Forest Resources: An Overview

J. S. Bethel and G. F. Schreuder

A growing concern for the long-term availability of nonrenewable resources has directed increased attention to the feasibility of their substitution by renewable resources. Proposals for direct substitution of renewable resources from farm and forest residues and energy plantations for fuels and chemical feedstocks have been vigorously advanced. This article will deal mainly with forest products, which represent about 98 percent of the tonnage of renewable materials currently used in the United States.

Wood and wood products have some advantages with respect to other materials. One is that when used as structural materials they provide energy conservation opportunities. Cliff (*1*) reported: "Only 453 kilowatt-hours of electrical energy are required to manufacture a ton of lumber. A ton of steel by way of comparison, requires 3780 kilowatt-hours and a ton of aluminum 20,160 kilowatt-hours." In a recent study (*2*), the Committee of the Survey of Materials Science and Engineering of the National Academy of Sciences concluded: "Considerable scope exists for expanding the range of materials obtained from renewable resources. Wood and vegetable fibers might become important sources of primary organic chemicals, although they are not economically competitive today." And the National Commission on Materials Policy, in its final report (*3*), concluded with respect to renewable materials: "They grow on the land, are visible, and need not be discovered, except as species are improved and new varieties are developed by genetic experiments and studies. Reserves grow as photosynthesis combines the energy of the sun with carbon dioxide in the atmosphere to produce vegetative materials. Under management, this supply can be perpetuated indefinitely and even, with improved technology, dramatically increased."

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Supply

A condition precedent to any major effort to substitute domestic renewable materials for foreign nonrenewable materials is an assessment of the available reserves of renewable materials and the potential for replenishment of these reserves after use. The United States is currently a net importer of wood, the principal renewable material. If we were already using our renewable materials to capacity, any effort to encourage substitution would be trivial.

The McSweeney-McNary Act (*4*) of 1928 called for the maintenance by the Secretary of Agriculture of a current census of forest land and its products, an analysis of national supply-demand relationships with respect to forest products, and instructions to suggest methods of achieving a balanced timber budget. The national forest survey is the department's response to this mandate. A general summary of this survey is published at approximately 10-year intervals. It is the only inventory of its kind available in this country, and has provided the factual basis for essentially all national, regional, and state reviews of timber supply. The forest survey as published by the U.S. Forest Service confounds the census and analytical functions in that it is difficult if not impossible for independent analysts to utilize and separately interpret the census information. The most recent version of the national forest survey (*5*) reported the status of American forests in 1970. Its conclusions concerning the future prospects for timber supply have been rather widely challenged. Since it is not feasible to maintain more than one such extensive inventory, it would be desirable to report the forest census data independent of the assumptions made by the department in preparing its analysis. Reporting the census in terms of whole tree volume would permit alternative analyses of materials supply and productivity from the same data base. The technological assumptions then would become part of each analysis, and successive census reports could be validly compared.

The survey could be improved in precision by more intensive use of modern aerial photo techniques and Earth Resource Technology Satellite imagery, combined with advanced sampling techniques. It would be advantageous to use the oncoming change to the metric system as an opportunity to institute change in survey mensuration.

The renewable materials system starts with land. The forest land base and estimates of its productivity are discussed in the following article by Spurr and Vaux. Here the discussion is confined to several problems of forest land classification and management. These problems may distort the estimates of timber resources, and at the same time they reflect deficiencies in national policy with regard to proper management of forest resources.

Given the amount of forest land currently classified as commercial, it is probably unimportant that the criteria for elimination of one-third of the nation's forest land from the materials production base are extremely arbitrary. The commercial production threshold of 20 cubic feet per acre per year probably reflects the nation's timber affluence. In many parts of the world, land well below this production level is managed for timber production. Some of the Alaska land excluded for accessibility reasons should be accessible in the future and indeed the development of the trans-Alaska oil pipeline has probably made some of it accessible already.

Perhaps the most serious questions concerning forest land classification criteria relate not to exclusions from the commercial materials base but to areas included in that base. According to the President's Advisory Panel on Timber and the Environment (PAPTE) (*6*), 18 percent of the commercial forest land in the United States is in the national forests. On the basis of timber productivity, one-third of this land is classified as site III (85 to 120 cubic feet per acre per year) and better. It is not clear how much of this land is available primarily for materials production. The Forest Service is under legal mandate to manage its land in accordance with the multiple use land use principle. Increasingly this mandate is being interpreted to give priority to nontimber uses. Recent court rulings invoking an extremely restrictive interpretation of the Organic Act of 1897 with respect to certain eastern forests and large national forest lands in Alaska move the Forest Service back to its custodial role at the turn of the century. If this type of management mandate is extended to the vast western federal forest holdings, it is doubtful that they can continue to play a significant role as commercial forest land. In large areas of federal forest land recreation and amenity values have been specified as dominant uses by the federal government, and materials supply is so restricted that its value as a significant materials supply base is doubtful. This is not a phenomenon unique to the United States. The British scientist, S. D. Richardson, has noted (*7*):

> In many countries of the developed world, the traditional wood production orientation of forest managers is being increasingly questioned. In the smaller countries of Europe (e.g., Holland and Denmark) forests are now managed primarily for recreation, with the harvesting of cellulose a by-product of decreasing importance; in North America, that opiate of the forestry profession—multiple use—is being given real substance, partly by pressures generated by the Sierra Club, and the Environmental Defense Fund, and other conservation lobbies.

There has not been a clear designation of national forest lands for which materials production is specified as the principal use with the same legal force associated with wilderness, wildlife, and recreation designations. The Public Land Law Review Commission (PLLRC) made such a recommendation (*8*), but it has not been implemented by Congress. Investments in timber production on national forest lands have been far below those on comparable industrial forest land. Productivity on these lands is further reduced by maintenance of overmature inventories and by lack of prompt reforestation. This apparently reflects decisions to emphasize other uses at the expense of materials supply. Clearly this is a legitimate position with respect to public land use if it is responsive to the body politic. Just as clearly it represents a major, if indirect and perhaps unintended, expression of national policy for materials supply. Given the time required for planning and implementing timber production, it is questionable to continue to assume that the national forests are likely to be significant reservoirs of materials supply in the absence of any clear designation of principal purpose in this domain.

A similar situation exists in the case of nonindustrial forest land. PAPTE (*6*) indicates that 59 percent of the area of commercial forest land is in nonindustrial private ownership. Of this area 32 percent is classified as site III or more productive. Little is known quantitatively about the objectives of these owners. A few are apparently interested in intensively managing their forests, but for the most part this land is being held for ultimate conversion to nonforest use, for speculation, or for its recreation value as a private park or hunting or fishing preserve, and these largely nonconsumptive uses are increasing. Some owners will sell timber if the price is high or if they need partial liquidation of capital. Although long-term management agreements with industrial forest owners have effectively moved other acreages into the intensively managed industrial base, and although public subsidies in a variety of forms has increased the level of management on some areas, these efforts have seriously impacted only a small fraction of the land in this ownership category. Increasing governmental restrictions in the form of forest practices acts and environmental monitoring discourage the nonindustrial owner of small forest holdings from attempting to practice forestry. The industrial forest owner can employ the professional talent required to achieve compliance with complicated regulations. The owner of small properties may be discouraged from trying to practice any forestry other than an occasional harvest from a natural forest stand.

Doubling the output of U.S. forest products over the next few decades is feasible (*6*), but it must be based upon a much more realistic assessment of the stability of the nation's forest system as a timber supply base and a more detailed classification of nonindustrial private forest land based upon some census of owner objectives. The present forest survey information is deficient in these respects. If it is in the national interest to increase the supply of domestically produced wood as a renewable material, there are a number of actions that might be taken by government at either state or federal level. The federal government could undertake to exchange federal forest land for industrial forest land to place a larger fraction of site III and better forest land in industrial ownership for intensive management and a larger fraction of less productive forest land in federal ownership. This would place the most productive land in the hands of those who have the incentive and resources required to take advantage of its productive potential and increase the area of federally owned forest land for dedication to nonmaterials use. The Congress can insist that the federal forest land most suitable for material production be dedicated to that purpose with the same rigorous legal protection now afforded to wilderness areas, primitive areas, wildlife preserves, and recreation areas, as recommended by the PLLRC (*8*). The states can provide incentives through their taxing, zoning, or regulatory functions for the small private forest owner to engage in some forestry practices other than harvesting.

In addition to the land area, estimates of yield from this land base are required in the assessment of materials supply. These estimates involve the measurement of the vegetation in terms of number of trees, volume, growth, and mortality, as well as certain hydrological and economic assumptions concerning the allocation of trees to products and the yield in terms of particular products produced from the trees or tree components. These technological and economic assumptions concern minimum usable sizes and top diameters of trees, different lumber yields obtainable from stem sizes, the product mix to be produced, and many other factors. Many of these assumptions of product yields are based on measures (such as the different board foot measures) or on technological conditions which are of ancient vintage and which generally do not reflect present and future economic and technological conditions and opportunities. Good or bad, these assumptions should be part of the analysis of the census and not of the census itself.

Substitution

The history of the use of substances as industrial materials is replete with substitution among substances. There are very few industrial materials for which another material is not technically substitutable. Furthermore, there are few industrial materials for which there is only one substitution option.

The necessity to abruptly consider substitution of one industrial material for another arose most recently with the oil embargo. It may be desirable to search for long-term alternatives to petroleum as an energy source or as a raw material. Wood has a long history of use as a fuel and clearly could be used again. However, harvested wood is presently used for other purposes, and in the case of residue left in the forest is expensive to collect and deliver to fuel consumption sites. The same problems exist with some of the other potential petroleum substitutes. Thus a decision to divert a renewable material to use as a fuel could result in a supply shortage or an increase in supply cost in the system currently using such a material.

The material system is quite complex in view of the availability of many natural sources, both renewable and nonrenewable. What is needed is a framework that incorporates the diverse information on the technical, economic, energy, and environmental aspects of the materials system and thus facilitates the study of the future role of the renewables as a source of materials and more specifically addresses the substitutions of renewable materials for nonrenewables in particular end uses. The Committee on Renewable Resources for Industrial Materials (CORRIM) of NAS used the concept of a reference materials system (RMS) originally employed by Brookhaven National Laboratory to define the use of energy in the economy. Dr. K. Hoffman of Brookhaven and his associates provided the leadership in CORRIM in the adaptation of RMS to the materials substitution problem. The analysis illustrated here emerged from part of the work of the CORRIM systems panel.

The RMS is a network representation of the physical flow of materials through all the production and shipment steps required to produce and convert that resource to a form that may be used for a specific purpose in the economy. These steps are referred to as "activities." An RMS describing the state of the materials system in the base year 1972 is shown in Fig. 1. The renewable resources included in the system are hardwood and softwood forests, minor forest products, agricultural crops and residues, and livestock. Nonrenewable resources introduced for comparison purposes are steel, aluminum, cement and concrete, glass, crude oil, natural gas, and coal. End uses are printing and publishing, packaging and containers, fibers and woven fabrics, nonwoven fabrics, building construction and its various components, durable goods transportation, chemicals, electric power, and fuels. Activities are production or growing, harvesting or extraction, processing, transport (including aggregated shipments during all flow stages), fabrication in primary form, installation, erection, maintenance, and recycling.

The completed RMS shows the flow of materials from the resource through all of the activities to a specific end use for a specific year in a path called "trajectory." Figure 1 is an example of one of the many trajectories developed by CORRIM. Individual trajectories have been developed for renewable as well as for nonrenewable resources, such as hardwoods, softwoods, glass, and steel. Initial trajectories are developed at the very detailed subsystem level and then aggregated into an overview of the whole materials system. Depending on whether the RMS format is to be used as a framework for organizing the diverse technical and economic information on energy, labor, or capital requirements, the number to be substituted for the numbers along the trajectory will portray energy, labor, or capital requirements or just simply the mass flow and material losses through the activities. Such substitutions are shown under **3** in Fig. 1. Energy, capital, and labor requirements can be portrayed as aggregates or can be converted to unit requirements on the basis of either a unit of material throughout for each activity or a unit of the final product. Regardless of the level or kind of detail portrayed, the RMS network can be used for overview and display purposes or as a tool for the analysis of policy alternatives.

The RMS is used for the analysis of materials utilization and substitution by the technique of perturbation analysis. It reflects current and projected use patterns; little by way of dramatic change is assumed in the role of renewables. Depending on the details of the analysis to be performed, the RMS's may be used at the level of aggregation or at the more detailed level of the subsystem. The technique of perturbation analysis involves examination of the specific end use projected in a utilization or substitution problem and definition of any new processes to be used in the affected trajectory from resource to end use. It provides for revision of flows through the affected trajectories in the RMS to reflect changed utilization or substitution of materials, new processes, or both. Finally, it accumulates and tabulates resource, energy, labor, capital, and environmental consequences of the utilization or substitution.

The definition of the technical characteristics of new processes must be done outside the RMS. The intent of the RMS format is to capture those characteristics of the technology that are important to materials policy. Frequently, such technical detail is overlooked in policy formulation because it is not available in a consistent and comprehensive format.

The perturbation of the appropriate trajectories and the accumulation of information on detailed consequences is straightforward with the RMS. When used in this fashion, the RMS can be a useful technique for the analysis of materials policy. It must be recognized that the technique focuses on the physical structure of the system and its requirements. Thus, substitution analysis may be performed in a rather direct manner, but in cases of more general policy analysis, the effects of a policy action on the supply or demand for materials used and on the physical structure of the system must be developed or estimated prior to use of the RMS.

Efforts to construct and utilize the RMS to evaluate potential substitutions within the domain of renewable resources and between renewable and nonrenewable resources clearly indicated the need for a better information base as a condition precedent to the establishment of a national policy for materials in general and renewable materials specifically. Some of the deficiencies in the information base have already been referred to in the discussion of the national forest survey. There are similar deficiencies in the technology area.

Increases in the resource base can be achieved through study of materials improvement and conservation. The study in wood science and technology has been declining in the past 20 years. Most of the federal research investment in this area is directed toward the U.S. Forest Products Laboratory in Madison, Wisconsin. Its research program has been reduced in size, and its efforts in basic research in materials science have been curtailed. Among the universities, several significant programs in wood science and technology have been phased out presumably in economy moves. There are only eight major universities still pursuing important materials research and education in the field of wood science and technology. Accordingly, there is a shortage of scientific and technical manpower in this field. A similar attrition has occurred with respect to research on renewable materials of agricultural origin. In contrast, the federal government has recognized the need for massive levels of research in the nonrenewable resource and energy fields. Finally, little progress has been made in changing building codes; this could lead to substantial materials conservation.

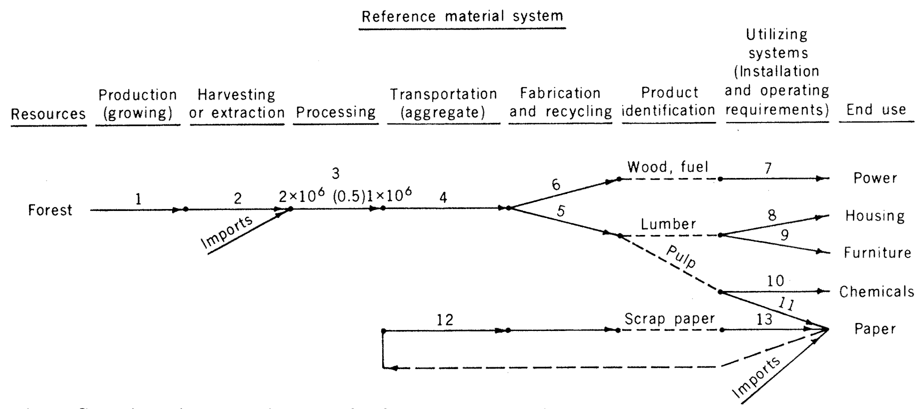

Fig. 1. Sample trajectory subsystem for forest products. The numbers under **3** denote mass flow input (2×10^6), loss factor (0.5), and mass flow output (1×10^6).

World Trade

The United States, originally a supplier of wood to the world, has been a net importer of wood since 1914. It continues to be a net importer and at the same time maintains a relatively inefficient forest production system in terms of achieving anything like its forest-based materials potential. While the U.S. potential in forest-based materials has been great, its supply of concentrated and cheaply exploitable nonrenewable resources has also been

Table 1. U.S. trade in wood products, 1971. Data are given as roundwood equivalents (10^6 cubic feet). [Source (*6*)]

Item	Imports	Exports	Net imports
Lumber			
Softwood	1,233	159	1,074
Hardwood	58	26	32
Plywood			
Softwood		10	-10
Hardwood	181	1	180
Veneer, hardwood	35	9	26
Pulpwood	95	118	-23
Pulp			
Alpha and dissolving	51	127	-76
Bleached sulfate	377	170	207
Other	86	31	55
Newsprint and other paper	649	50	599
Paperboard	2	159	-157
Building boards	19	4	15
Sawlogs			
Softwood	10	381	-371
Hardwood	5	10	-5
Total	2,801	1,255	1,546

great. As the most readily and inexpensively accessible supply of these renewable resources became limiting, it was cheaper to seek inexpensive foreign sources of nonrenewable materials than to create the technology required to shift to domestically available sources of alternative renewable resources. The United States has had some self-imposed restrictions on the use of its forest-based renewable resources that encouraged this trend. Its most productive forest land is located in the Southeast and the Northwest. Its greatest population densities are in the Northeast, the Southwest, and the northern Midwest. Movement of its forest-based material resource from production centers to consumption centers requires an effective and inexpensive transportation infrastructure. The nation's long-haul railroad transportation system, originally imaginative in its development, has degenerated in the past 30 years. The federally regulated railroad rate structure has not encouraged long-haul transportation of wood. Alternative water transportation of wood from production site to consumption site has been inhibited by the Jones Act, which requires that ships carrying goods between U.S. ports be under the U.S. flag. The increased shipping costs caused by this legal restriction have essentially eliminated what was once a flourishing intercoastal waterborne timber trade. It has effectively denied to the markets of the contiguous 48 states, on an economic basis, the materials of the forests of Alaska.

Federal legislation implies that it is national policy to achieve a balanced wood budget. References to a balanced timber budget in the McSweeney-McNary Act (*4*) suggest such a national policy, although it isn't clear whether these references are to an internally or an externally balanced budget. In any case, since the act was passed in 1928, the country has never achieved a balanced timber budget either internally or externally, nor has it made significant efforts to move toward either type of balance.

From 1914 to 1971, the percentage of national consumption represented by imports increased from 0 to 12.2. The Forest Service estimates that the nation will continue to import and export wood, remaining a net importer. Given the transportation problems that inhibit matching wood production with wood consumption internally, it would seem more feasible to set as a national goal an externally rather than an internally balanced wood budget. Table 1 shows the import-export status of individual forest product commodities for 1972. For hardwoods, of which the United States grows substantially more than it harvests, the only commodity which shows a substantial excess of imports over exports is hardwood veneer and plywood. This is almost the only major item of international trade in wood that cannot be produced in the United States from domestic forest products supply. This country is a net exporter of hardwood logs and hardwood pulp products and a net importer of hardwood lumber, although the balance of trade in each of these commodity items is relatively minor in terms of value and volume.

On the softwood side, the nation is a net exporter of logs and plywood and a net importer of lumber and pulp products. These international trade movements represent economic trade-offs that largely reflect U.S. transportation restrictions. The largest import volume is softwood lumber from Canada in the amount of 1.165×10^9 cubic feet per year (33×10^6 cubic meters per year). This is predominantly Douglas fir from British Columbia moving into the northern markets of the Midwest and East. The other major softwood import item is pulp products from central and eastern Canada. As with softwood lumber, this very largely reflects importation of newsprint, a commodity that is produced in the United States. Preference for imported materials is largely a matter of price.

Logs represent the only major softwood export item. These are shipped from the northwest states—Washington, Oregon, and Alaska—and go almost exclusively to Japan. In 1972 more than 70 percent of these exports were from Washington. Most of the export logs originated from forest lands in private ownership and from state-owned forest lands in Washington. The federal government and the states of Oregon and Alaska have imposed restrictions upon the export of logs originating from government-owned land. This has sometimes resulted in the artifice of splitting logs into large cants to avoid the export restrictions on logs. The Japanese log export market is attractive to Northwest log producers because of the transportation problems associated with movement of lumber and other softwood forest products to major U.S. consuming centers. In the past, Japan has preferred to buy softwood logs rather than finished products for a variety of reasons. The Japanese construction industry uses lumber and timber sizes that are different from standard U.S. lumber sizes, and its lumber industry typically obtains much larger yields from a log than does ours. The Japanese are partial to white woods such as hemlock and the true firs, species that in the United States typically go into lower valued pulp products. Recently, Japan has moved significantly in the direction of adopting the U.S. stud wall construction method, which makes standard U.S. lumber and structural plywood items more acceptable and competitive in the Japanese market. If this trend continues, the potential for the export of products manufactured from West Coast softwood will improve, and current restrictions on the export of softwood in log form will be less significant.

Canada has very large areas of natural softwood stands, principally in British Columbia. These forests carry the large standing volumes typical of virgin forests but, located as they are in the northern portion of the north temperate zone, many of them have low production potential compared to the highly productive forests of the U.S. Southeast or West Coast. Based upon its large timber reserves, Canada is likely to be a major supplier of softwood to the world for many years. It currently removes only about half of its estimated sustainable harvest and it exports about three-quarters of its production. The United States is its largest customer, but Canada exports significant quantities of wood to Japan and Europe. Historically wood has moved relatively freely across the Canadian–U.S. border. However, Canada can be expected to serve as a reservoir of wood for the United States only as long as it perceives this to be its most profitable market. The United States is currently so dependent upon Canada as a source of softwood lumber and newsprint that any major restriction in price or volume could create a major materials supply problem for this country. Canada's relationships with its former commonwealth partners and with the European Common Market may influence the availability and price of Canadian softwood to the United States.

A very large reservoir of softwood timber exists in the Soviet Union. Like Canada, much of its forest land is in the far north, where productivity is likely to be low. Nonetheless, the large quantities of wood in the present natural stands represent a reserve that is apparently being reduced at a low rate. Two features of the large eastern reserve may influence the rate of its use. More than a third of the volume is larch, which is not a preferred softwood species on the world market. Many of the eastern forests are inaccessible, and the Soviet Union has not committed the capital required to open this resource to use. Russia has been an exporter of softwood to Europe. It supplies some wood to Japan; if the eastern forests were opened to exploitation, this would be a logical market. The Soviet Union is not likely to be an important source of softwood for the United States but if it develops its lumber industry, it could become a factor in the world softwood market and thus indirectly influence the U.S. export-import position.

The northern European countries are important producers of softwood and manufacturers of softwood forest products. Most Scandinavian forests are very intensively managed in comparison to U.S. standards. They are not reducing natural overmature forests as is the case in Canada, Russia, and western United States. Because their silviculture and forest management are much more intensive than those of the other major producers of softwoods, they are growing forests at much nearer their biological capacity than are the other major softwood producers. The Scandinavian countries are major exporters of wood products to the rest of Europe and the United States. There is some evidence that their capacity for manufacture exceeds their capacity to grow wood, and they have been aggressively seeking other supplies of softwood raw material recently in the United States and elsewhere.

The United States has been able to buy softwood at reasonable prices from the softwood-exporting countries and has been content to fill out its softwood needs by importing. This places it in a somewhat vulnerable position if foreign sources of softwood were to change their marketing policies and practices in the pattern of the petroleum and natural gas producers. This country has the opportunity to avoid this vulnerability in the long run, but this would require a change in priorities for forest land use, particularly at the federal level, and in those for the development and use of its long-haul transportation systems.

For hardwoods, the world has a large surplus of supply over requirements. About half of the world's standing timber volume is located in the less developed countries of the tropics. The United States is a large importer of tropical hardwoods, although it grows more hardwoods than it uses. As a result, the hardwood growing stock in the United States is increasing rapidly, much of it in nonindustrial ownership and in the form of unmanaged natural stands. This country could easily become self-sufficient in hardwoods.

In the case of both hardwoods and softwoods, a major limiting factor in any effort to increase the share of the U.S. market supplied from U.S. sources would be an inadequacy of manufacturing capacity. In recent years compliance with environmental regulations has sharply reduced growth in domestic conversion capacity. A substantial fraction, perhaps as much as half, of new capital investment in wood conversion plants during the past several years has been in the installation of pollution control equipment that has not added to the production capacity of the country. New mill construction, in the fiber sector, has been inhibited by concern for ability to produce at a profit in the face of uncertainties about government regulation. Several developments in wood technology could foreshadow a change in the general world wood market. Methods are being developed that permit hardwoods to be substituted for softwoods in traditional softwood uses, particularly in the area of pulp and paper manufacture. Some of the new composites, such as structural particleboard, can be produced from hardwood and may be able to compete effectively in the structural timber market where softwoods have traditionally been dominant. Worldwide there is a growing interest in structural plywood produced from hardwoods, which would also provide opportunities for softwood replacement by hardwoods.

In many of the developing countries the trend toward conversion from wood and charcoal to petroleum as a heating fuel may be reversed as a consequence of the increased cost of petroleum. While the conversion of wood residues to liquid and gaseous fuels still seems to be a marginal undertaking in the United States, it has the possibility of being a much more viable enterprise in tropical hardwood-rich countries that do not have the options of large-scale hydroelectric developments, and exploitable oil and coal resources. Many tropical hardwood forests support 4000 to 5000 cubic feet (110 to 140 m^3) of biomass per acre in vegetative cover, but only 1 to 2 percent of this volume is useful in the production of industrial materials. These concentrations of raw material may make the production of liquid and gaseous alternatives to petroleum feasible. Such developments could influence U.S. materials supply problems by reducing the worldwide demand for petroleum, thus easing the U.S. position as it competes in the world market for fossil fuels.

Another development that could ease the future pressure on softwood timber supply is the conversion of native tropical hardwood forests to introduced softwood species. Such conversion has been successful in many temperate zone hardwood areas in Europe, the United States, Australia, New Zealand, Chile, and Argentina. It is much more difficult and costly in the tropical regions of the world but experimentation with this sort of conversion is widespread throughout the tropics. It would probably be much more feasible technically and less expensive to convert more hardwood areas to softwoods in the United States than in the tropics. This is becoming less acceptable from a social standpoint in the industrial countries, where hardwood forests are prized for their recreation and aesthetic values. This attitude has not yet represented a serious restriction in most of the less developed countries of the tropics.

Given the great potential of the tropics in the long-term timber supply picture and the heavy dependence of the United States on foreign wood resources, it is surprising that this country has very largely ignored the opportunities for bilateral cooperative programs with potential wood suppliers in the tropics. Many U.S.-based corporations are very active in tropical regions, but the federal government has been inactive. Development of forest resources has never been a strong objective in U.S. foreign assistance programs. Those programs that have been undertaken at the request of foreign countries have been ad hoc, intermittent, and, lacking central planning, often ineffective. This is a mistake that is not being made by the other major industrial countries, whether exporters or importers. While most bilateral research, development, and education programs have as their central purpose the advancement of the recipient country, many of the best of these foster the mutual interests of the two countries involved.

Summary

The United States has a large potential capacity for increasing the supply of renewable materials that could substitute for scarce nonrenewables or for renewables in foreign jurisdictions. It has not elected to give high priority to this development. If such a goal were viewed as a desirable national policy, several actions would be indicated. The national forest survey could be improved to provide a better basis for assessment of current reserves and long-term production capacity. Federal and state land use policies could emphasize the importance of encouraging materials production on the most productive forest sites. The research needed to improve product yields from renewable raw materials and to advance cost-effective technologies could be encouraged at government laboratories and in the universities pursuing these lines of research.

Given the possibilities of sudden change in resource price and availability on the world market, it would be prudent for the nation to improve its options for substitution of domestic renewable materials for foreign nonrenewable materials. Rapid substitution is not feasible if the essential foundation in science and technology has not been fostered in advance.

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Timber: Biological and Economic Potential

Stephen H. Spurr and Henry J. Vaux

Forests are estimated to cover 33 percent of the land surface and 10 percent of the total surface of the earth. In terms of the world net primary production, they account for 67 percent of all dry matter production on land and 45 percent of the total produced on both land and water (*1*).

If we define as timber the merchantable stems or boles of trees in the forest at least 5 inches (12.7 centimeters) in diameter at breast height, including all the wood above a 1-foot stump and extending up to a 4-inch top (this is the definition of roundwood used in the forest survey of the U.S. Forest Service) it would appear that approximately half of the total biomass produced by the forest is timber (*2*). Roughly 20 to 25 percent of all photosynthetic matter produced on earth is accounted for by this one product.

From a biological point of view, timber (or more strictly speaking, wood) as a renewable natural resource has great potential. From an economic point of view, however, many factors operate to reduce the use of wood and indeed the use of forested land to produce wood under intensive management. These are the subjects of this article.

The overall biological potential of the forests of the United States can be most simply expressed in terms of the area of land devoted to the growing of trees to be utilized as wood or timber and the average growth of wood per unit area under different intensities of management. The total productive potential is the product of the two. Economic and institutional considerations will determine in large part that portion of the potential forest acreage that will actually be utilized and the degree of management intensity that will in fact be practiced.

Area of U.S. Commercial Forest

One-third of the land area of the United States or 754 million acres (305×10^6 ha) was classified as forest land in 1970 (*3*), of which two-thirds or 500 million acres (202×10^6 ha) is commercial timberland according to the definition established by the U.S. Forest Service. This provides that such lands are capable of growing at least 20 cubic feet of timber per acre per year (1.4 m^3 per hectare per year) and are not legally withdrawn from the possibility of timber harvesting (such as wilderness area) (*4*). The definition is thus in part biological in that it is based upon potential growth per unit area and in part legal in that it excludes productive land legally withdrawn from use. It is in no sense economic, and thus the term "commercial" is a misnomer.

The commercial forest base of 500 million acres will change as a result of additional withdrawals of forest land, clearing of forests to convert land to agricultural use, abandonment of agricultural land to forest use, and clearing of forests to convert land to urban or industrial use.

Some 20 million acres (8×10^6 ha) of productive timberland is currently used for parks, wilderness, and other purposes not compatible with the harvesting of trees for timber. Substantial political pressures currently exist to withdraw additional forested lands from timber production. At present there are some 12.3 million acres (5×10^6 ha) in the National Wilderness Preservation System, 93 percent of which is in the national forests and much of which would not be classified as commercial forest because of the slowness of growth.

The area of formally designated wilder-

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