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UTILIZATION OF SOUTHERN HARDWOODS

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Abstract.--During the rest of the century, hardwood supplies will likely be sufficient for the nation's rising needs for paper and for structural and architectural products; but sawlogs will be in short supply. Therefore, the products mix will incorporate increasing quantities of reconstituted and composite products. Using hardwoods on sites better suited to pine--the South's major utilization problem--will probably be solved by large-scale enterprises converting these low-quality hardwoods to various fiber and solid wood products. Some hardwood acreage may be intensively managed to yield fuel for generating electricity. Small private landholdings could be brought under intensive management by designing management systems that will provide increased remuneration to artisan-owners who manufacture some high-value product like furniture.

Additional keywords: Small logs, shaping-lathe headrig, chipping headrigs and edgers, flakeboard, structural particleboard, fiberboard, lumber, plywood, flooring, hardwood plywood, material balances, energy requirements, medium-density fiberboard, low-grade hardwoods, resources, trends.

Before looking at the South, we first need some overall view of the national hardwood situation. How much hardwood growing stock do we have, and how much can we expect to have in the future? What is the degree of utilization; and, in this energy-pinched age, how much energy is expended in making various hardwood products?

Fortunately, many of these questions have been answered by the National Research Council. In 1974 the Council appointed a Committee on Renewable Resources for Industrial Materials (CORRIM) to assess the interchangeability of renewable resources, to define the limits on their supply and utilization, and to forecast the possible consequences of increased demand on energy consumption, society, and the environment. Panel II of that committee was charged with studying wood for structural and architectural purposes as of 1970 and with projecting scenarios for 1985 and 2000.

I will draw largely on CORRIM Panel II's report (Boyd et al. 1976, 1977 in the first half of this paper and then focus on the South in detail.

NATIONAL HARDWOOD SUPPLY AND USE IN 1970

Hardwoods are a major component of our national timber resource. In 1970 they comprised nearly 40 percent of the total growing stock (USDA Forest Service 1974, Boyd et al. 1976, 1977); tonnages including bark were as follows:

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	Sawtimber	Pulpwood and pole-size timber	Total
	- - - - *Million tons, ovendry* - - - -		
Hardwood	1,544	2,371	3,915
Softwood	4,770	1,740	6,510
Total	6,314	4,111	10,425

Hardwood growth substantially exceeded removals. In 1970, net annual hardwood growth totalled 143 million tons (ovendry); removals totalled only 80 million tons. The 80 million tons removed, plus 8 million tons of dead salvable timber and noninventoried rough or rotten timber, yielded 58 million tons of sawlogs, veneer logs, pulpwood, miscellaneous industrial wood, and fuelwood (fig. 1). Complete tree utilization would permit about 35 percent greater commodity recovery (Keays 1971).

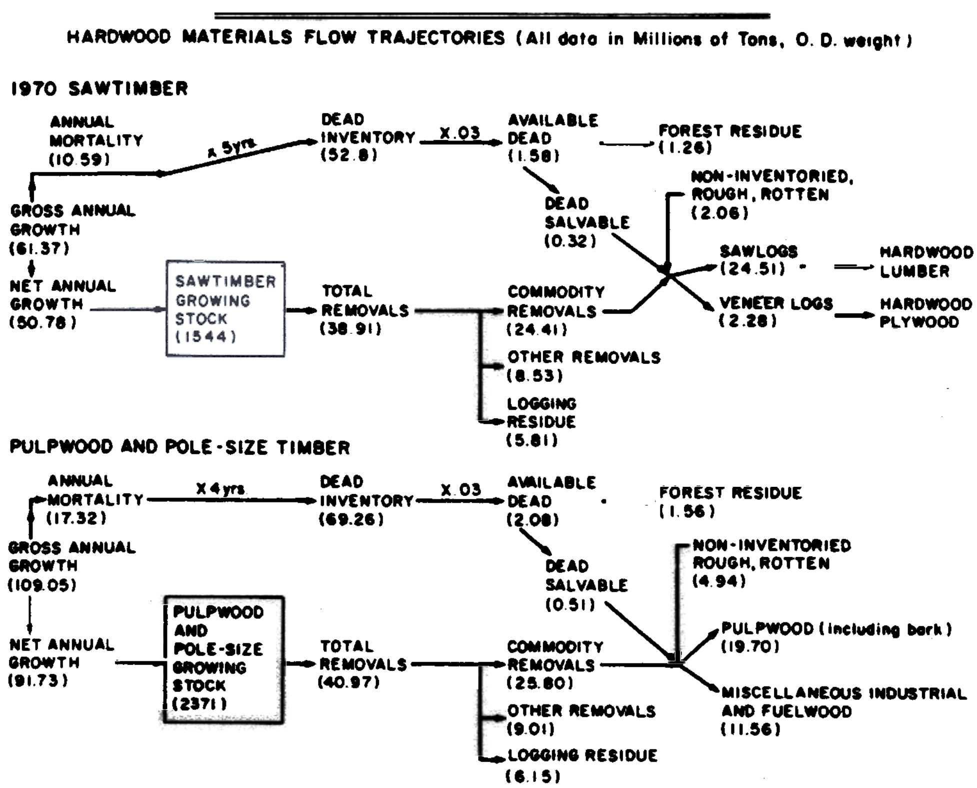


Figure 1.--1970 materials flow trajectories for hardwood sawtimber (top) and pulpwood and pole-size timber (bottom) in the United States. All tonnages include bark. Data on growth and removals reflect 1970 inventory standards; therefore, tonnages do not add up to total biomass. (To prepare this drawing, Boyd et al. (1976) converted cubic feet data (from USDA Forest Service 1974) to oven-dry tons of wood through multiplication by 0.0164; bark tonnage was estimated at 10 percent of wood weight.)

In 1970, therefore, total harvest of hardwood sawlogs, veneer logs, pulpwood, and miscellaneous industrial wood including fuel, was 58 million ovendry tons. Diversion of these tonnages of roundwood into products was as follows:

Commodity	Barky roundwood consumed
	Million tons, ovendry
Hardwood lumber	24.51
Hardwood plywood	2.28
Paper, paperboard, and fiber panels	19.70
Miscellaneous industrial wood and fuel	11.56
Total	58.05

MATERIAL BALANCES

During conversion of these 58 million tons of roundwood, substantial quantities of byproducts, e. g., chips, shavings, trim ends, and bark, were produced and incorporated into paper, fiberboard, particleboard, and fuel. Materials balances (figs. 2-10) illustrate the quantities and nature of these byproducts. Also evident from the material balances is the wide variation in furnish input per ton of product, as follows:

Figure no.	Commodity	Form of woody furnish	Input of woody furnish
			Tons, ovendry
2	Insulation board	50-50 mix of bark-free and barky chips of mixed species	0.96
3	Underlayment particleboard	Planer shavings, sawdust, and plywood trim	1.02
4	Wet-formed hardboard	50-50 mix of bark-free and barky chips of mixed species	1.15
	Medium-density fiberboard	50-50 mix of bark-free chips and barky roundwood of mixed species	1.16
	Structural flakeboard and pallet lumber	Mixed-species barky logs	1.24
7	Lumber laminated from veneer	Barky logs	2.13
8	Lumber (dry, planed)	Barky logs	2.86
9	Hardwood plywood paneling	Barky logs	3.33
10	Oak flooring	Barky logs	3.57

The input listed for structural flakeboard is based on use of a shaping-lathe headrig to manufacture cants and flakes from presently unmerchantable roundwood. In this process pallet lumber, as well as flakeboard, is a primany product (fig. 6). Hardwood lumber is usually sold unplaned and with only a rough end trim for subsequent cut-up in a remanufacturing plant. Figure 8, illustrating kiln-dried, surfaced, end-trimmed lumber, is the utilization likely in 1970 assuming 100-percent yield of cuttings.

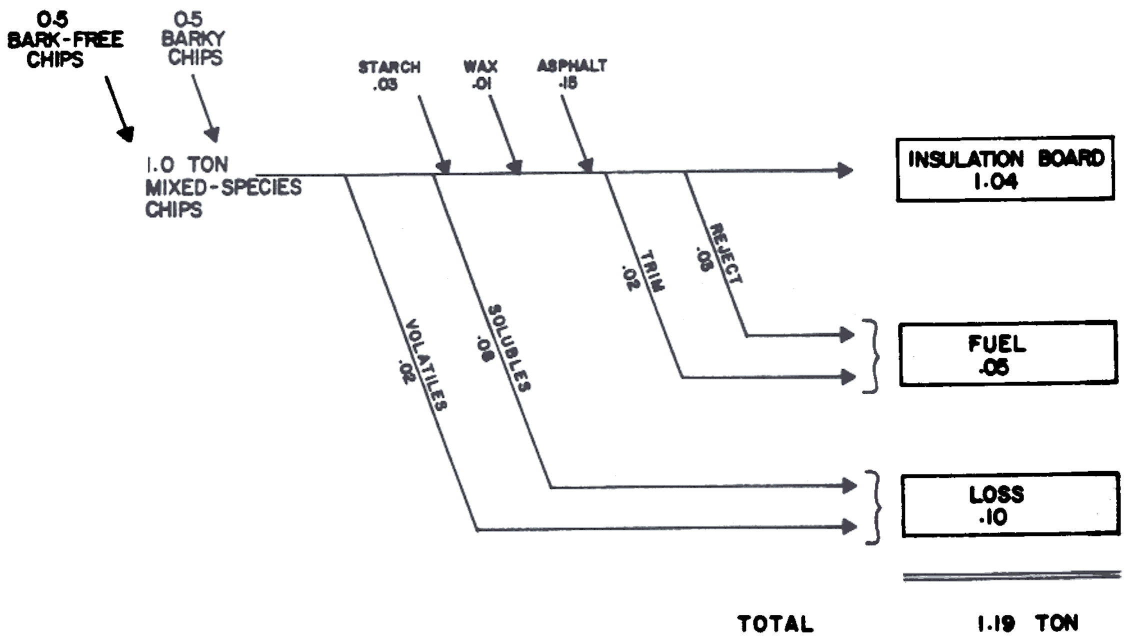


Figure 2.--Wet-formed insulation board--a materials balance based on ovendry weights. Barky chips are forest residual chips. The materials balance assumes steam pretreatment of chips and mechanical pulping with disk refiners. Bark content of mixed chips is assumed to be 5 percent or less.

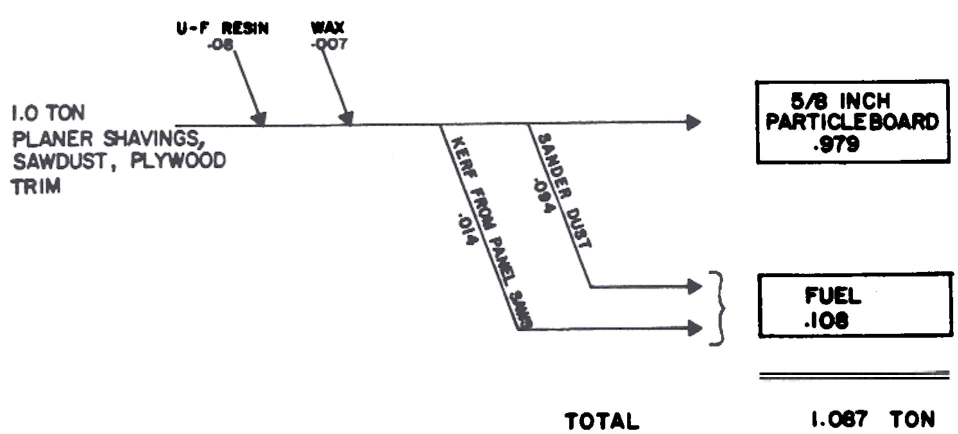


Figure 3.--Underlayment particleboard--a materials balance on the basis of ovendry weights.

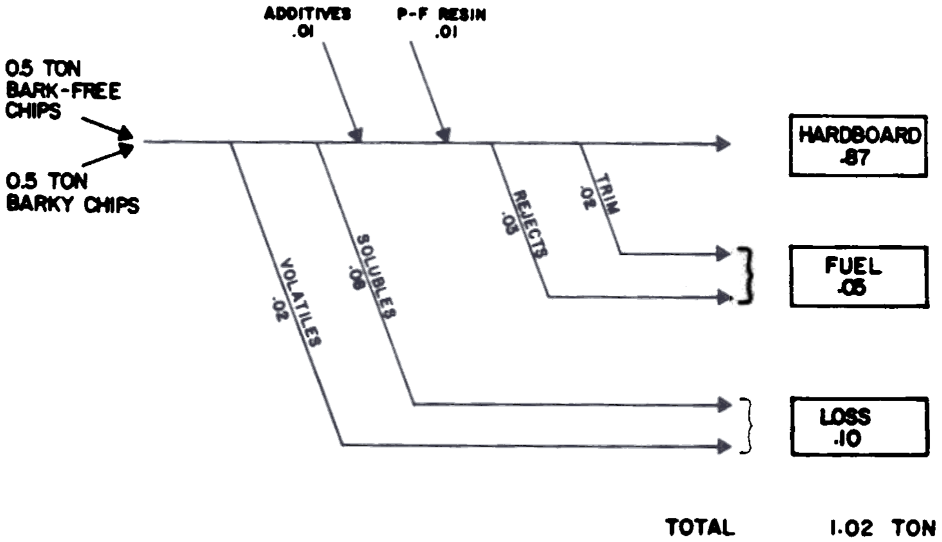


Figure 4.--Wet-formed hardboard--a materials balance based on ovendry weights. Barky chips are forest residual chips. The materials balance assumes steam pretreatment of chips and mechanical pulping with disk refiners. Bark content of mixed chips is assumed to be 5 percent or less.

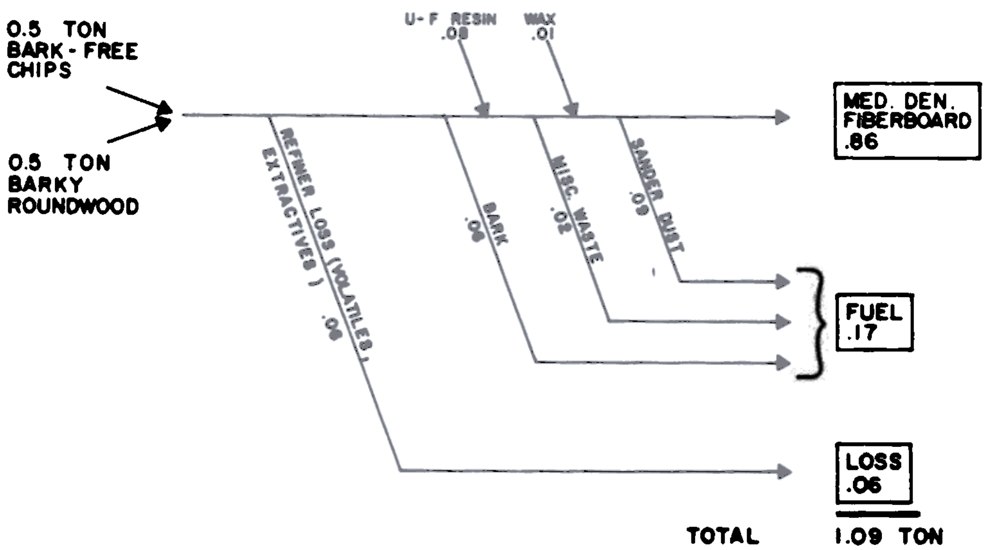


Figure 5.--Medium-density fiberboard (MDF)--a materials balance based on ovendry weights. In MDF manufactured for use as exterior siding, the resin additive is phenol-formaldehyde rather than urea-formaldehyde. The materials balance assumes steam pretreatment of chips and mechanical pulping with disk refiners.

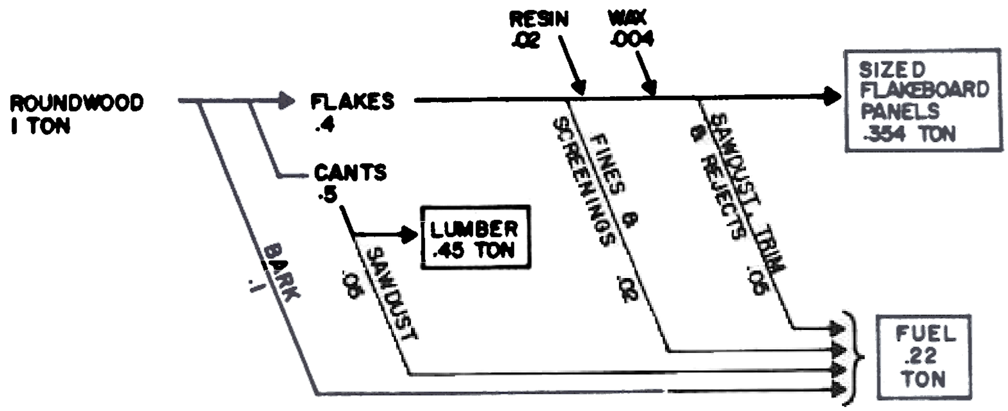


Figure 6.--Structural exterior flakeboard--a materials balance based on use of shaping-lathe headrig to make flakes as a residue from pallet cant manufacture. All weights are on an ovendry basis.

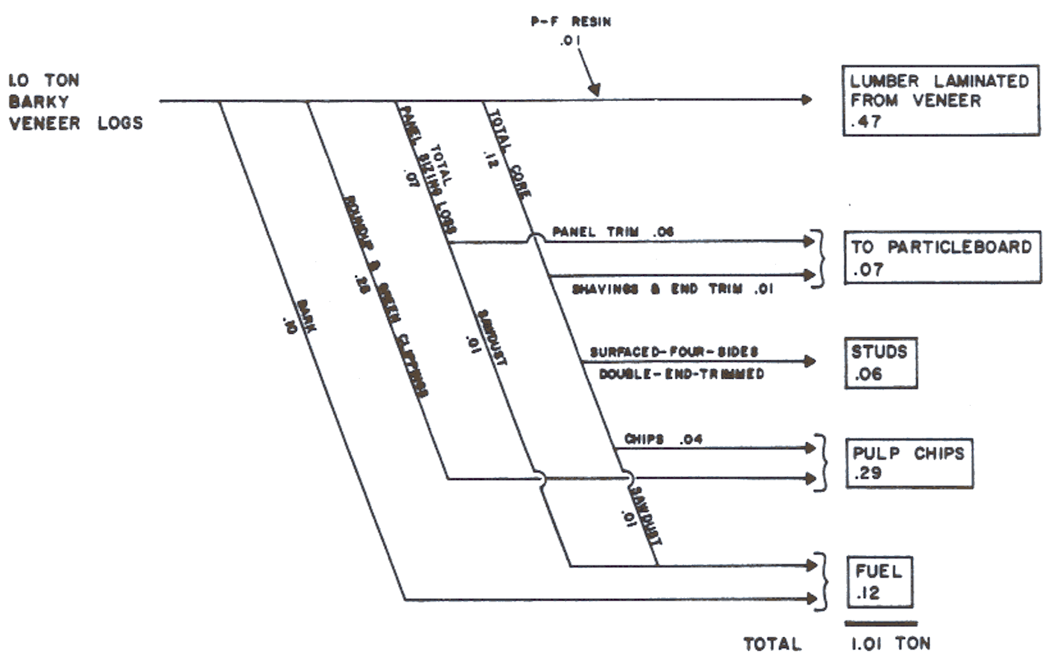
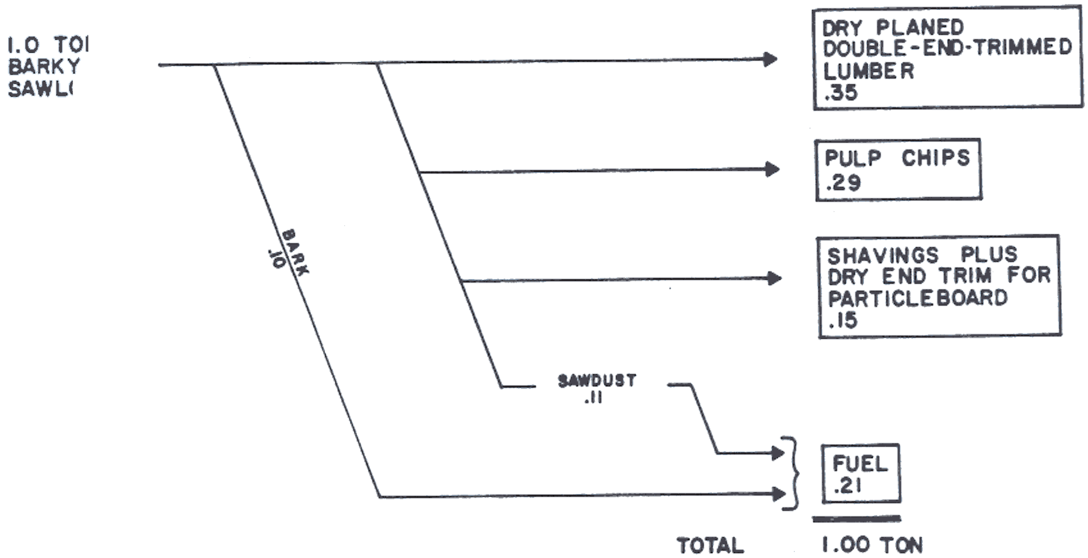


Figure 7.--Lumber laminated from ¼-inch, rotary-peeled, veneer--a materials balance on the basis of ovendry weights. P-F means phenol-formaldehyde resin.



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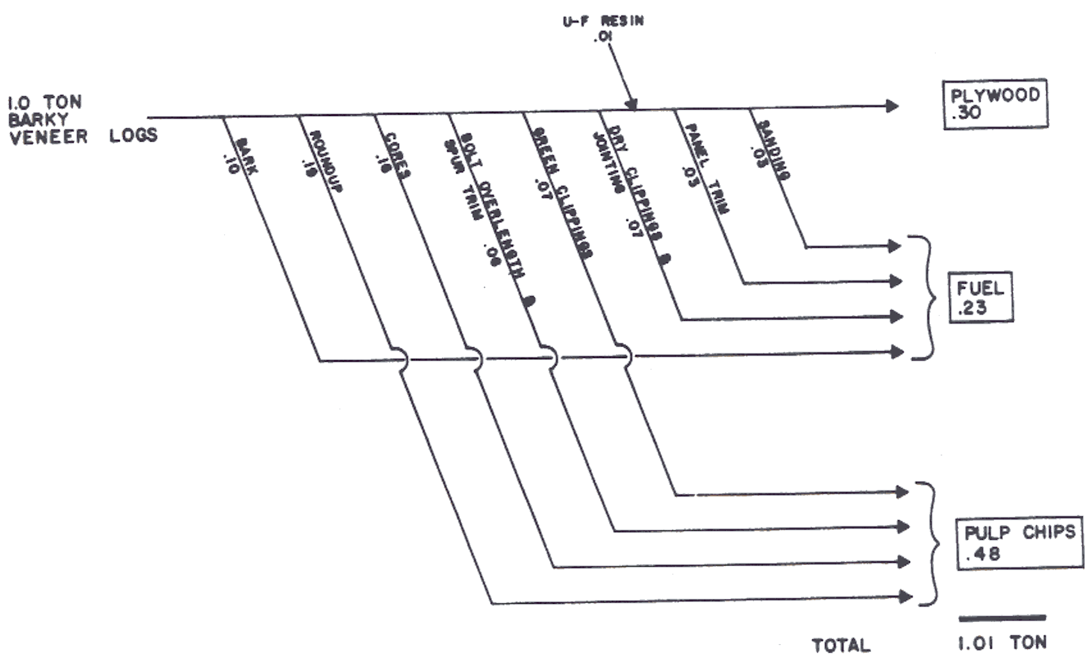

igur .-Hardwood plywood panelling--a materials balance on
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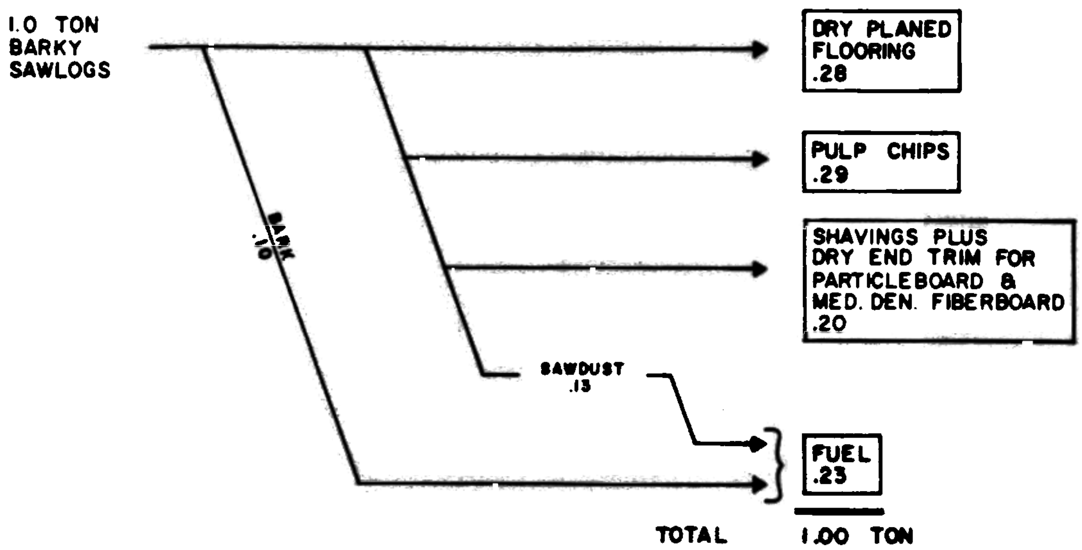

Figure 10.--Oak flooring--a materials balance on the basis of ovendry weights and production of 3/4-inch tongue-and-groove material.

No figures are at hand for hardwood paper production, but it is likely that 2 to 2½ tons of dry barky pulpwood are required per ton of paper produced--the exact figure depending on the pulping process and the product desired.

Thus, on an ovendry basis, structural wood commodities require from 1 to 3½ tons of woody furnish per ton of commodity manufactured; reconstituted boards have the highest product yield, and lumber the lowest; veneer products are intermediate.

ENERGY, MANPOWER, AND CAPITAL REQUIREMENTS

To produce hardwood products requires considerable quantities of energy, manpower, and capital. CORRIM Panel II analyzed these expenditures for all phases of the conversion process including forest activities, manufacturing, transport from forest to mill and from mill to building site, plus additional requirements for any needed additives such as wax and resins in composite commodities.

Net energy expenditures were found to be lowest for structural flakeboard, lumber, and oak flooring (2.3 to 3 million Btu of oil equivalent per ton of product) and highest for particleboard and fiberboards (8.5 to 21 million Btu) (table 1). The Panel also found that producing wood-based commodities requires much less energy than producing comparable commodities from nonrenewable resources. For example, exterior walls sided with brick or constructed of concrete block require 7 to 8 times the energy of all-wood constructions, and walls framed with metal require about twice the energy of wood-framed walls.

Manpower required in producing wood products ranged from 8 man-hours per ovendry ton for medium-density fiberboard to 20 man-hours for wet-formed hardboard (table 2); lumber was intermediate, requiring 10 man-hours. Capital depreciation was lowest for lumber ($10.25 per ovendry ton) and highest for wet-formed hardboard ($54.85)(table 3). With a few exceptions, manpower and capital costs were not shown to be appreciably different for wood-based and nonwood-based systems.

Table 1.--Energy needed to log, manufacture, and transport to building site selected wood-based commodities (Data from Boyd et al. 1976)

	Logging	Gross manufacture Electric	Gross manufacture Heat	Transport	Gross total	Available residue energy	Net total[a]
	Million Btu (oil equivalent) per ovendry ton						
Lumber (dry, planed)	0.943	0.786	4.060	1.966	7.755	8.313	2.909
Oak flooring	1.073	.844	4.847	1.977	8.741	11.388	3.050
Lumber laminated from veneer	.740	.144	6.443	1.966	9.293	3.540	5.753
Structural flakeboard	.956[b]	.578	6.933	1.314	9.781	8.616	2.270
Medium-density fiberboard	.783[c]	3.748	5.555	1.146	11.232	2.741	8.491
Insulation board	.622[c]	4.920	5.619	1.243	12.404	.667	11.737
Hardwood plywood panelling	1.041	.244	9.998	1.977	13.260	10.629	3.018
Underlayment particleboard	4.617[d]	2.503	5.598	1.198	13.916	1.529	12.387
Wet-formed hardboard	.743[c]	9.919	9.743	1.146	21.551	.797	20.754
Total	11.518	23.686	58.796	13.933	107.933	48.220	70.369
Percent of total (gross)	10.7	21.9	54.5	12.9			
Mean	1.28	2.63	6.53	1.55	11.99	5.36	7.82

[a] Assumes residue energy can be offset only against gross manufacturing energy (but not against logging or transport energy).

[b] Includes logging plus preparation of bark-free chips input.

[c] Includes logging plus preparation of chips.

[d] Includes energy input in logging plus preparation of particleboard furnish in form of planer shavings, plywood trim, and sawdust.

Similar data on requirements for furniture manufactured from hardwoods are not at hand. In general, however, yields of finished furniture would be substantially lower than that of oak flooring, and inputs of labor, energy, and capital would be higher.

Also, no parallel data on paper made from hardwood are presented here because of the diversity of processes and products.

Table 2.--Man-hours needed to log, manufacture, and transport to building site selected wood-based commodities (Data from Boyd et al. 1976)

	Logging or extraction	Manufacture	Transport (Mill to bldg. site)	Total
	- - - - *Man-hours per ovendry ton* - - - -			
Medium-density fiberboard	3.43	2.86	2.08	8.37
Underlayment particleboard	5.04	2.64	1.99	9.67
Lumber (dry, planed)	3.92	3.06	3.06	10.04
Structural flakeboard	3.97	3.99	2.14	10.10
Lumber laminated from veneer	3.08	4.53	3.06	10.67
Insulation board	2.28	6.54	2.13	10.95
Hardwood plywood panelling	4.33	8.03	2.67	15.03
Oak flooring	4.46	8.07	2.67	15.20
Wet-formed hardboard	2.72	14.72	2.08	19.52
Total	33.23	54.44	21.88	109.55
Percent of total	30	50	20	100
Mean	3.7	6.1	2.4	12.2

Table 3.--Capital depreciation associated with logging, manufacturing, and transport to building site of selected wood-based commodities (Data from Boyd et al. 1976)

	Extraction	Manufacturing	Transport	Total
	- *Dollars per ovendry ton* -			
Lumber (dry, planed)	3.09	3.91	3.25	10.25
Structural flakeboard	3.13	11.37	2.36	16.86
Lumber laminated from veneer	2.42	11.98	3.25	17.65
Underlayment particleboard	6.72	13.74	2.20	22.66
Hardwood plywood panelling	3.41	18.37	3.14	24.92
Insulation board	3.84	24.06	2.29	30.19
Oak flooring	3.51	26.07	3.14	32.72
Medium-density fiberboard	3.21	27.89	2.18	33.28
Wet-formed hardboard	4.59	48.08	2.18	54.85
Total	33.92	185.47	23.99	243.38
Percent of total	14	76	10	100
Mean	3.7	20.6	2.7	27.0

NATIONAL HARDWOOD SUPPLY AND USE IN 2000

In assessing trends, CORRIM Panel II recognized that in the future trees available for harvest will, on the average, be smaller, and economic and social pressures for complete utilization of all stems will increase. Improved precision sawing and improved planing techniques should significantly raise lumber recovery from each cubic foot of log volume, but average hardwood lumber grade will decrease. Also, wood in a variety of composite and reconstituted forms will be increasingly used for structural products, thereby improving the degree of use substantially.

With the foregoing in mind, Panel II pooled all hardwood timber in commercial sizes when developing a materials balance for 2000; i.e., distinctions between sawtimber, pulpwood, and poletimber will have less practical significance in 2000 than in 1970. The projection (fig. 11) shows that hardwood removals (148 million tons) will be less than the gross annual growth that year (184 million tons) but slightly more than the net annual growth (144 million tons) after deduction for annual mortality (40 million tons). By 2000, the hardwood growing stock inventory of 4,827 million tons will be substantially greater than the 1970 inventory of 3,915 million tons.

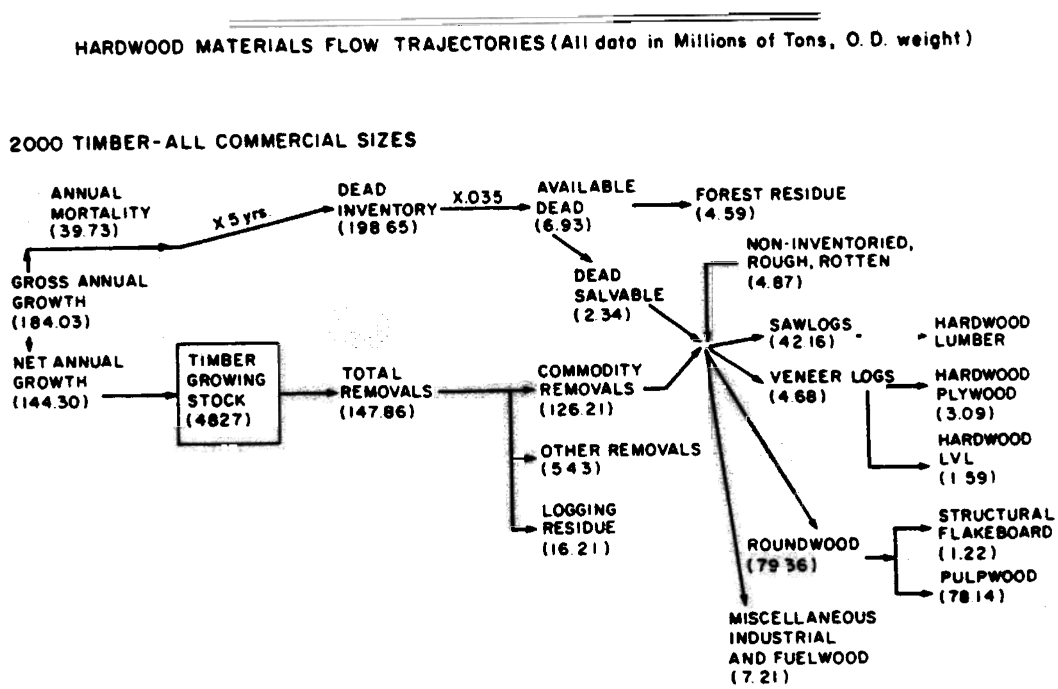

Figure 11.--Hardwood materials flow trajectory for the year 2000 Data on growth and removal reflect 1970 inventory standards and include bark estimated at 10 percent of wood tonnage. (To prepare this drawing, Boyd et al. (1976) converted cubic feet data (from USDA Forest Service 1974) to ovendry tons through multiplication by 0.0164.)

In the year 2000, therefore, the 147.86-million-ton removals from hardwood growing stock, together with 2.34 million tons of dead salvable hardwood, will yield 133.41 million tons of sawlogs, veneer logs, roundwood, and miscellaneous industrial and fuel wood:

Commodity	Barky roundwood consumed
	Million tons, ovendry
Sawlogs for lumber	42.16
Veneer logs for plywood	3.09
Veneer logs for lumber laminated from veneer	1.59
Roundwood for structural flakeboard	1.22
Roundwood for pulp and fiberboard	78.14
Miscellaneous industrial wood and fuelwood	7.21
Total	133.41

As in 1970, these tonnages of logs will additionally yield byproducts of chips, shavings, and trim ends for incorporation into paper, fiberboard, and particleboard. Bark will find use as fuel, mulch, and a spectrum of more sophisticated products.

CORRIM Panel II concluded that hardwood supplies would probably be adequate to meet national demand but that traditional product mixes would be considerably altered. That is, high-grade solid hardwood lumber in desired sizes will be in short supply, but important new classes of reconstituted products such as medium-density fiberboard (Suchsland and Woodson 1976), structural flakeboard (Hse et al. 1975), dowel-laminated crossties (Howe and Koch 1976), and lumber laminated from veneer (Koch 1973) will appear in the market place to satisfy our national demands for wood products.

SOUTHERN HARDWOOD RESOURCES

In 1970 the United States had a total hardwood growing stock of 217 billion cubic feet of wood in trees 5 inches and larger in diameter at breast height to a 4-inch top measured outside bark; the South contained 81.1 billion cubic feet, or about 37 percent of the total (USDA Forest Service 1974). In other words, the South's hardwood growing stock equalled 1,463 million ovendry tons of wood and bark.

A later estimate (Murphy and Knight 1974) placed the southern hardwood resource at 108.3 billion cubic feet of wood (1,954 million tons of wood and bark, ovendry). The latest report (Staff, For. Resour. Res. Work Unit 1976), based on data gathered during 1964-1974, indicates a total hardwood resource in the 12 Southern States of 113.7 billion cubic feet; this amounts to 2,051 million tons of wood and bark, ovendry. Evidently the southern hardwood resource is increasing in total volume, and the South will continue to be a major source of needed hardwoods.

The hardwood resource of the South can be divided into that on southern pine sites and that on hardwood sites. For the purposes of this paper, pine sites are defined as forested uplands, excluding those growing cove-type hardwoods, that are supporting southern pine or show evidence, like stumps, of its former occurrence. Hardwoods on pine sites total about 49.2 billion cubic feet of wood (888 million tons of wood and bark, ovendry) or 43 percent of the total hardwood inventory of the 12 Southern States (table 4). How have pine sites become so heavily invaded by hardwoods? In most of the South, plant succession--the replacement of one plant community with another--climaxes with a hardwood forest (Billings 1938; Quarterman and Keever 1962). Establishment of pine stands requires the absence of heavy litter and freedon from competing plant cover; wildfires often provided these conditions and checked the succession to hardwoods. But man has largely excluded fire from the forest, thus favoring the shade-tolerant hardwoods.

Table 4.--Volume of all hardwoods on pine sites and hardwood sites in 12 Southern States (Staff, For. Resour. Res. Work Unit 1976)[a]

	All sites	Pine sites	Hardwood sites
	- *Million cubic feet*		
Alabama	10,886	6,456	4,430
Arkansas	11,174	4,926	6,248
Florida	5,461	1,078	4,383
Georgia	12,999	6,600	6,399
Louisiana	9,879	3,085	6,794
Mississippi	8,416	3,827	4,589
North Carolina	17,074	6,838	10,236
Oklahoma	1,601	633	968
South Carolina	8,093	3,358	4,735
Tennessee	10,255	3,724	6,531
Texas	4,222	2,593	1,629
Virginia	13,651	6,118	7,533
	113,711	49,236	64,475

[a] From source data gathered during 1964-1974 on systematic sample plots 2 to 4 miles apart. The volume is expressed in cubic feet inside bark, of trees from stump to a minimum 4-inch top diameter (outside bark) of central stem. All trees 5 inches in diameter at breast height are included.

THE UTILIZATION PROBLEM

Quality hardwoods growing on good hardwood sites present no serious utilization problem. However, such hardwoods in sawlog sizes will be in increasingly short supply because prime hardwood acreage in the lower Mississippi Valley (and elsewhere) is rapidly being cleared for agronomic crops

(Sternitzke 1976). By contrast, the vast inventory of hardwoods on pine sites presents a real challenge to the industry.

Today, almost 73 million acres of the 138-million-acre southern pinery are covered by a mantle of unwanted hardwoods; and southern pine sites harbor nearly 0.8 cubic foot of these hardwoods for every cubic foot of pine (Murphy and Knight 1974).[2] Oaks (Quercus spp.) predominate; and sweetgum (Liquidambar styraciflua L.), hickory (Carya spp.), yellow-poplar (Liriodendron tulipifera L.) and black tupelo (Nyssa sylvatica Marsh.) are other important components of the resource (fig. 12).

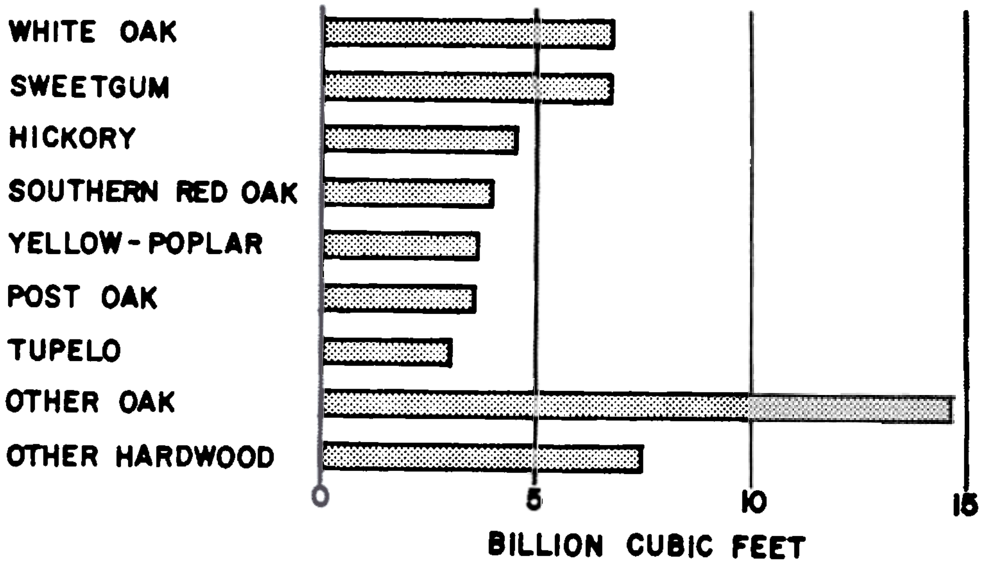

Figure 12.--Volume of all hardwoods on southern pine sites by species (Murphy and Knight 1974).

Virtually all forest economists agree that substantially more wood products must be harvested from these southern pineries to meet the country's anticipated needs. However, major opportunities for forest improvement are vanishing. Virtually all commercial forests are protected from fire; so little additional growth can be obtained from further investments in fire protection. Intensive planting programs have left few opportunities for regenerating bare land. The chief opportunity for increasing forest productivity, therefore, lies in raising the proportion of fast-growing, versatile pines on these sites on which hardwoods have intruded.

One approach to type conversion is to deaden, chop, and burn the unwanted hardwoods and replace them with thrifty stands of pine. Such conversion of all acreage usurped by hardwoods would cost several billion dollars (Anderson and Guttenberg 1971, Anderson 1974) and would undoubtedly offend the environmentally conscious public, which objects to the ugliness

[2] The ratio 1:.753 was computed from survey data developed during preparation of the Murphy and Knight (1974) manuscript.

and waste of unutilized debris. A second approach is to utilize hardwoods from pine sites rather than destroy them. Hardwood utilization would offset part of the outlay for clearing sites for replanting and would alleviate some of the anticipated excess demand for southern pine.

The difficulties in utilizing this hardwood resource are many. Trees are often scarred and defective from fires and from previous pine harvesting. They are slow growers because the sites are not right for them--trees 6 inches in diameter at breast height are typically 40 years of age (Manwiller 1974). They are short and crooked in bole. The low cubic content per stem, the highly variable species mix from stand to stand and even from site to site within stands, and the low cubic volume per acre all combine to raise harvesting costs. Moreover, their value after harvest is low. Knots and other defects, short lengths, and small diameters preclude any hope of sawing quality lumber in conventional lengths. Not least among the problems is that of maintaining a species mix suitable for a manufacturing operation (Barber 1975).

Offsetting these disadvantages are some advantages. The resource is distributed throughout the southern pineries and therefore is available in close proximity to a large number of potential consumers. Moreover, the volumes are substantial. They can supply a market of almost any realizable magnitude--and at a variety of locations. There will always be a supply because on many sites hardwoods replace southern pines in natural succession and certain sites, such as areas bordering intermittent streams in uplands, will remain in hardwoods for environmental reasons. The stumpage is low in cost, thus leaving a considerable proportion of final product value for harvest and manufacture. New industries based on these hardwoods can be located in depressed rural areas where labor is readily available and local communities are frequently eager to help in plant establishment. Finally, factories utilizing these hardwoods can be energy self-sufficient (Barber 1975).

Improved utilization of hardwoods from all sites should hasten the time when wood production can be maximized by concentrating hardwood management on sites best suited for hardwoods, and pine production on lands best suited for pines. Hardwood sites intermingled with pine lands will permit a desirable pattern of diveristy in most areas. Moreover, substantial acreages suitable for high production of either hardwoods or pine are available; these lands can be allocated to either species group as needed to balance demands, not only for industrial wood products, but for wildlife habitat, recreational areas, visually pleasing landscapes, and water management.

THREE NON-PULP UTILIZATION CONCEPTS

How can we economically utilize these low-quality, pine-site hardwoods? Indeed, how can we use more of the biomass of all trees, large and small, pine and hardwood, growing on southern pine sites? Three solutions are proposed here, two for large acreages and one for small landholdings. In the first solution, species are used as they occur for manufacture into commodity products; following harvest, the acreage would be converted to more productive species. The second possibility is type conversion to coppicing hardwood and intensive forestry to product maximum biomass for energy. The third plan is appropriate for small acreages and uses the natural species mix in furniture.

Biomass Recovery and Utilization With Shaping-Lathe Headrigs

In 1963 not over 30 percent of the biomass (above and below ground) of southern pine trees harvested for lumber or pulp was recovered and sold as dry, planed, double-end trimmed lumber or as kraft paper. Virtually none of the hardwoods on pine sites were utilized to a significant degree. Even today the major forestry expense in the South is destroying these low-quality hardwoods.

A new harvesting and utilization system (fig. 13) could recover 67 percent of tree biomass of all species as solid wood products saleable at about $150 per ton (table 5) (Koch 1976a). Thus, product yield from a mixed-species forest would be four times that obtained in 1963 since hardwood tonnage on pine sites is 0.8 of pine tonnage (i.e., 0.67 x 1.80/0.30 = 4.0). Technology exists to put this system known as BRUSH into effect immediately; by the early 1980's it could be in widespread practice.

Table 5.--Merchantable solid-wood product recovered by proposed facility for processing mixed species

		Percent
Total biomass (above and below ground)		100
Less:		
75% of roots and stump[a]	12.3	
Foliage	4.0	
Stem bark	12.5	33[d]
50% of barky tops and branches[b]	4.2	
Sawdust and trim losses[c]	0	
Percentage ending as product		67

[a] 25% recovered as flakeboard furnish.

[b] 50% recovered as flakeboard furnish.

[c] These residues recycled by fiberizing and used as flakeboard furnish.

[d] Most of this, except foliage, ends as fuel.

By this system trees of all species measuring 5 to 12 inches in d.b.h. are harvested with the central root mass intact by a tree puller developed by the Southern Forest Experiment Station (Koch 1976c). Trees larger than 12 inches are cut 6 inches above ground level. Tops and limbs are severed on the site, and full-length stems (including roots) are transported to the mill. Tops, branches, and all residual trees are chipped in place with a mobile chipper (Koch and McKenzie 1976), and the chips are then hauled to the mill and screened; half are utilized for fuel and half for core flakes made on a ring-flaker. At the mill merchandising deck, roots and bark are removed from the stem. The bark and most of each root are used as fuel (Koch and Wellford 1977); about one-quarter of each root is processed as core flakes.

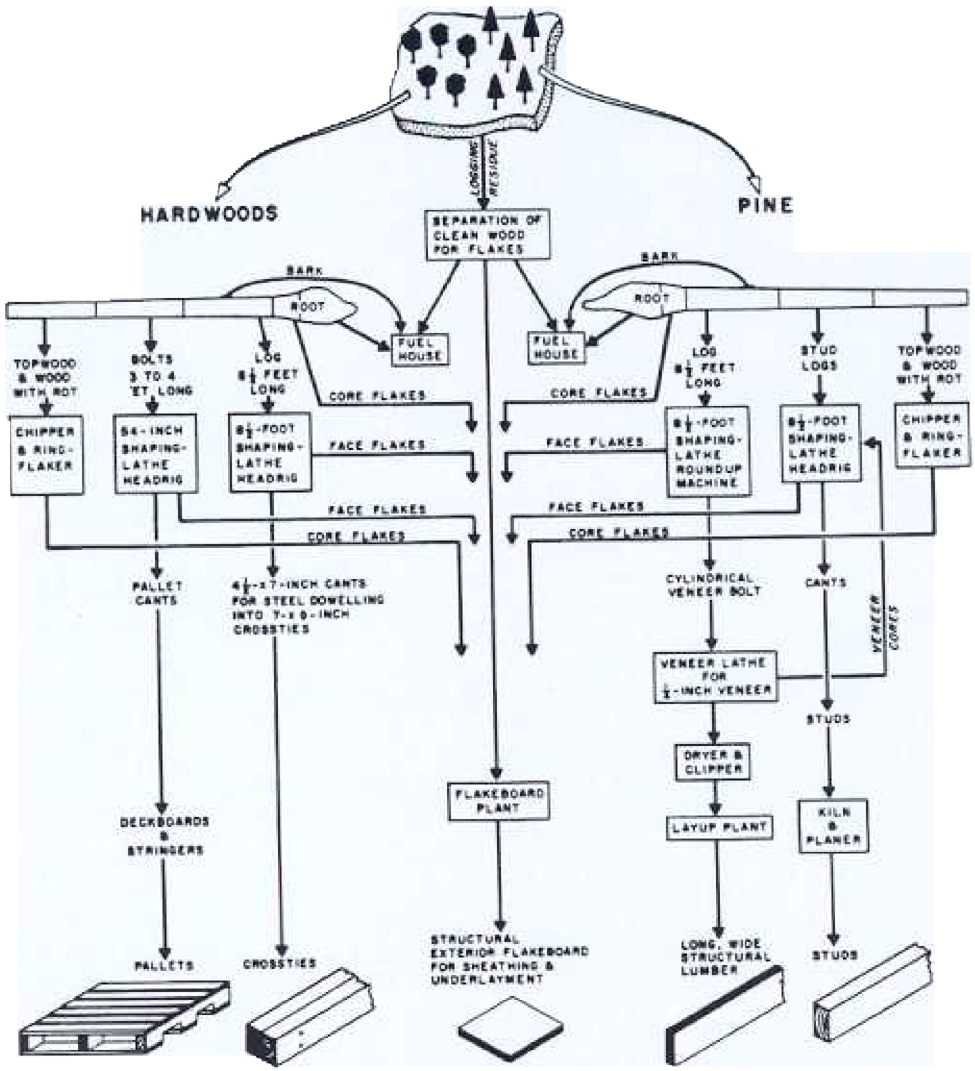

Figure 13.--Flow plan whereby 67 percent of the above- and below-ground biomass of trees in mixed-species southern forest end as pallets, crossties, structural exterior flakeboard, long wide structural lumber, or as studs. The system is self-sufficient in energy.

A few high-grade sawlogs and veneer logs are cut from the hardwood stems and resold. Remaining hardwood logs down to 8.5 inches in diameter are cut in 8½-foot lengths and converted by a shaping-lathe headrig into face flakes and cants that are later dowel-laminated into 7- by 9-inch mainline crossties (Howe and Koch 1976). Hardwood boltwood 5 to 8.5 inches in diameter is converted on a 54-inch shaping-lathe headrig (Koch 1975) to face flakes and pallet cants (to yield deck boards and stringers). Hardwood less than 5 inches in diameter and rotted bolts are chipped and ring-flaked to yield core flakes.

With pine, 8-foot logs down to 8 inches in diameter are rounded on a shaping-lathe to yield flakes plus perfect cylinders to be peeled into ⅛-inch veneer. The veneer is then paralled-laminated into wide, long structural lumber (Koch 1973). Veneer cores and small pine logs are converted on another shaping-lathe headrig into flakes and cants for resawing into studs. Very small bolts are chipped and ring-flaked to yield core flakes.

Thus, output of the plant (table 6) is crossties, pallets, studs, structural exterior flakeboard (Hse et al. 1975) that can compete in price and function with sheathing grades of plywood, and structural lumber in any desired length or width laminated from ⅛-inch veneer.

Table 6.--Annual output, by product,[a] of the processing plant depicted in figure 13 when equipped with seven shaping-lathe headrigs (Koch 1976b)

Commodity	Ovendry tons	Other measures
Crossties (7- by 9-inch)	46,440	675,000 pieces, or 30,121,875 bd ft
Long, wide lumber	64,462	4,297,467 ft
Studs	26,250	31,980,000 bd ft
Pallets	48,555	31,500,000 bd ft
½-inch sheathing	206,243	215,172,700 ft
Fuel (approx.	193,050	
Total	585,000	

[a] 100 effective operating hours per week, 50 weeks per year.

Appropriate regeneration techniques applied immediately to the harvested sites will quickly yield plantations of much greater productivity than the present-day forests.

Biomass Plantation for Energy

Hardwood growth naturally occurring the the South varies significantly by site, stocking, and species. The Southwide average is low, however. Based on inventories of stems 5 inches in dbh and larger, hardwood growth is only 16.7 cubic feet per acre per year, i.e., 0.27 tons ovendry per acre per year (USDA Forest Service 1974, p. 62).

Well stocked stands of hardwoods on pine sites southwide probably grow only a third to a half the annual volume produced by the same sites when stocked with southern pine. For example, 30-year-old second-growth upland oak on an average site with 84 square feet of basal area yielded 10.35 cords of merchantable stem to a 4-inch top outside bark; this amounts to 0.34 cord (29 cubic feet) of wood per acre per year (Schnur 1937, p. 8). In contrast, 30-year-old loblolly pine (P. taeda L.) should yield 31 cords of peeled wood to a 4-inch top; this amounts to about 1 cord (95 cubic feet) of peeled wood per acre per year (USDA Forest Service 1976, p. 68).

One obvious method of increasing hardwood supplies is to increase annual yield per acre. Because maximum yield likely calls for more stems per acre (3,000?) than is usual and hence smaller stems than usual, the end product resulting from maximum-yield hardwood plantations will probably not be sawlogs. It could be energy.

Several researchers have proposed that intensively cultivated coppicing hardwoods be grown through short rotations on close spacing to provide wood for energy--specifically to burn to make steam to drive turbines to generate electricity. Many foresters and wood technologists are skeptical, but others, principally engineers and agronomists, think the idea may be feasible.

A major study of the subject is under way by METREK Division of MITRE Corporation, Washington, D.C. The data presented to date are both interesting and challenging. The underlying assumption is that 12 tons of dry hardwood biomass can be grown per acre per year on substantial southern acreage. Sites would be selected only if they have at least 25 inches of precipitation annually, are arable (i.e., in Soil Conservation Service capability classes I-IV), have a slope equal to or less than 30 percent (17 degrees), and have water (probably from wells) available to irrigate every acre.

With substantial acreages of such land, say 20,000 acres, acquired at the going price, electricity can apparently be generated at prices competitive with oil-, gas-, or coal-fueled plants but not with nuclear-fueled plants. To accomplish such economics, work roads would be built at 500-foot intervals, plantations would be heavily fertilized, and all acres would be irrigated with moving tower-mounted, cannon-type sprinklers. Coppicing species of trees would be planted on 4-foot spacing and harvested every 6 years with a mobile chipper (fig. 14). Four harvest cycles totalling 24 years would elapse before replanting. Chip vans would transport material from roadside to a conventional, wood-burning power plant. Cost of chipped wood and bark delivered to the fuel pile is computed to be $25 per ovendry ton. Based on a 20,000-acre plantation in Louisiana, power cost would be about 35 mills per kilowatt hour, and annual power sales would be perhaps $12,000,000. Under these circumstances, return to equity capital (half of total dollars required) is projected to be 15 percent annually after federal income taxes.

The engineers have thrown down a real challenge to the silviculturists, that is, to develop techniques for growing 12 tons (ovendry) of coppicing hardwood biomass per acre per year, over a broad range of southern sites. Agronomists seem to see no insurmountable obstacles; silviculturists, however, appear less optimistic about delivering this level of productivity.

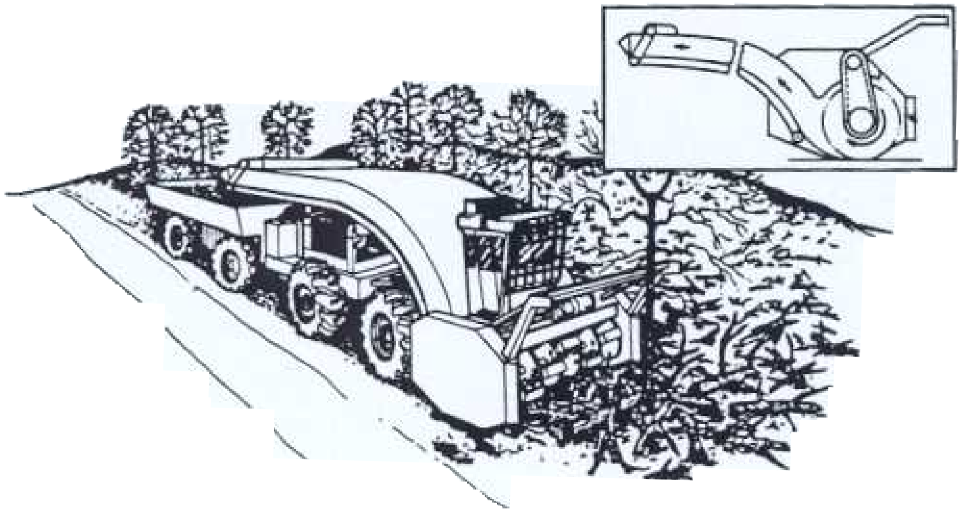

Figure 14.--Concept drawing of a forestland residue machine to retrieve wood for fuel or fiber (Koch and McKenzie 1976). The production machine will likely be a tracked mobile chipper equipped with front-mounted felling bar and top-mounted grapple; it will be trailed by a couple of self-powered chip carriers to forward chips to roadside.

Advocates of energy plantations must be cautioned against diminishing the growing stock of hardwoods needed for paper and for structural and architectural purposes (fig. 11). Diminution of such growing stock available for conventional conversion would call for substitution of nonrenewable resources for wood products--a poor trade-off in terms of national energy consumption.

A 160-Acre Solution

Wood technologists frequently overlook one of the most interesting challenges--that of the small landowner. In 1970, about 73 percent of the commercial forest land in the South was in farms and miscellaneous private ownerships. Growing stock on these lands averaged only 773 cubic feet per acre, i.e., 341 of softwoods and 432 of hardwoods (USDA Forest Service 1974, p. 54, 64). Most of this forestland is in small holdings ranging from 40 to 640 acres. If these small ownerships could be more intensively managed for timber production, the nation would have a more-than-adequate supply of growing stock. However, intensive management will occur only if wood technologists and economists can devise compelling economic arguments for it.

I would like to challenge southern technologists to design silvicultural treatments, harvesting procedures, manufacturing methods, and marketing arrangements profitable for a 160-acre forest managed for sustained yield. The arrangement should be tailored to an owner who is not only a forest farmer but also an artisan with some marketing skill.

Suppose we require a minimum wage to the artisan-owner of $10,000 annually plus a 20-percent pre-tax return on his investment in land, shop buildings, and equipment. If we value the land and timber at $230 per acre ($36,800) and the equipped shop at double this amount, total investment would be $110,400, not including working capital. Under our formula, annual pre-tax return to the artisan-owner should therfore be $10,000 + 0.20 x $110,400, or $32,080. If all other operating expenses (including depreciation) total double this amount, or $64,160, then net sales after discounts and commissions must total $96,240.

If, under intensive management, sustained yield of wood is 120 cubic feet per acre per year, the 160-acre farm will yield 19,200 cubic feet, or 315 tons ovendry, of bark-free hardwood annually. If we assume that 10 percent of this tonnage is converted to salable product (32 tons), then net sales value per ton of manufactured product, after discounts and commissions, must amount to at least $96,240/32 tons, or $3,007 per ton. This required tonnage price indicates that the product should be fine furniture of some kind, perhaps a limited line of fine desks or chairs.[3] To make 32 tons annually of chairs averagaging 15 pounds each, calls for manufacture of 4,267 chairs, or about 18 chairs per day. At a sales price of $75 per chair, gross income from such an operation would be nearly half a million dollars annually This approach to furniture manufacture circumvents the usual procedure of sawing long grade lumber from high-quality trees for later conversion to small furniture cuttings. In other words, the artisan-owner would convert his roundwood directly to furniture cuttings without the wasteful intermediate step of grade lumber manufacture. It is pertinent to note that an unpublished study by S. A. Bingham (Ross Associates, Inc.) and J. G. Schroeder (USDA Forest Service, Southern Forest Experiment Station) showed that average cutting length of a major manufacturer of a full line of furniture was only 31 inches, and 92 percent of the cuttings measured less than 54 inches in length.

Doubtless I have depicted an over-simplified manufacturing and sales situation. Given sufficient study, however, I think the idea has much merit. Among these merits are the potential for greatly intensified forest management, the capability of producing fine furniture from moderate sizes and grade of trees, and optimum utilization of the rich diversity of species on Southern lands. Not least of the advantages would be the social benefits derived from having numerous profitable rural enterprises operated by artiisan-owners.

CONCLUSION

In summary, the South is blessed with an abundance of diverse and interesting species, in amounts adequate to the nation's needs, spread over a vast area all of which is close to markets and none of which is far from rail lines or paved roads. Viable sustained-yield systems are possible for small as well as large acreages. Silviculturists, forest products technologists, and economists should work together to develop and implement these systems.

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[3] A 15-pound chair that sells for $75 brings $5 per pound, or $10,000 per ton.

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