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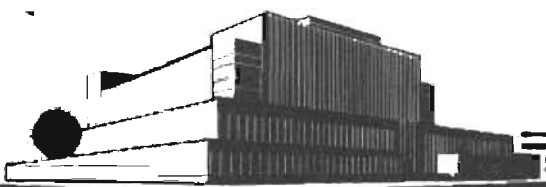
June 1961

No. 2224



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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

WOOD--A SOURCE OF RAW MATERIAL FOR CHEMICAL UTILIZATION[1]

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Summary

More than 80 million tons of low-value wood could be made available annually as raw material for conversion to organic chemicals. This material would be available primarily as processing residues and harvesting residues. Data (originally collected in 1952) are given for quantities and types of residues available by region in the United States.

Introduction

The forests of the United States offer a continuing supply of raw material to the chemical industry. The 484 million acres of commercial timberland in continental United States represent one-fourth of the total land area--a considerably larger area than that devoted to farm crops (1).[3] These forest areas are presently stocked with 860 billion cubic feet of wood, and produce in net growth each year 22 billion cubic feet of timber. The cut in 1952 totaled 10.8 billion cubic feet of wood. While these values show that the material cut from the forest was about half the annual growth, much of this growth was in small size timber. The timber cut, however, was mainly from the larger sizes. The quality of much of the growing stock is below the standards needed for lumber and veneer, but is still satisfactory for processing to chemicals.

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[1] Presented at the American Institute of Chemical Engineers meeting in Atlantic City, N. J., March 18, 1959.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Underlined numbers in parentheses refer to literature cited at the end of this report.

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Utilization of Forest Resources

To illustrate the utilization of the annual cut of forest resources, a material balance in tons of wood substance would be most useful. The total timber input, wood substance only excluding bark, approaches 204,100,000 tons annually. Bark would increase this figure by another 20 million tons. These figures, however, represent only the timber cut, and do not take into account the cull timber that must be removed from the stands being logged. Cull timber will usually average approximately 10 percent of the total volume, although in some stands it may run as high as 60 percent.

On the output side, the two main products, lumber and pulpwood, account for 52 million tons and 39 million tons, respectively. Fuelwood and mill residues used for fuel comprise the major remaining amount of material--56 million tons. The unused logging and plant residues, which are of interest to the chemical industry as a raw material, amount to 51 million tons. In addition to these unused residues, approximately 31 million tons of wood are used mostly at a low level, so their value is that of the replacement cost of fuel.

The magnitude of the annual harvest of forest resources can be demonstrated by comparing the yield of 91 million tons of lumber and pulpwood, two major products of the forest, with the 1956 steel output of 115 million tons. Or, the annual production of 56.5 million tons of iron ore might be compared with the 82 million tons of raw material available for chemical processing.

The most important factor in considering the utilization of the timber resource is the great demand for high-quality timber for lumber, veneer, and products making use of wood in its natural form. Since wood used for these purposes has the highest value, the highest quality wood will enter these markets. The second claim on the timber source is that made by the pulp and paper industry, which has less stringent requirements on the physical size and shape of the raw material. The chief requisites for the fiber industry are that the wood is dense and has fiber of high strength.

Utilization of Residues

Still remaining is a large amount of material that has in the past been classified as waste. It consists of two types, logging residues and processing plant residues. The logging residues are the broken stem sections, tops, limbs, thinnings, and cull trees that comprise a part of the yield of every forest. The plant residues are made up of the chippable or coarse material, such as slabs, edgings, trim, and veneer clippings, and the fine material, such as sawdust and shavings. Utilization of these residues for purposes other than fuel is one of the major problems of the timber industry. In table 1 are data on the use of plant residues by regional source and type of use.

Plant residues constitute a very large volume of wood, and contributing generously to their total are the lumber and veneer industries. Table 2 provides an accounting of the total plant residues produced in the United States in 1952.

With the advent of mechanical and hydraulic barkers for sawlogs, more bark-free material became available without further drain on the resource. Many chippers have been installed at sawmills and veneer plants for converting slabs, edgings, trim, and veneer clippings to chips. Forty-three percent of the raw material for pulpmills in the Pacific Northwest now comes from this source (2). These installations also are spreading rapidly in the South, and they now supply the raw material for 8 percent of the pulp produced there. During 1957, chipping facilities in the South more than doubled, reaching a total of 224 installations that produce the equivalent of 1.5 million cords of wood.

A recent investigation (3) into the weight of wood residue developed from the sawing of 1,000 board feet of lumber reveals that these chippable residues would approximate four-tenths of a ton of dry wood substance. Likewise, the sawdust and shavings that result would amount to about six-tenths of a ton, and this material is of particular interest to the chemical industry, since it has no other major use except for fuel. In 1952, approximately three-fifths of the total volume of plant residues was utilized in various ways, with the used portion about equally divided between coarse and fine material. Information on used and unused plant residues by regions is listed in table 3.

A recent report on the cost of chips from sawmill residues stated that an electric furnace operation in the State of Oregon was purchasing this material for $4.50 per ton of dry wood substance. This figure appears to be an average value in many areas of the country.

By conventional methods of logging, the forest residue and cull material would cost $8 to $14 per cord, which would be the price paid for chemical wood or pulpwood. Portable chippers for woods operation, however, now are available that handle material up to 18 inches in diameter. Chips can be loaded directly into trucks hauling 10 tons of dry wood substance per load, and distances of 135 miles are not an uncommon truck haul. Rail hauls up to 250 miles are also being made.

Chemical Composition of Wood

The two major groups of wood are the softwoods and the hardwoods. All species in each group have approximately the same chemical composition, but the major difference between the two is the amount of pentosan present in the hardwoods. When converting wood substance to chemicals, the four major components to be considered are hemicellulose, cellulose, lignin, and acetyl groups. A representative analysis of a hardwood would be 25 percent of hemicellulose, 45 percent of cellulose, 23 percent of lignin, and 7 percent of acetyl groups. The

composition of the hemicellulose is approximately 82 percent of pentosan, mainly xylan, and 10 percent of mannan. A representative softwood would contain 25 percent of hemicellulose, 42 percent of cellulose, 30 percent of lignin, and 3 percent of acetyl groups. In this case, approximately 50 percent of the hemicellulose is mannan, and only 10 percent is xylan. In both cases, the cellulose is glucosan.

For many chemical reactions, the hexosans of which there are three in wood, glucosan, mannan, and galactan, generally react in a similar fashion. The pentosans, of which there are two, xylan and araban, likewise react similarly. A fairly clean separation of the hemicellulose can be made from the cellulose by a prehydrolysis. In chemical utilization, the hemicellulose might be considered as the easily hydrolyzable portion which can be removed at low temperature and low pressure by a mild acid hydrolysis. This fraction would also contain the acetic acid.

Another component of wood substance should be considered; namely, the extractives. The extractives will vary from a low figure of 1 to 2 percent in some species to as high as 20 percent in the butt log of western larch, but generally are found to be in the neighborhood of 3 to 5 percent. This is the material on which the Naval Stores industry, and particularly the tall oil and sulfate turpentine industry, which will be mentioned later, is based.

Outlook for Chemical Utilization of Wood

One of the major points to be considered in determining the availability of raw material is that all timber stands, no matter how carefully managed, will always produce a certain amount of material that can be used only for the chemical composition. This refers to an intensively managed timber stand in which frequent timber stand improvement cuts must be made. Some of this material, of course, would be available for fence posts and pulpwood, but a great deal would be in the form that would not be satisfactory for these conventional uses.

One of the major areas of the country that appears promising for the location of chemical industry based on wood is the South, where much of the material is in the form of low-grade hardwoods that should be removed from the timber stands. Some of this area will be replaced with pine, but much of it will always remain in hardwoods.

Again, all processing of wood by the lumber industry produces about half of its weight as a byproduct for further use. Consequently, the chemical utilization of wood will serve the forest products industry as a useful management tool (4), since material cannot be removed from the woods without a market. Likewise, a sawmill operation is in a much better competitive position when it can market the residues it has accumulated from the manufacture of lumber and veneer logs. Many sawmill companies, in recent years, report that their net profit each year was about equivalent to their income from the sale of chips.

This introduces another subject; namely, the integrated utilization of our forest resources (5,6). A growing tendency prevails among sawmill companies to add veneer and plywood plants, board plants, and to enter the pulp and paper field. Conversely, a growing tendency exists for the pulp and paper industry to add sawmills, plywood plants, and board plants. This integration, along with the capital investment required in the pulp and paper industry, has caused the more progressive companies to acquire large areas of timberland, and to place the timber stands thus acquired under a long-term, intensive, sustained yield management plan. A company with large timber holdings and with a large capital investment will be a permanent operation, and will develop the raw material supplies for a chemical industry.

The competition of wood in the construction industry is becoming greater each year. With rising costs, more of the raw material brought into central processing plants must be converted to profitable products. Subsequently, lower grade material can be brought in from the woods as a market for the plant residues is developed. Here again, chemical utilization will play a vital role in both rehabilitating our present timber stands and making profitable the operation of timber holdings.

Thus wood, a renewable resource of large magnitude, should, in the near future, be the raw material for a large chemical industry based primarily upon the 70 percent of carbohydrate (7) and the 25 percent of lignin which it contains.

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Table 1.--Plant residues by type of use, 1952

Region	Total used	Fuel	Fiber	Other[1]
	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight
North	7,129,003	5,477,925	42,774	1,608,303
South	12,457,555	11,536,941	198,075	722,538
West	14,080,623	11,869,965	1,433,407	777,250

[1] Includes materials for cut stock, handles, brush, blocks, chemical wood, boxboard, particle board, floor cleaning compound, wood floor, insulation, livestock bedding, poultry litter, soil conditioner, metallurgical use.

Table 2.--Total plant residues produced in the United States, 1952

Region	Softwood				Hardwood				Combined residues
	Timber cut		Residues produced		Timber cut		Residues produced		
	Saw logs	Veneer logs	Coarse	Fine	Saw logs	Veneer logs	Coarse	Fine	
	Board feet	Board feet	Tons--dry weight	Tons--dry weight	Board feet	Board feet	Tons--dry weight	Tons--dry weight	Tons--dry weight
North:									
New England	835,737,000		952,490	438,300	222,834,000	69,554,000	450,670	204,270	
Middle Atlantic	393,313,000	873,000	449,200	206,730	1,003,490,000	43,409,000	1,613,650	731,400	
Lake States	249,167,000	403,000	284,400	130,900	593,142,000	81,012,000	1,039,100	471,000	
Central	77,696,000	390,000	88,550	40,750	1,246,062,000	69,844,000	2,028,300	919,300	
Plains	10,455,000		11,900	5,480	45,586,000	7,306,000	81,000	36,900	
Total			1,786,540	822,160			5,212,720	2,362,870	10,184,290
South:									
South Atlantic	2,587,600,000	16,871,000	2,401,200	1,105,200	1,486,772,000	304,305,000	2,800,000	1,268,000	
Southeast	4,114,283,000	21,038,000	3,813,300	1,755,300	2,036,884,000	438,315,000	3,868,000	1,750,000	
West Gulf	2,036,922,000	4,985,000	1,883,000	866,000	1,076,227,000	213,199,000	2,010,500	910,000	
Total			8,097,500	3,726,500			8,678,500	3,928,000	24,430,500
West:									
Pacific Northwest	10,928,906,000	1,190,608,000	8,971,000	4,128,000	18,660,000		29,500	13,400	
California	5,266,878,000	201,000	4,017,000	2,078,000	15,104,000	522,000	24,200	11,200	
Northern Rocky Mountain	1,770,653,000	8,797,000	1,435,000	660,600	201,000		320	145	
Southern Rocky Mountain	536,006,000		432,000	199,000	696,000		1,100	510	
Total			14,855,000	7,065,600			55,120	25,255	22,000,975
Total (all regions)									56,615,765

Information sources:

TGUR - Canadian Survey--Hardwood log volume to lumber = 48.7 percent and to chippable material = 35.3 percent. Fines = 16.0 percent. Softwood log volume to lumber = 50.5 percent and to chippable material = 33.9 percent. Fines = 15.6 percent.

Timber Resource Review--Table 14 for saw log and veneer log cut by regions. Table - Saw timber Factors p. 641, board feet to cubic feet by regions.

Table 3.--Plant residues--used and unused by regions, 1952

Region	Softwood				Hardwood				Combined residues
	Coarse		Fine		Coarse		Fine		
	Used	Unused	Used	Unused	Used	Unused	Used	Unused	
	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight	Tons-- dry weight
North	1,250,578	535,962	575,512	246,648	3,648,904	1,563,816	1,654,009	708,861	
South	4,129,725	3,967,775	1,900,515	1,825,985	4,426,035	4,252,465	2,001,280	1,926,720	
West	9,507,200	5,347,800	4,521,984	2,543,616	35,276	19,844	16,163	9,092	
Total used	14,887,503		6,998,011		8,110,215		3,671,452		33,667,181
Total unused		9,851,537		4,616,249		5,836,125		2,644,673	22,948,584
									56,615,765

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