Concept for Southern Pine Plantation Operation In the Year 2020

Peter Koch

ABSTRACT—Fertilization, close spacing, very early thinning, and application of new harvesting and manufacturing technology could yield—over a 35-year rotation—146 tons per acre (ovendry basis) of pulp, 2-by-4 studs, random-length conventional lumber, millwork and structural laminated wood, long-wide structural lumber laminated from veneer, sheathing plywood, structural flakeboard, and animal food supplement (muka). At $200 per product ton (ovendry basis, 1979 dollars), each acre could yield a gross realization of about $29,200 of these products per 35-year rotation; additionally, about 47 tons (ovendry basis) of fuel would be harvested over the 35-year rotation.

Conversations with forest economists and landowners lead me to believe that the market value of stumpage in forests of the United States will increase in the next few decades at about 3 percentage points more than the inflation rate. If this is so, southern pine stumpage prices, measured in constant 1979 dollars, will more than triple by the year 2020.

Additionally, the price of fossil fuels will probably increase more rapidly than inflation. In recent months the price of meat has risen faster than the inflation rate, an indication that food for cattle and poultry should become more valuable. The price of forestland has been increasing more rapidly than inflation; a study of land values in heavily populated areas of the world suggests that, as populations increase, forestland values will continue this pattern.

To managers of tree plantations and tree conversion plants, these trends suggest that lands should be handled so as to yield maximum tree biomass per acre and that forest-based industries should strive to be energy self-sufficient. Moreover, the conversion plants should use the biomass to make not only the conventional fiber and wood products, but new products that will utilize almost all parts of every tree of every diameter class. Some of these products and processes can yield food supplements for animals and perhaps tree-based chemicals that substitute for more expensive oil-based products.

Given the economic trends as driving forces, and the likelihood of intensive forest management and utilization, what kind of plantations and conversion systems might be appropriate for southern pine by the year 2020?

THE AUTHOR—Peter Koch is chief wood scientist, Forest Products Utilization Research, Southern Forest Experiment Station, USDA Forest Service, Pineville, Louisiana. This article is condensed from a paper presented as the banquet lecture at the First Weyerhaeuser Science Symposium, Tacoma, Washington, May 1, 1979.

What Sizes and Age Classes of Trees Should Be Grown?

My premise is that southern pines of all diameters will be economically convertible to products, but that trees large enough to yield lumber and plywood will offer highest returns. With this in mind, I propose a rotation of 35 years—long enough to grow trees that are 15 to 16 inches in d.b.h. and yield sawlogs and veneer bolts. Such trees will have d.i.b. at breast height of about 14 inches and will average about five rings per inch—a growth rate well suited for the products proposed.

Sawlog-size trees can be grown most rapidly by spacing seedlings widely, but biomass production will be reduced. Thus, I propose the following as a planting and harvesting regime (*fig. 1*):

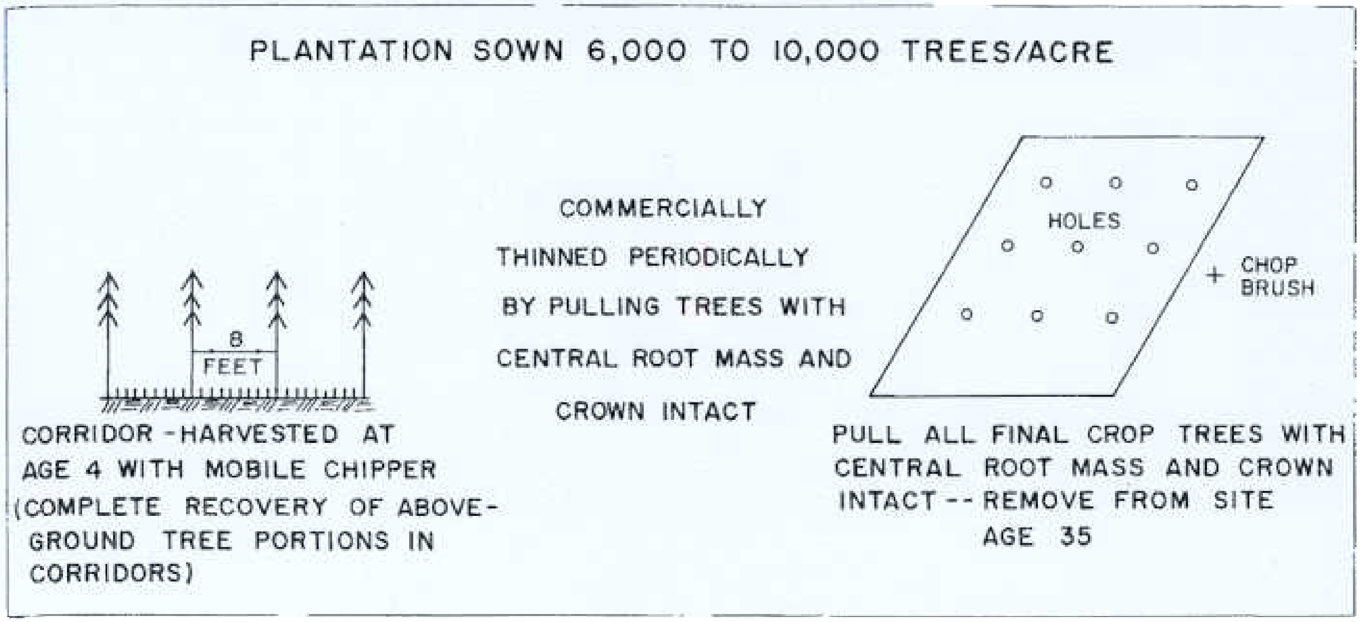
> Establish, through direct seeding, a stand with 6,000 to 10,000 trees per acre.
>
> At age four years, thin in corridors so as to leave spots of one or two trees spaced 8 feet apart in a checkerboard pattern.
>
> Later, thin the remaining stand by periodically pulling trees with taproot and crown intact.
>
> Select 60 to 100 final crop trees early, and prune them mechanically (by a system not yet devised).
>
> Harvest crop trees at the end of the 35-year rotation by pulling them with taproot and crown intact; tree d.b.h. might average 15 to 16 inches on fertilized sites of good to average quality. On poorer sites, diameters would be smaller—perhaps 12 to 14 inches.

Because the best seed will always be in short supply, an alternative planting regime such as that described in *figure 2* might be more practical.

What Will Yields Be?

Tree tonnages that I have tabulated (*table 1*) for intermediate thinnings and final crop trees are based on studies of selected stands of loblolly pine (*Pinus taeda* L.) owned by the Weyerhaeuser Company (10). Data on the tonnage recoverable in corridor checkerboard thinnings at age four are extrapolated from tree weight estimates of White and Pritchett (16). Herbage estimates came from the USDA Forest Service's Range Management Project at Pineville, Louisiana.

Possibly these tonnages are somewhat optimistic, but by the end of this century advances in genetics and plantation culture should permit attainment of such biomass yields on a fairly wide range of southern pine



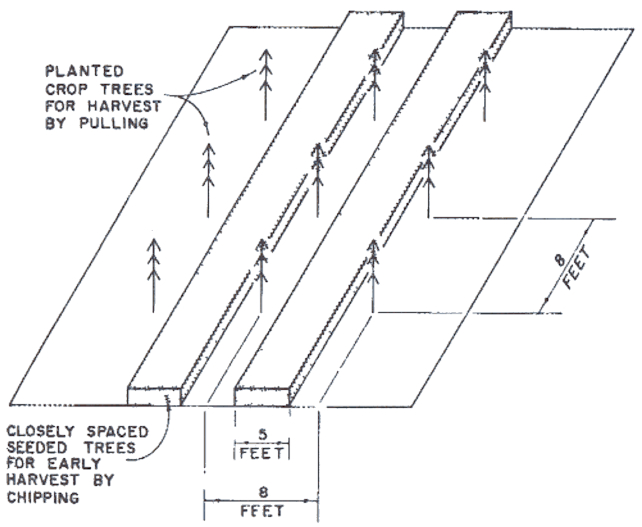


Figure 1 Planting and harvesting regime and biomass removal per acre during each 35-year rotation. The initial corridor thinning would be in a checkerboard pattern leaving spots with one or two trees spaced 8 feet apart The total above- and belowground biomass produced during one rotation is 355 tons per acre, ovendry basis. Of this amount, 162 tons (46 percent) remain on the site and 193 tons (54 percent) leave by loggers' trucks.

Figure 2. In this alternative to the regime illustrated in figure 1, superior seedlings—perhaps containerized—would be planted 8 or 9 feet apart on a square grid. Then beds 5 or 6 feet wide would be direct-seeded between rows. For simplicity, the beds are shown here in parallel rows; they could, however, run the width as well as the length of the plantation if the superior seedlings were accurately planted

About 4 years after the beds are seeded, the closely spaced trees could be harvested with a mobile chipper; at harvest they might weigh about one pound each (ovendry) and measure 4.5 feet in height and 1.5 inches in groundline diameter. Saplings in the grid pattern would be thinned by periodically pulling trees with taproot and crown intact. Final crop trees would be selected early in the rotation, pruned, and harvested by pulling at age 35.

Table 1. Biomass production during a rotation, and biomass left on the site after harvest (ovendry basis).

Classes and components of biomass	Total produced	Left on the site
	— *Tons per acre* —	
Forage and brush		
Herbage mortality	10.0	10.0
Herbage standing	.5	.5
Brush standing	4.0	4.0
Brush burned	4.0	4.0
Roots of brush	.8	.8
Twig and needle cast	112.8	112.8
Trees corridor-chipped at age 4		
Stump-root systems entire	3.0	3.0
Aboveground tree portions	11.0	—
Trees from intermediate thinnings on remaining strips		
Lateral roots	14.2	14.2
Stumps and central taproots	14.2	—
Stems and stem bark	62.7	—
Tops, branches, and foliage	21.5	—
Crop trees in final harvest		
Lateral roots	12.3	12.3
Stumps and central taproots	12.4	—
Stems and stem bark	56.5	—
Tops, branches, and foliage	14.8	—
Total	354.7	161.6

sites. Of the estimated 355 tons per acre of biomass (ovendry basis), 46 percent (162 tons) would remain on the site and 54 percent (193 tons) would be harvested and removed for conversion into products and fuel.

How Will the Trees Be Harvested?

Corridor thinning of the stands at age four years could be accomplished with a swathe-felling mobile chipper of the kind described by Koch and Savage (11) but lighter, narrower, and with a felling bar of smaller diameter (see also reference 12, p. 146-154). Another possibility for cutting the swathes is an accumulating feller-buncher teamed with grapple skidders and a roadside whole-tree chipper (12, p. 115-119). With either system, all aboveground tree parts can be chipped and delivered to the mill

Intermediate thinning of the residual stand could be accomplished by pulling trees with their taproots and crowns intact (7, 8). These complete trees would be grapple-skidded to the roadside and loaded on trucks designed for stems with intact crowns and taproots (12, p. 211-215 and 274-276).

Final crop trees would be harvested similarly but with larger, more powerful equipment. These trees would be transported to the mill complete with crowns and taproots, but might be segmented to reduce their length and bulk.

Remaining brush would be chopped and fertilizer applied—probably wood ash from the mill's power plant, adjusted for pH and fortified with nitrogen and phosphorus where required. The area would then be regenerated with seed from genetically improved southern pines.

How Will the Value of Each Tree Be Maximized?

Harvested biomass will enter the proposed mill through three merchandising centers (*fig. 3*). At these centers incoming material will be segregated to maximize the value of each component. Material from corridor thinning will be divided into clean pulp chips (few), bark and fines for fuel, and technical foliage (twig ends smaller than 0.24 inch in diameter plus needles) in a beneficiating plant similar to that decribed by Sturos and Marvin (12, p. 277-293).

Complete trees from intermediate thinnings will enter a merchandising deck such as that described in principle by Kwasnitschka (12, p. 211-215) with the added features of foliage and taproot recovery. Products will be clean pulp chips, bark for fuel, foliage for muka, and rootwood to be cleaned for pulp chips. In later thinnings some small logs could be converted to 2-by-4 studs and a few small-diameter bolts could be peeled for veneer.

Crop trees from the final harvest will enter the mill over a merchandising deck similar to that used for thinnings, but larger. Besides the products from thinnings, the final crop trees will yield some poles and piling, larger and longer sawlogs of higher quality, and larger veneer bolts. The merchandising decks described by Murphy (12, p. 234-245), with addition of foliage, branch, and taproot recovery systems (12, p. 274-276 and 294-297), are appropriate for this center.

What Conversion Processes Will Be Used?

The proposed mill will have four major utilization centers, as follows:

Utilization center	References describing the process
1. Mill to convert technical foliage into animal food supplement (muka)	4, 12, p. 309-313
2 High-yield kraft pulp mill and tall oil recovery plant	12, p. 249-256
3. A series of solid-wood processing plants	
Lumber (and millwork)	12, p. 325-364 and 389-393
Straight 2-by-4 studs	12, p. 365-371
Long-wide lumber laminated from veneer	5; 12, p. 401-405 and 458-459
Plywood	12, p. 394-398 and 406-410
Structural flakeboard	12, p. 427-442; 15

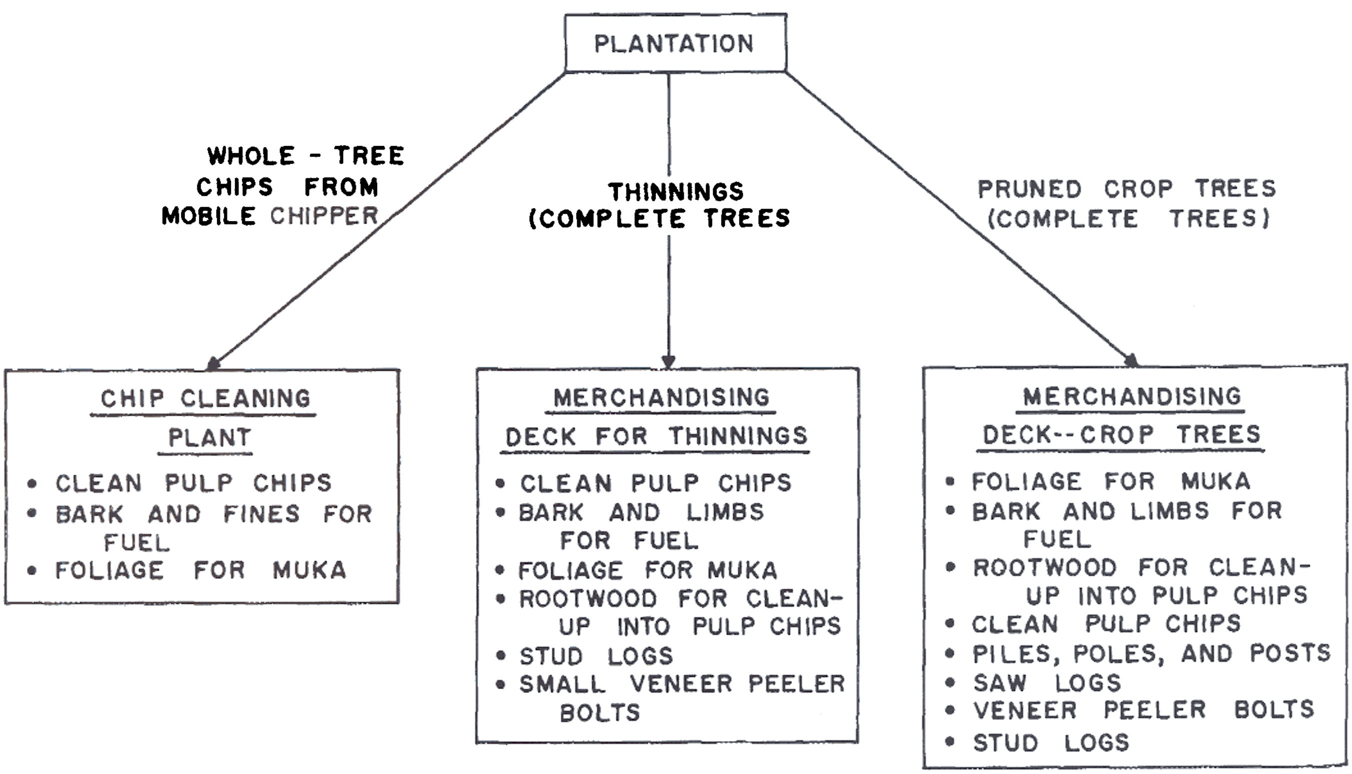


Figure 3. Three merchandising centers whereby tree biomass harvested from the plantation is segregated or upgraded to achieve maximum value from each component

Poles, piling, and posts — 12, p 372-385

4. Power plant to convert bark to electricity and process steam — 3

The manufacture of cants to be resawn into 2-by-4 studs and cylindrical peeler bolts for veneer for plywood or laminated lumber calls for use of shaping-lathe headrigs that produce flakes as a residue; these flakes are suitable for pressing into structural flakeboards (6; 9; 12, p. 416-426; 15).

With the conversion facilities described (*figs. 3* and *4*) and the degree of utilization outlined in *table 2*, 38 percent of the corridor-tree biomass (excluding lateral roots), or 4.9 tons (ovendry basis) per acre, would be used. Fifty-five percent (54.1 tons per acre) of the biomass of the thinned trees, and 60 percent of the crop trees (50.2 tons) would end as product. The total product tonnage, excluding fuel, per acre per rotation would be 109.2 (ovendry basis). This amounts to about 56 percent of total tree biomass, excluding lateral roots. Fuel accounts for 84 of the 193 tons removed (ovendry basis).

And What of Alternative Processes?

Because a 60-percent-yield kraft pulping process was assumed, significant tonnages of product were lost to pulping liquor that ends as fuel. Possibly an improved mechanical pulping process with near 100-percent yield—such as that proposed by McMillin (13)—will prove practical. Development of such a pulp and the technology to convert it to light-weight containers deserves high priority. These containers could

Table 2. Percentage of complete tree[1] (ovendry weight basis) ending as primary products and as fuel during the three stages of harvest.

Tree class and component	Proportion of complete tree		
	Total	Ending as a product	Ending as fuel
		Percent —	
Crop trees			
Stemwood	60	46	14
Rootwood	12	7	5
Branchwood	10	3	7
Needles	5	4	1
Stembark	8	0	8
Branchbark	4	0	4
Rootbark	1	0	1
	100		
Thinnings			
Stemwood	50	35	15
Rootwood	13	7	6
Branchwood	19	10	9
Needles	4	3	1
Stembark	8	0	8
Branchbark	4	0	4
Rootbark	2	0	2
	100	55	45
Corridor thinnings			
Stemwood	40	20	20
Branchwood	26	13	13
Needles	6	5	1
Stembark	9	0	9
Branchbark	5	0	5
Rootwood and bark[2]	14	0	0
	100		48

[1]*Above- and belowground tree parts including lateral roots to a 1-foot radius*
[2]*Left on the site, unharvested.*

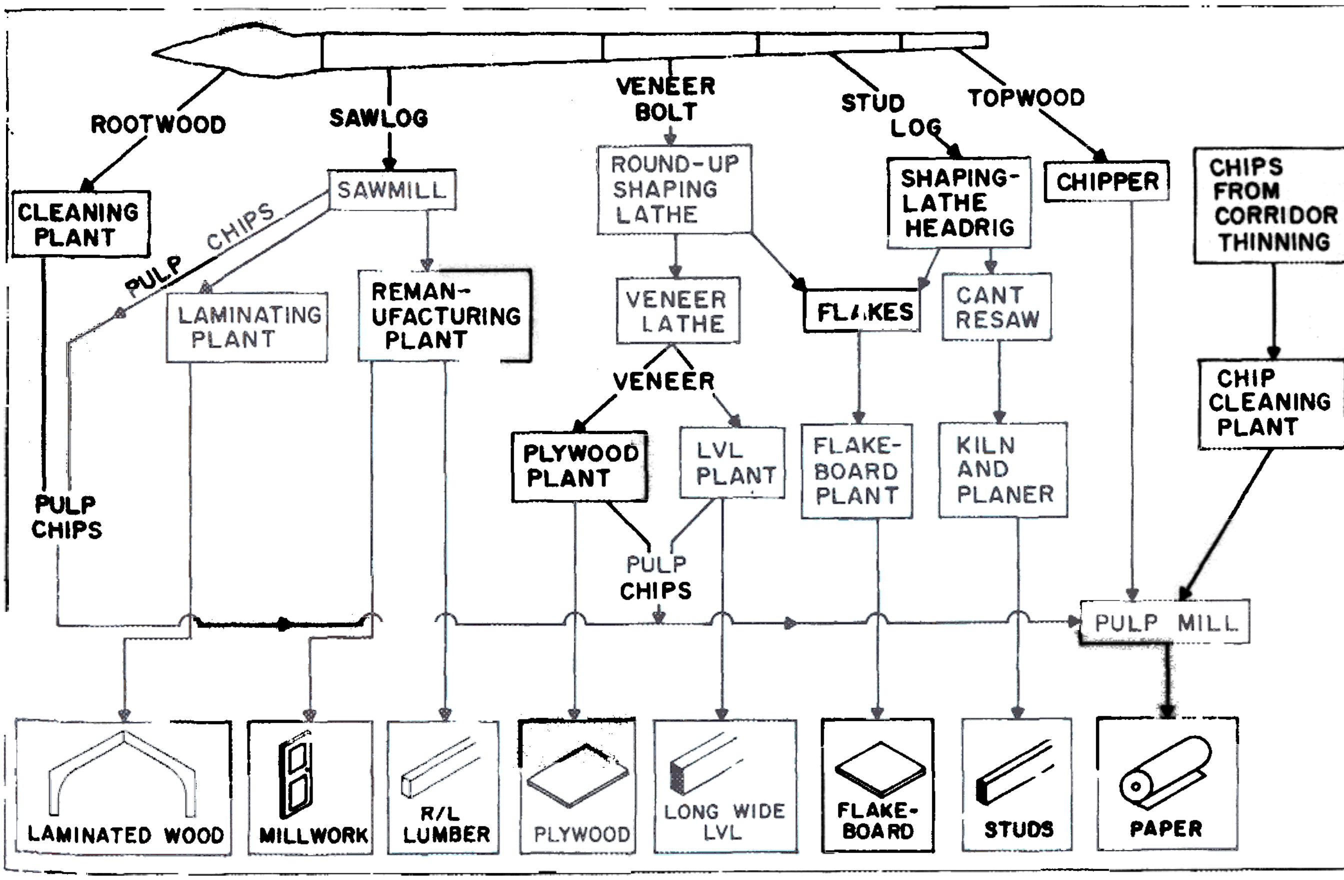


Figure 4. System flow-plan for processing delimbed bark-free stems of crop trees. Not shown is disposition of foliage to muka plant, branch chips to a bark separation plant, and stembark to the power plant. LVL means laminated-veneer lumber. R/L means random length.

compete with boxes made of kraft linerboard over corrugating medium.

Replacement of the kraft plant with a mechanical pulping facility for paper or fiberboard would raise product recovery per acre to about 146 tons (ovendry basis) and reduce fuel tonnage to 47 tons (146 tons plus 47 tons equals the 193 tons harvested per acre per rotation).

Other process alternatives are possible and may prove practical. For example, the plywood and flakeboard operations might be combined to produce the composite structural panels described by Springate (12, p. 416-426).

Production of some chemicals from tree biomass may also be practical. Essential oils could be steam-distilled from the foliage and the residue converted to muka. Or chlorophyll-carotene paste could be extracted from foliage (4). A third alternative would be to dry and grind foliage, bring it to neutral pH, and use it as an adhesive extender and filler in phenol-formaldehyde glues for plywood and flakeboard (1, 2).

Polyflavonoids in southern pine bark are an abundant source of highly reactive and potentially valuable phenolic polymers. They can be obtained in yields of 10 to 40 percent of the dry bark weight, depending on the extraction process and properties required of the extract. Costs of the production of bark polyflavonoids are largely determined by the extraction and drying processes. Chemical demands could be readily integrated into kraft mill chemical processes, and extracted bark could be used for fuel. At present fuel prices for fossil fuels, the fuel value of bark is perhaps 1.5 cents per dry pound. Since most possible uses for bark polyflavonoids can be related to replacement of phenol requirements for the production of phenolic wood adhesives, their potential value is perhaps best related to the price of phenol, which has been fluctuating at around 20 cents per pound. If exterior plywoods, flakeboards, and fiberboards are to be produced in large amounts, adhesives of reasonably low cost will be required. Although bark polyflavonoids have good potential for filling this need, success in their application has been elusive and research is continuing (12, p. 443-457).

A byproduct not considered in the foregoing tabulation of tonnage is tall oil. Fatty acids, terpenes, and resin acids are normal chemical byproducts of the kraft pulping process (and can be produced from chips prior to mechanical pulping). Wood and root chips destined for the pulp mill could yield much greater quantities of these oleoresin compounds if the trees were treated with paraquat one to two growing seasons before being harvested (14). For maximum benefits under the manufacturing regime proposed, the oleoresins should be concentrated in the portions to be pulped—the central root system and the crown. Techniques to accomplish such concentration will require research.

Closing Comment

In 1979 dollars, the finished products I have described (*fig. 4*) are worth about $200 per ton, ovendry basis, f.o.b. mill. This amounts to a gross realization of $29,200 worth of products (146 tons) per acre per 35-year rotation. Each acre would also yield about 47 tons of fuel per rotation (ovendry basis). The gross realization should increase at, or above, the inflation rate; unfortunately, production costs will likely increase at a comparable rate.

Such plantations could logically follow operations to utilize the low-grade hardwoods that now occupy much of the southern pinery. A plan for utilization of these mixed pine-site hardwood stands is described by Koch (9) and calls for a land base of 450,000 acres with annual product output of 392,000 tons (ovendry) plus 193,000 tons of fuel.

On a similar scale, the pine plantations envisioned here for the year 2020 will produce about 1,877,143 tons of product per year plus 604,286 tons of fuel annually. An enlarged power plant, a pulp mill, a sawmill for random-length pine lumber, a plywood mill, a muka plant, and possibly a chemical recovery plant would be the additions required to the manufacturing complex I described in the earlier article (9). The additions reflect the increased output occasioned by conversion from a slowly growing mixed-species forest to a high-production southern pine plantation. ■

Literature Cited

1 Barton, G M, J A McIntosh, and S Chow 1978 The present status of foliage utilization AICHE Symp Ser. 74(177).124-131. (Am Inst Chem Eng.)

2. Chow, S 1977. Foliage as adhesive extender a progress report P 89-98 *in* Proc 11th Wash State Univ Symp on Particleboard, Pullman, Wash.

3. Karchesy, J. J, and P Koch. 1979 Energy production from hardwoods growing on southern pine sites USDA For Serv Gen Tech. Rep SO-24, 59 p

4. Keays, J L., and G. M. Barton 1975. Recent advances in foliage utilization West. For Prod. Lab Inf Rep VP-X-137, Can For Serv., Vancouver, B C. 94 p

5 Koch, P. 1973 Structural lumber laminated from ¼-inch rotary-peeled southern pine veneer For Prod J 23:17-25

6 Koch, P 1975 Shaping-lathe headrig now commercially available South Lumberman 231·93-97

7 Koch, P 1976 New technique for harvesting southern pines with taproot attached can extend pulpwood resources significantly. P. 403-420 *in* Applied Polymer Symposium 28. Wiley and Sons, New York.

8 Koch, P. 1977 Harvesting southern pines with taproots is economic way to boost tonnage per acre 20 percent South Pulp and Pap Manuf 40·17, 18, 20, 22

9 Koch, P 1978 Five new machines and six products can triple commodity recovery from southern forests J For. 76 767-772

10 Koch, P, and C W Boyd 1978. Effect of harvesting method on biomass removal from southern pine sites. P 146-154 *in* Proc. A Symposium on Prepared Sites Tom Tippin, ed, Miss State Univ, March 21-22

11 Koch, P, and T Savage 1980 Development of the swathe-felling mobile chipper J. For. 78 17-21.

12 McMillin, C W, ed 1978 Complete Tree Utilization of Southern Pine Symp. proc, For Prod Res Soc, Madison, Wis., 484 p

13. McMillin, C W 1978 Mechanical pulping with a sequential velocity refiner—a new concept Svensk Papperstidn. 18·567-574.

14. Roberts, D. R, W Peters, T A. Harrington, E Crews, and J. Broomfield. 1974 Method of chemically inducing lightwood formation in pine trees U S Pat. 3,839,823 U S Pat Off., Washington, D.C.

15 USDA Forest Service. 1978 Structural flakeboard from forest residues. Symp. proc, Gen Tech Rep. WO-5, 241 p

16 White, E H., and W L Pritchett. 1970 Water table control and fertilization for pine production in the flatwoods Bull 743, Agric Exp. Stn, Inst Food and Agric Sci, Univ. Florida, Gainesville, 41 p.