. Tree planting by individual farmers in Gujarat, India, has spread to such an extent that the 50 million seedlings distributed by the Forestry

Photo credit: *OTA* staff

Eucalyptus fuelwood supplied by Farm Forestry Projects in India. Farmers are encouraged to plant trees to supply their fuelwood needs as well as provide income from sales

Department in 1980 (equivalent to an annual planting of at least 25,000 ha) were insufficient to meet demand (22).

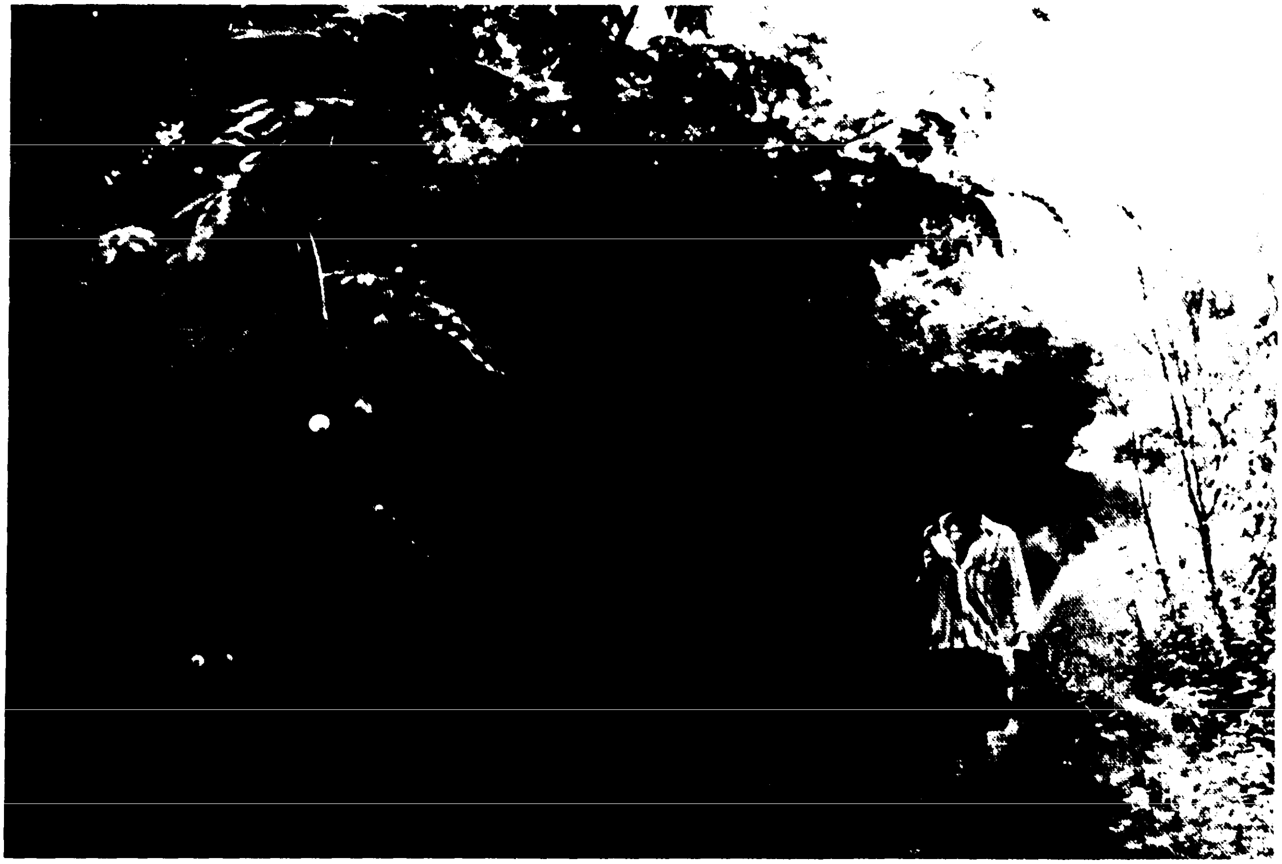
Village Woodlots—Village or communal fuelwood plantations are larger in scale than individual plantings. Management of these plantations resembles conventional forestry in many respects, except that even existing low-quality coppice trees are exploited. Trees may be multipurpose or for energy production only. Rotations vary between 5 and 30 years, depending on species and site conditions. Because the area cropped generally is larger than where trees are in individual holdings, and because the land is dedicated entirely to tree crops, harvesting techniques can be similar to those used in conventional forestry.

The management techniques for many species suitable for village woodlots are relatively well-known. But sociocultural and economic problems can affect acceptance. Constraints that can impede village forestry include:

- heterogeneous social structure that hinders village-level decisionmaking and cooperation;
- competition with other village priorities for limited village resources;
- loss of whatever production currently comes from the woodlot site (especially grazing);
- lack of government and forestry department support for promotion, extension, free seedlings, technical advice, etc.;
- lack of an institutional structure to define ownership and distribution of woodlot products;
- shortage of labor for plantation maintenance; and
- tendency of foresters or other outsiders to dictate what species to use in village woodlots with too little consultation with villagers, especially women, who are most likely to tend, harvest, and use woodlot products (22).

Too little is known about how village people make decisions about land use, land tenure, and tradeoffs in production of different goods and services. In a World Bank project to establish 500 ha of village woodlots in Niger, for example, village people either pulled out seedlings as fast as the trees were planted or allowed uncontrolled grazing to take place. The villagers had not been involved in formulating the project and perceived the woodlot area as a traditional grazing ground (22).

Trees in some fuelwood plantations (e.g., ***Eucalyptus camaldulennsis)*** in some Sahelian countries have not been well accepted locally. Fast-growing plantations generally supply fuelwood only. But the native brushland they replace also supplied other products such as gums, medicines, food, and forage. In some cases native brush could be managed to maximize fuelwood production while sustaining production of other products. One opportunity is in-



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terplanting native brushland with fuelwood-producing, nitrogen-fixing shrubs. Development of such systems will require more research on subjects such as management techniques and species compatibility (2).

There is no complete package that can be universally applied to encourage participation in a village woodlot program; each must vary according to the needs and priorities of a village. Several general guidelines can be extracted from recent experience. For village woodlot programs to succeed, there must be: 1) strong government commitment to village forestry, 2) perception of the forestry department's role in rural forestry, 3) villager participation (especially village women) in program formulation, 4) understanding of village perceptions, priorities, sociocultural framework, and economic needs, and 5) design of a program understandable to village people that caters to their needs and provides incentives effective within the particular sociocultural framework (e.g., improved agricultural practices, monetary incentives, improved infrastructure, employment) (22).

Industrial fuelwood plantations–Although much more wood is consumed for household use in tropical countries, wood fuel used for processing and service activities is still very substantial. According to available surveys, these uses account for between 2 and 15 percent of total wood fuel use in Africa and Asia. Though some of these uses are scattered (e.g., charcoal for commercial food preparation, firewood for brickmaking and cement), others give rise to vary large demands concentrated in single locations or small areas. For example, tobacco-curing is estimated to have required 1.1 million m^3 of fuelwood in Tanzania in 1970 and, together with rubber preparation fuelwood, nearly 300,000 m^3 in Thailand (23). Industrial demand is growing much faster than household demand (3).

In Brazil, about 2 million ha of plantations produce an estimated 3 million tons of charcoal from ***Eucalyptus*** wood to support the country's metallurgical industry. The planted area is expected to exceed 4 million ha by the year 2000 (16). In Kenya, large-scale charcoal production is a byproduct of the use of bark to produce tanning extract.

Recently, opportunities to run factories on wood have been enhanced by the availability of wood chips and pellets. These standardized forms are more convenient to store and use than logs or split wood and, thus, are gaining acceptance as a source of industrial energy. High-speed chipping machines have been developed that make standard, matchbox-sized wood chips and then shoot them into a waiting van. The chips are suitable to use in woodfired boilers for industrial applications. Wood-chip machines are especially advantageous alongside logging operations, since they can make a useful product from the debris left by loggers. wood chippers also can cull old, diseased, or contorted trees from forests managed for timber.

Wood chips are bulky and contain about 50 percent water so they cannot be profitably hauled over long road or rail distances for use as fuel. Wood chips can be transported over long distances by ships, however, as the per mile cost is relatively low. Wood pellets are smaller than wood chips; they are made from wood waste bound together under heat and pressure. These can be used in coal or charcoal furnaces without modifications. Since pellets are drier and denser than wood chips, they can be transported economically over greater distances. The use of wood chips and pellets is confined largely to North America, but the practice is spreading to other countries (30).

Large-scale energy plantations are also used by forestry agencies to protect timber reforestation sites and protected areas from illegal fuelwood gathering. In Indonesia, 341,000 ha of ***Calliandra*** have been established as a buffer zone around national forests to protect the natural trees from fuelwood gatherers.

The removal of trees for fuel eventually can exhaust the soil. In energy plantations, the nutrient drain may be more severe than in conventional timber plantations because younger trees contain a proportionately larger share of some nutrients. Furthermore, wood chipping machines shred leaves and twigs as well as trunks and branches. This depletion could be alleviated in industrial energy plantations by spreading furnace residues around the trees. Nitrogen fertilizer would still be required for trees that do not have nitrogen-fixing microorganisms. Growing several kinds of trees in plantations could alleviate some of the wildlife disruption problems. In theory, this and the use of indigenous species could also make plantations less susceptible to catastrophic damage by insects and disease.

Eucalyptus, Acacia, Calliandra, Leucaena, and ***Prosopis*** are among many potentially useful trees that are beginning to be used in plantations, village woodlots, and individual sites (20), The trees most likely to prove useful for fuelwood plantations are fast-growing species that can withstand degraded soils, exposure to wind, and drought (20). The ability to coppice (regrow from cut stumps or root suckers) is important for fuelwood species because this allows repeated harvest without the cost and effort of replanting. For example, *Leucaena IeucocephaJa* is a legume tree that supplies fuelwood, fodder, and timber and enriches the soil. On favorable sites yields of 40 to 100 m^3/ha/yr can be expected from selected strains of ***Leucaena.*** These trees can be harvested every 3 to 6 years and the seedling generation rotation can be followed by three or more coppice generations, all of which give comparable yields (21).

To achieve sufficient profits at all levels, from farm forestry to large-scale projects, the aver-

age net energy harvested needs to be high per area and per time unit. Since labor costs may be formidable, productivity must be sufficiently high to make product prices competitive with available commercial fuels. But high productivity usually needs high-quality land. This can lead to conflicts between wood fuel production and food production (29).

The following types of land are likely to be most readily available for forestry because they are least in demand for agriculture: abandoned farmland, low-grade coppice forest, sedge or cane-growing coastal or riverine areas, saline land, mountain slopes, dry areas; sludge deposits, other types of unproductive land. Few of these are suited to high-input, short-rotation forestry. In many cases, low-input, fuelwood forestry may offer a better prospect.

Unless it is clearly profitable within a few years, growing wood for fuel, whether on a large or small scale, demands social and political commitments that may be difficult to obtain and maintain. High investment costs for fuelwood plantations also serve as a disincentive. In areas where substantial forest or brush cover remain, it is cheaper to harvest wood from the forests (even though they may be badly overcut) than to pay for plantation-grown wood.

Gathering wood from natural forests, as long as they remain, requires no investment outlays. In such situations, fuelwood plantings are more likely to succeed if natural forests are protected from cutting and if plantations provide additional marketable products, serve some additional desired function, or are integrated with agriculture. In areas where no natural forests remain within a considerable radius of a town, village woodlots or wood fuel plantations can be highly profitable.

Evidence throughout the developing nations shows that cash incentives are among the most widely and readily received. Recent studies have shown that the economic and financial (primarily cash) benefits of tree growing derive from products other than fuelwood (25,28) and that the increased availability of fuelwood is almost always a ***byproduct*** of stepped-up tree growing for other purposes. In other words, although it maybe socially worthwhile to plant more trees, the incentives to do so will be influenced by how well those trees serve as income-producing assets (28). Increased supplies of fuelwood, therefore, maybe best promoted by recognizing the secondary financial importance fuelwood holds relative to other forest products (27).

Development or expansion of fuelwood markets, however, may induce relatively powerful villagers or people from cities to gain control of fuelwood supplies. This would then deny landless people access to needed subsistence resources (l).

Conclusion

The rate at which forests are converted to other, less sustainable uses can be reduced by decreasing the demand for wood. This can be done by enhancing the efficiency of wood use or by substituting alternatives for wood from foresters.

The efficiency of domestic wood use can be improved through better stove and kiln technologies. Since most fuelwood and stove projects have been initiated only recently, it is premature to stipulate which techniques are most likely to achieve widespread diffusion. Several observations, however, can be made.

- To develop effective methods of technology dissemination, high priority must be given to social and economic research and to field evaluation of the technologies.
- Farmers, artisans, and entrepreneurs are most likely to adopt and spread improved techniques for wood growing, charcoal production, and stove design if they can profit from the improvements through existing market channels.
- Improvements in charcoal production should generally be introduced as incremental changes in existing methods.
- Dissemination strategies for fuelwood technologies must take into account the differences in male and female roles and incentives as they relate to how house-

holds' land and labor resources are used, who makes purchase decisions, who benefits from alternative tree products, etc. (27),

- The greatest potential for farmers to profit from tree growing comes not from single-purpose fuelwood plantations but rather from sale of other forest products, for which market development may be needed, and from agroforestry, which not only produces wood but also improves yields of associated crops.

Improved stoves may reduce the range of fuels that can be used, may be too expensive, or simply may be outside the abilities of local craftsmen. Improved charcoal production does not necessarily lead to expected reductions in the wood consumed to make charcoal. Unless there is an effectively enforced ceiling on the exploitation of woodlands, charcoal makers may use the time they gain from using more efficient kilns to make even more charcoal, thus accelerating the depletion of wood resources rather than slowing it.

Securing future wood supplies is a political, economic, and social problem. It is affected by problems of land ownership, local customs, and social organization. until these are resolved, measures to reduce demand will fail to reach the root of the problem. Demand reduction creates no incentives for increased supply; it may even achieve the reverse. where fuelwood has sufficient commercial value above the cost of harvesting and transport, it is more likely that someone will be prepared to invest in planting trees (10).

Interest and experiments in the use of small-scale, renewable energy technologies (solar driers, small hydropower, etc.) are widespread. Such technologies are not yet able to substitute for wood use, however, and their adoption is inhibited by economic and managerial constraints. Further, it will be difficult to achieve widespread adoption of these technologies because of the problems inherent in trying to change the long-held habits of large, diverse, and often isolated rural populations.

Similarly, substituting nonwood fuels (kerosene, bottled gas, electricity, etc.) for fuelwood has potential to reduce demand temporarily for forest wood while plantations are being established and while the natural forest is recovering. However, the costs of obtaining and distributing these fuels are often prohibitive. Subsidies to facilitate the adoption of nonwood energy sources may be necessary in regions of critical deforestation, but they cannot be seen as a long-term remedy. Substituting plantation-grown wood for natural wood is the more sustainable option for many tropical regions.

Tree planting is constrained where access to "free-for-the-taking" forest wood is not restricted. In such cases, people are unlikely to invest land and labor in fuelwood plantations even if other inputs are government-subsidized. The economic feasibility of fuelwood plantations can be improved if they also are designed to provide marketable products other than woods, such as fodder, or to provide some additional service, such as shelterbelts. However, even in these cases, the regulatory controls on fuelwood gathering from the natural forest must be enforced.

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