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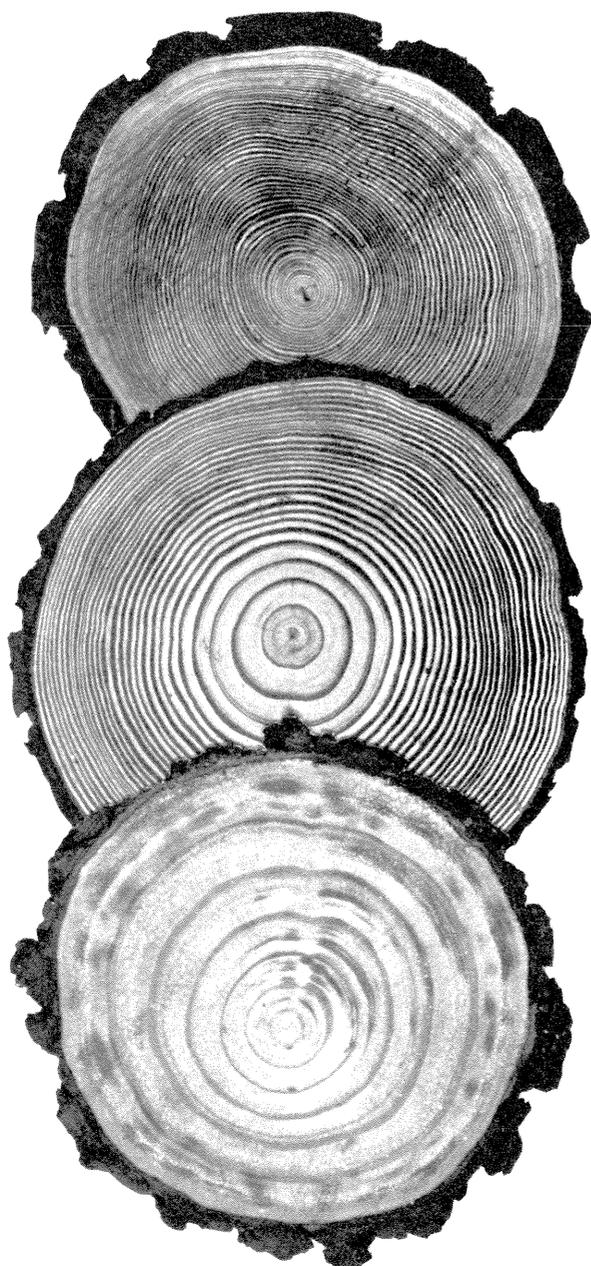
Southeastern Forest
Experiment Station

General Technical
Report SE-63

PROCEEDINGS OF SOUTHERN PLANTATION WOOD QUALITY WORKSHOP

A
WORKSHOP ON
MANAGEMENT,
UTILIZATION,
AND ECONOMICS
OF THE
SOUTH'S CHANGING
PINE RESOURCE

ATHENS, GEORGIA
JUNE 6-7, 1989



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Station. 95 pp.

Six papers and one slide talk describe problems associated
with the large proportion of juvenile wood in plantation-
grown southern pines. A research approach to solve the
problems is outlined.

KEYWORDS: Wood quality, juvenile wood, lumber, composites,
pulp and paper, forest management.

These proceedings have been prepared using copy
supplied by the authors. Authors are responsible for
the content and accuracy of their papers.

PROCEEDINGS OF
SOUTHERN PLANTATION WOOD QUALITY WORKSHOP

A Workshop on Management, Utilization, and Economics
of the South's Changing Pine Resource

Sponsored by

The USDA Forest Service:
Southeastern Forest Experiment Station
Southern Forest Experiment Station
Forest Products Laboratory

The University of Georgia
School of Forest Resources

The Southern Industrial Forestry Research Council

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PREFACE

The Problem

Plantations currently comprise one-third of the pine forest area in the South, but contribute only about 15 percent of mill furnish in the region. By the year 2000, only a decade away, the area of pine plantations will increase modestly, but they will by then provide about 50 percent of the South's softwood fiber supplies. At the very least, this substantial shift in our resource base will require us to make rapid technological and market adaptations. Greater impacts of the change could be reflected in poorer wood quality, reduced product yields from plantation wood, adverse effects on solid wood and fiber products, and loss of market share to other wood-producing regions or to nonwood products.

This substantial, rapid change in our resource base should mandate immediate strategic planning and research. If the South is to retain its competitive advantage and its market share in softwood-based industry, we must assess the impacts of the changing resource on our manufacturing processes. A cooperative effort is needed to gain scientific knowledge of growth and utilization of plantation wood, to develop regional strategic plans to develop and implement new manufacturing and forest management technology, and to produce and market goods that take advantage of our resource. Most other major world softwood producers--the Pacific Northwest, British Columbia, and New Zealand--have developed integrated research and planning efforts to deal with their second-growth softwood resources. The South should do the same now.

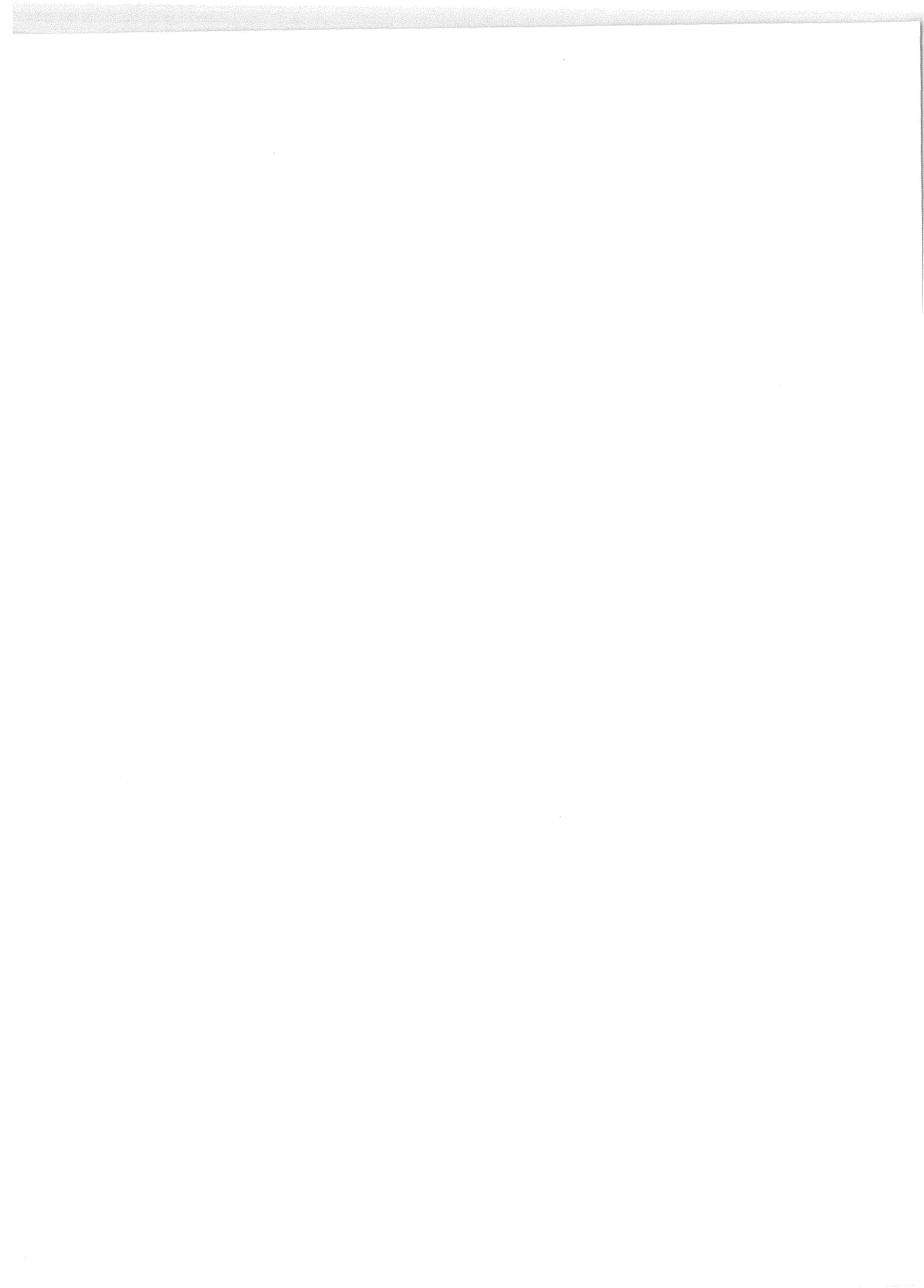
The Workshop

Scientists, manufacturers and forest managers were invited to this workshop to identify the problems and opportunities associated with the changing southern pine resource base. Attendees participated in commodity group sessions to identify information needs that may then be used to guide forest management and manufacturing research associated with the pine plantation resources.

These proceedings contain overview papers presented at the workshop and the recommended research information needs identified in each group session. It is hoped that this workshop will serve as the basis for future integrated research and planning efforts for the southern softwood industry.

CONTENTS

	<u>Page</u>
Preface.	ii
Panel I: Resource and Utilization Impacts	
Moderator: Hank Montrey, Forest Products Laboratory	
Pine Stands Across the South--Trends and Projections Mark J. Brown and William H. McWilliams.	1
Impacts on Lumber and Panel Products James C. Oberg	17
Impact of Changing Raw Material on Paper Manufacturing and Properties Richard J. Thomas and R. C. Kellison	33
Forest Management and Wood Quality Joseph R. Saucier.	47
Panel II: Economic Impacts and Strategic Research Planning	
Moderator: Kenneth Peterson, Georgia Pacific Corp.	
Economic Impacts of Southern Pine Wood Quality Changes Frederick W. Cubbage	57
The Pacific Northwest Stand Management Cooperative James Cahill	71
An integrated Forest Management and Resource Quality Research Effort for Coastal Douglas-fir in Canada R. M. Kellogg.	75
Facilitated Group Meetings	83
Lumber Group	84
Composite Products Group	86
Pulp and Paper Group	88
Forest Management Group.	90
Suggested Organizational Structure for Dealing With a Changing Pine Resource	93
List of Attendees.	94



PINE STANDS ACROSS THE SOUTH - TRENDS AND PROJECTIONS

Mark J. Brown and William H. McWilliams¹

Abstract.--Across the South, 61.9 million acres were classified as pine management types in 1985. One-third of these acres were pine plantations. Plantations have steadily increased in area during the last three decades, and this trend is expected to escalate. Rates of change in the plantation resource differ by ownership. On all ownerships the area of natural pine stands is decreasing, mainly because of conversion to plantations after harvest. Stand-age profiles suggest that a younger pine resource is developing. In 1985, plantations accounted for one-fifth of the softwood volume in pine stands. This proportion should increase dramatically as more plantations reach merchantable size. Softwood removals from plantations accounted for one-sixth of the removals from pine stands and are also expected to increase rapidly. Southeast Georgia and Northeast Florida are characterized by very high concentrations of plantations. This area provides insight into important resource changes which will likely develop across the Southern Coastal Plain and portions of the Piedmont. The diameter distributions of both inventory volume and recent removals from pine plantations suggest that wood supplies will probably be substantially smaller than natural pine supplies unless rotation lengths are raised.

INTRODUCTION

As we move toward the 21st century, the South's pine resource is changing rapidly. The changes are not confined to declines in area or shifts in ownership patterns. The actual composition of pine stands is evolving toward plantation dominance. Since plantation pines contain more juvenile wood than do natural pines, significant impacts on the wood processing industry could lie ahead. In this paper we analyze changes in the South's pine resource.

In analyzing the pine resource, we could look at total softwood volumes by individual species regardless of forest type or we could focus only on those stands where pines make up a majority of the stocking--the pine forest types. We have chosen to do the latter and to separate planted pine stands from natural pine stands.

This paper reports areas, volumes, and removals in pine stands of the South. As referred to here, the South includes the 12 Southeastern and South Central States. However, only the timber producing regions of Oklahoma and Texas are included. We will compare both planted and natural stands by ownership class.

We look at current figures, past trends, and future projections. Finally, we focus on an area of the South with a very high proportion of timberland in plantations for some insight into the future complexion of the pine resource.

¹ Authors are research foresters with the Southeastern Forest Experiment Station, Asheville, NC, and the Southern Forest Experiment Station, Starkville, MS, respectively.

SOUTHWIDE CONDITIONS

Most of the data and projections presented here were developed for the "South's Fourth Forest" publication (U.S. Department of Agriculture 1988). Three main models were used to make the projections in the "South's Fourth Forest" (McWilliams 1987). The Southern Area Model (SAM) was used to simulate changes in timberland area and ownership (Alig 1985). The Timber Resource Inventory Model (TRIM) was used to simulate changes in inventory, growth, and removals (Tedder et al 1987). The Timber Assessment Market Model (TAMM) was used to simulate roundwood harvest (Adams and Haynes 1980).

Area

In 1985, the South contained 182 million acres of timberland. Pine types account for nearly 62 million of these acres, or about 34 percent of the South's timberland. Pine plantations make up one-third of the area in pine types in the South (fig.1).

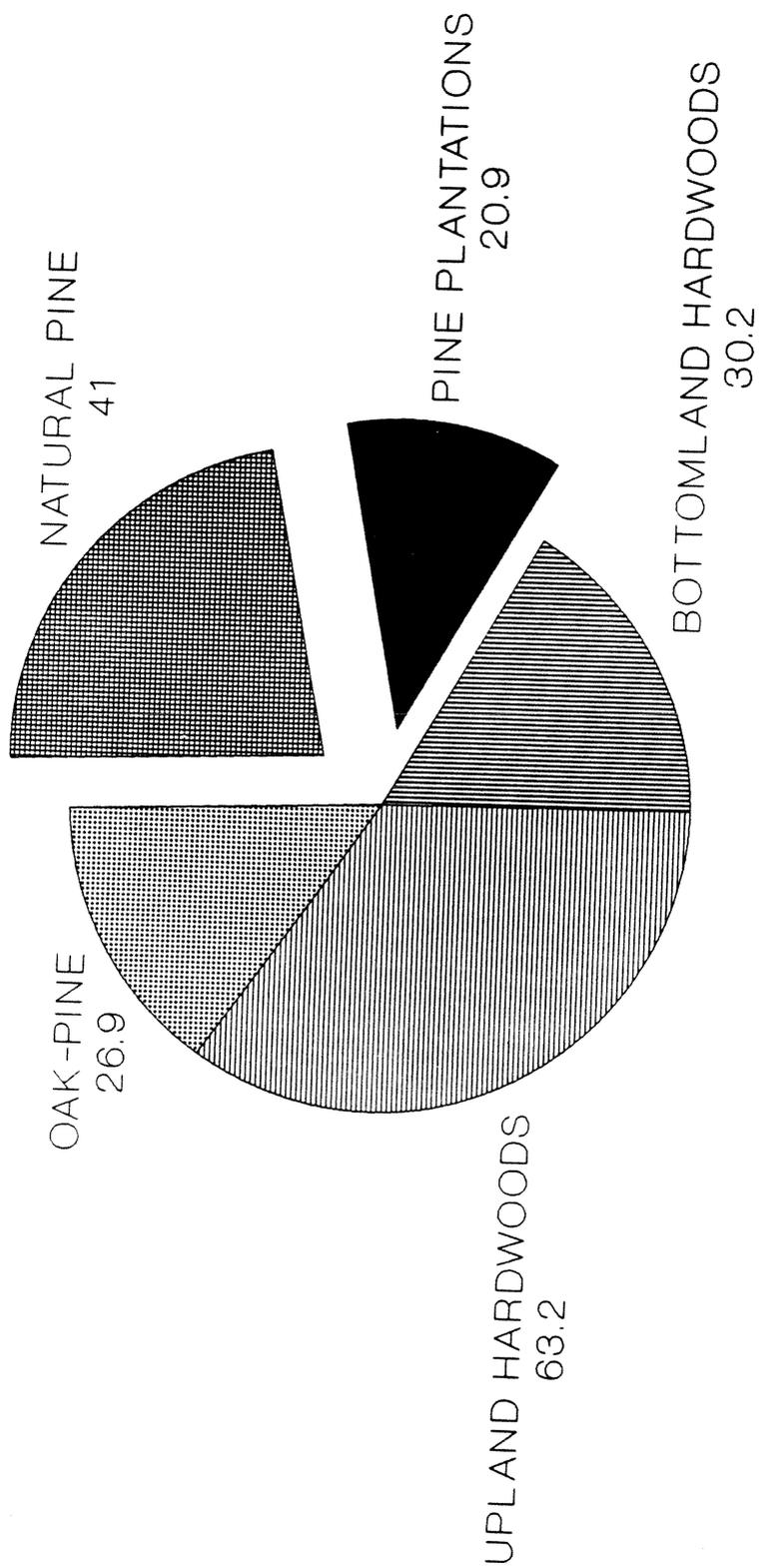
Of the 21 million acres of planted pine stands, forest industry controls 63 percent, nonindustrial private forest (NIPF) owners control 32 percent, and the public owners about 5 percent (Knight 1986). Of the 41 million acres in natural pine stands, NIPF owners hold 65 percent.

Figure 2 depicts the area planted to pine in the South between 1952 and 1988. Not until 1983 did we exceed plantation establishment rates of the soil bank era. Since then, new records have been set each year and have exceeded 2 million acres for 4 years in a row. Also, there has been a 34 percent increase in planting rates since 1985. Note that these numbers do not reflect plantation failure and may include some replanting.

The area of pine plantations by State varies widely across the South. Georgia has more pine plantations than any other Southern State with 4.3 million acres. Florida is next with 3.6 million acres, followed by Alabama with 2.4 million acres. Tennessee has the least acreage in plantations with less than one-half million.

Pine plantations presently make up one-third of the acreage in pine types, but are projected to account for 56 percent of all pine stands by the year 2000. By 2030, plantations are expected to make up two-thirds of the South's pine types (fig. 3). Acreage of natural pine is projected to fall to about 23 million acres by 2030 and planted pine to increase to 48 million acres by then. Although acreage in natural pine stands is declining rapidly, the combined area of planted and natural pine timberland is stable and will likely increase from 1985 on. Future gains are expected to come from conversion of areas presently in oak-pine and hardwood types.

The replacement of natural pine stands with pine plantations is a trend that is evident in each major ownership category. On forest industry land the total area in pine stands has increased to 22 million acres and is expected to continue to increase beyond 2000 before slowing. In 1985, 60 percent of forest industry's pine stands were already in pine plantations. By 2000, this proportion is projected to reach 83 percent. By 2030, 89 percent of forest industry's pine stands should be in plantations.



MILLION ACRES

Figure 1.--Area of the South's timberland in 1985, by management type.

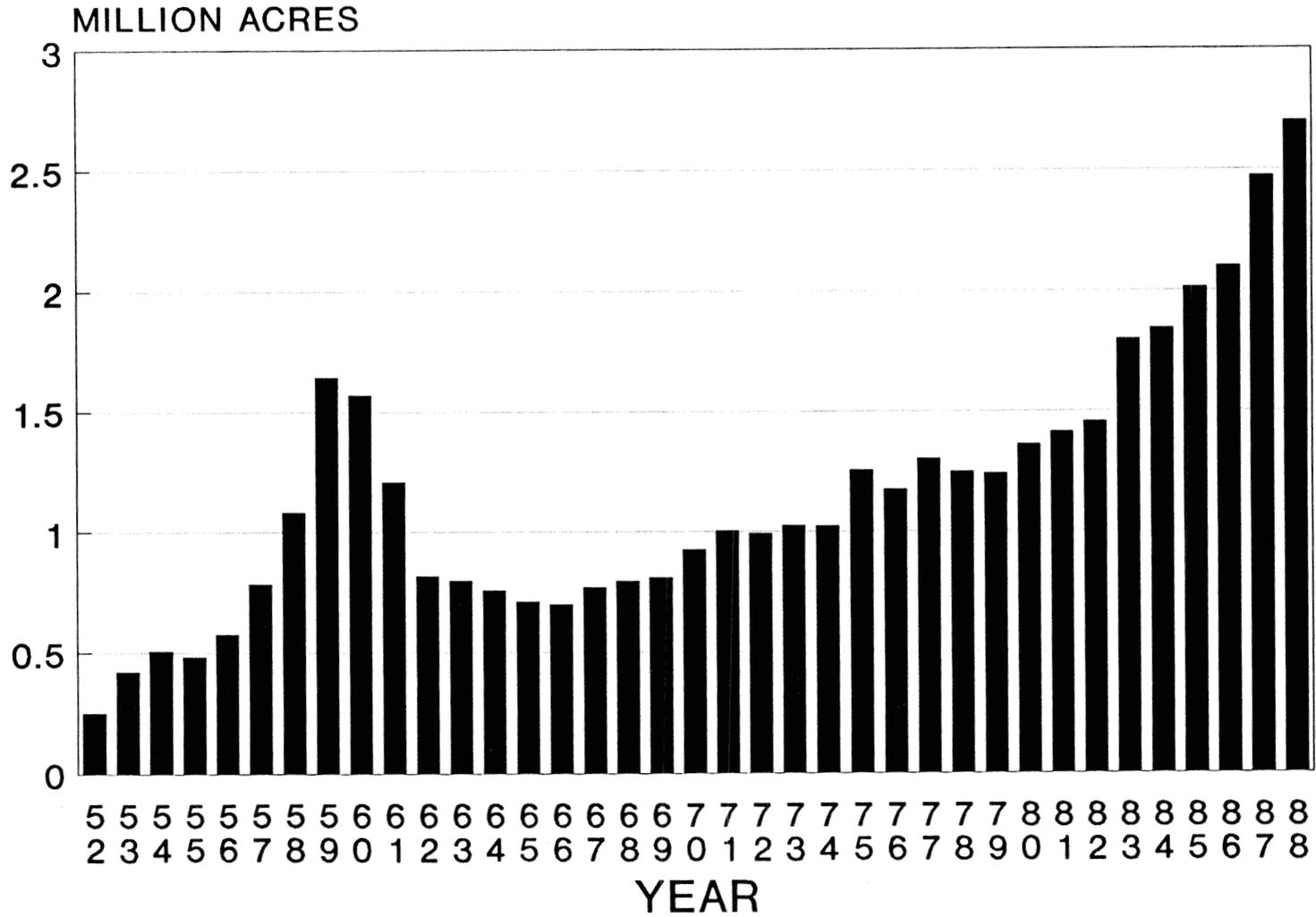


Figure 2.--Acres planted annually in the South, by year.

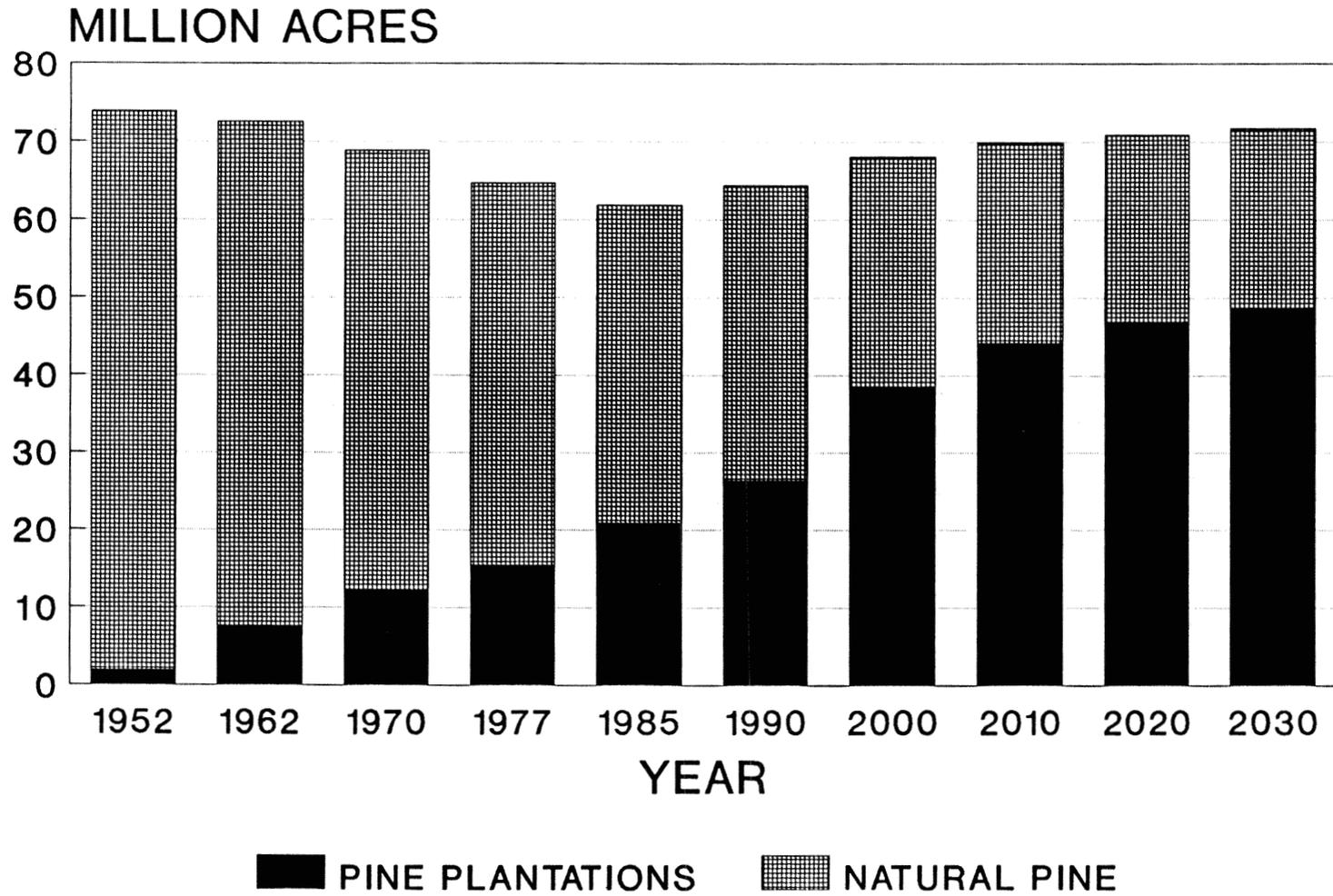


Figure 3.--Area of planted and natural pine stands in the South, trends and projections.

On NIPF timberland, the total area in pine stands has declined steadily from 1952 until 1985 and now totals 33 million acres. Acres of NIPF pine stands are projected to level off and remain fairly stable from now through 2030. However, the proportion of these pine stands in plantations is projected to continue increasing beyond year 2000 before leveling off. Pine plantations currently make up 20 percent of the NIPF pine stands. By 2000, this proportion should reach 41 percent. By 2030, they should account for 54 percent of the NIPF pine stands.

On public timberland, the total area in pine types has changed little, and now totals 6.6 million acres. This area is expected to remain fairly stable throughout the projection period. Pine plantations currently occupy only 18 percent of pine stands on public land. They are expected to reach about 41 percent by 2030.

From 1952 until 1970, the area of plantations established was about equal for forest industry and NIPF ownerships. Since then, forest industry has exceeded NIPF plantation establishment, and the current industry total of 13.2 million acres is double the NIPF area in plantations. Between now and the year 2000, large increases in plantation establishment are projected for NIPF and forest industry land. Between now and 2030, forest industry is expected to continue to have the most acreage in pine plantations. Its plantation acreage is projected to reach 27 million acres by 2030. At that time, NIPF ownerships are expected to have 19 million acres in plantations. Public lands are projected to have less than 3 million acres in pine plantations by 2030.

Some 39 percent of all pine plantations across the South are less than 10 years old, and 74 percent are less than 20 years old (Knight 1986). Only about 3 percent of the pine plantations in the South are more than 30 years old. Forest industry has 68 percent of all pine plantations under 20 years old.

Volume

In 1985, softwood inventory volume in the South totaled 102 billion cubic feet. Of this, 72 billion cubic feet were in pine forest types. Nineteen percent of the softwood volume in pine forest types was in pine plantations (13.6 billion cubic feet). In contrast to the projected increases in total area of pine stands, the long upward climb in softwood volume on pine stands has ended and is projected to decline through year 2000 before turning up again. It doesn't regain 1985 levels until 2030 (fig. 4). This decline is related to declines in total area of timberland, particularly on NIPF land, and conversion of older natural stands to young pine plantations. Pine plantations are projected to contain 48 percent of the softwood volume in pine stands by year 2000, and as much as 73 percent by 2030.

Removals

The South has recently supplied an average of 5.4 billion cubic feet of total softwood removals each year. Softwood volume from pine stands accounted for 76 percent, or 4.1 billion cubic feet, of this total. Pine plantations provided 18 percent of the softwood volume removed from these pine stands. Softwood removals from pine stands have generally increased between 1952 and 1985. They are also projected to continue a steady increase throughout most of the projection period. Softwood removals from natural pine stands will continue to decline as these stands are replaced after harvest by plantations. By year

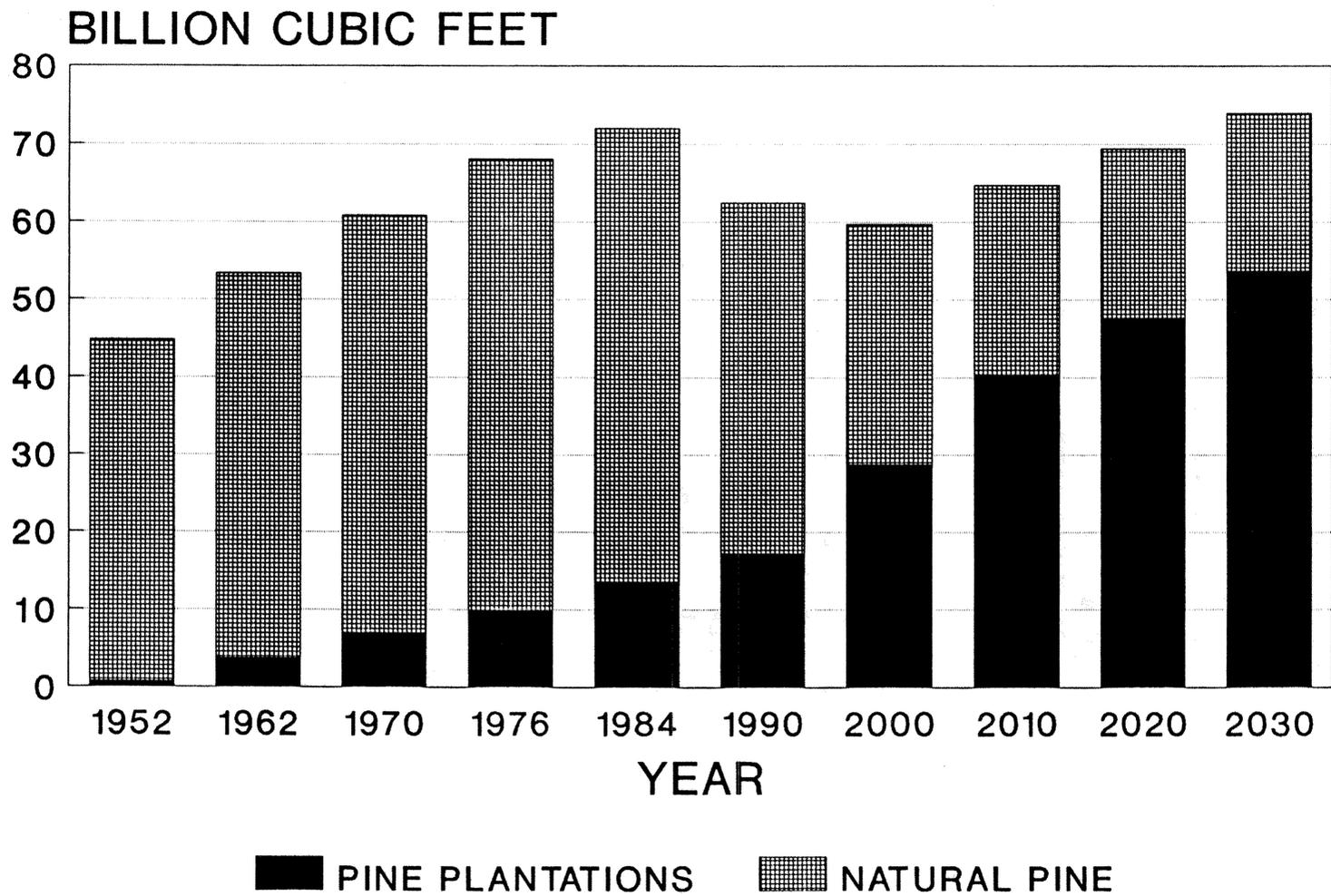


Figure 4.--Softwood volume in planted and natural pine stands of the South, trends and projections.

2000, plantation wood will supply 54 percent of the softwood removed from pine stands (fig. 5). The proportion of pine cut from plantations is expected to jump to 69 percent in 2010 and reach 74 percent by 2020.

SOUTHEAST GEORGIA - NORTHEAST FLORIDA

Plantation establishment is not uniform across the South. Mapping plantation acreage as a proportion of timberland in Southern counties provides an excellent impression of where these stands are located (fig. 6). Counties with at least 25 percent of their total timberland in pine plantations are concentrated in southeast Georgia and northeast Florida. The complexion of the pine resource in this region already approaches the conditions projected Southwide by the year 2000 and beyond. We will focus on the area, volume, and removal statistics for this region (Brown 1987 and Johnson 1988) as our window to the future.

Area

Southeast Georgia and northeast Florida contain 4.9 million acres of planted pine and 2.8 million acres of natural pine (fig. 7). Sixty-three percent of this regions timberland is in pine plantations, compared to one-third Southwide. Forest industry controls nearly two-thirds of the plantations and NIPF owners have 61 percent of the natural pine stands in this region.

Table 1 shows pine stands in the region by stand-age classes. Although there is substantial acreage in the no manageable stand category, many of these acres were recently harvested and are in need of site preparation and regeneration. Pine plantations account for 93 percent of all pine stands under 20 years old. Forty-seven percent of the pine plantations are less than 10 years old, compared to 39 percent for the whole South. Slightly more than 3 percent of the plantations are over 30 years old. The latest increases in planting on NIPF land are already showing up in the planted 0-10 year age class. Plantations in this class are more than triple the area of NIPF in the 11-20 age class. Note the reduction in area of natural pine stands below 20 years old. Most natural pine stands here are more than 30 years old. Also note that NIPF owners control most of these natural pine stands.

Table 1.--Area of timberland in planted and natural pine stands in Southeast Georgia/Northeast Florida, by stand-age class, by ownership, 1987.

Stand Age Class	Total Pine		Ownership					
	Planted	Natural	Forest Industry		NIPF		Public	
years			Planted	Natural	Planted	Natural	Planted	Natural
	Thousand Acres							
NMS(a)	132.2	866.2	71.4	233.0	57.1	543.0	3.7	90.2
00-10	2284.5	157.1	1278.6	17.2	919.2	122.2	86.7	17.7
11-20	1330.7	129.5	1010.5	25.4	283.8	94.2	36.4	9.9
21-30	994.6	291.1	758.4	71.9	201.0	183.4	35.2	35.8
31-40	143.4	592.5	61.8	170.1	78.1	325.1	3.5	97.3
41-50	16.3	395.7	5.2	78.1	9.0	226.0	2.1	91.6
51-60	4.1	258.6	0	32.4	0	144.7	4.1	81.5
61+	0	158.6	0	13.6	0	99.8	0	45.2
TOTAL	4905.8	2849.3	3185.9	641.7	1548.2	1738.4	171.7	469.2

(a) No Manageable Stand

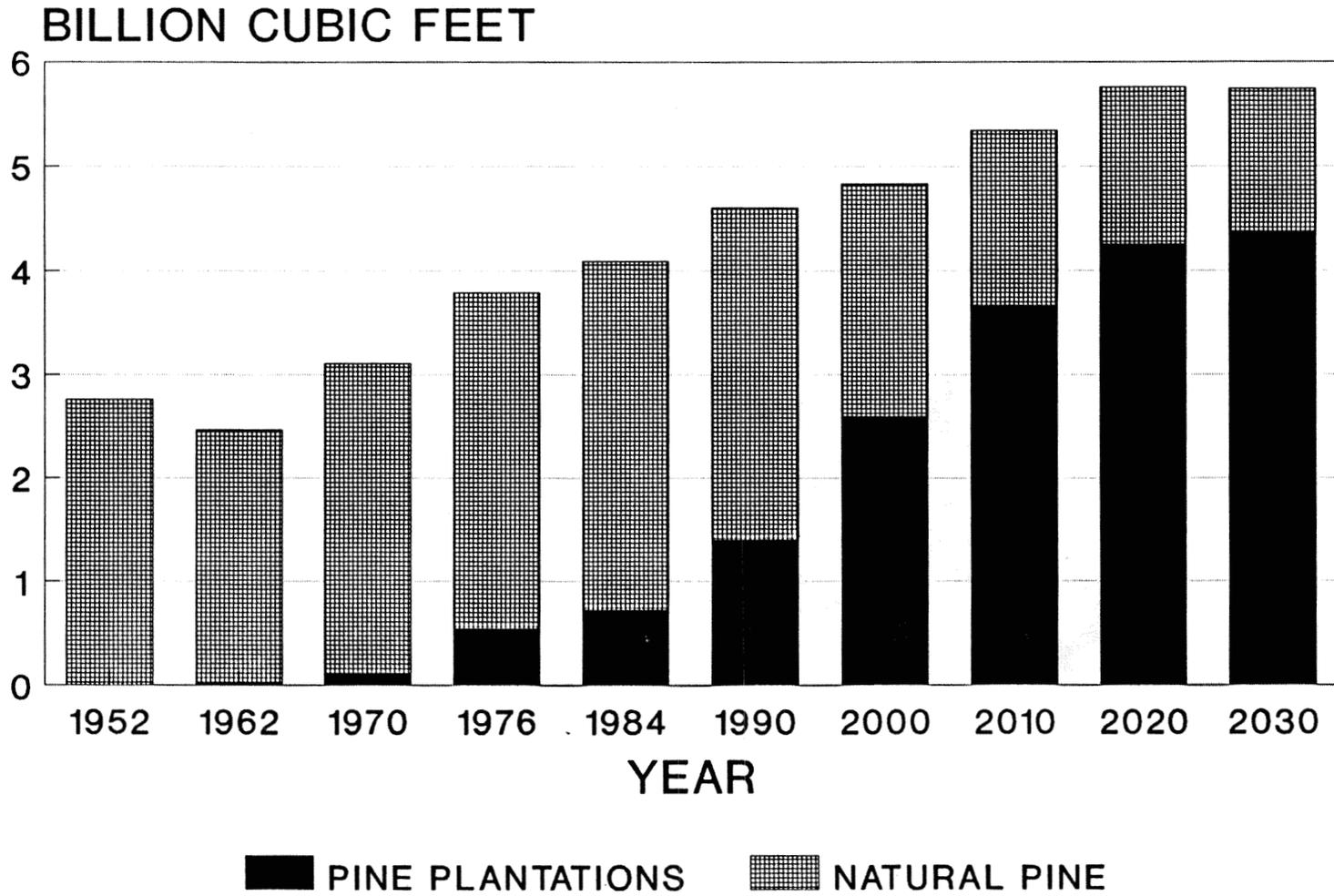


Figure 5.--Average annual softwood removals from planted and natural pine stands in the South, trends and projections.

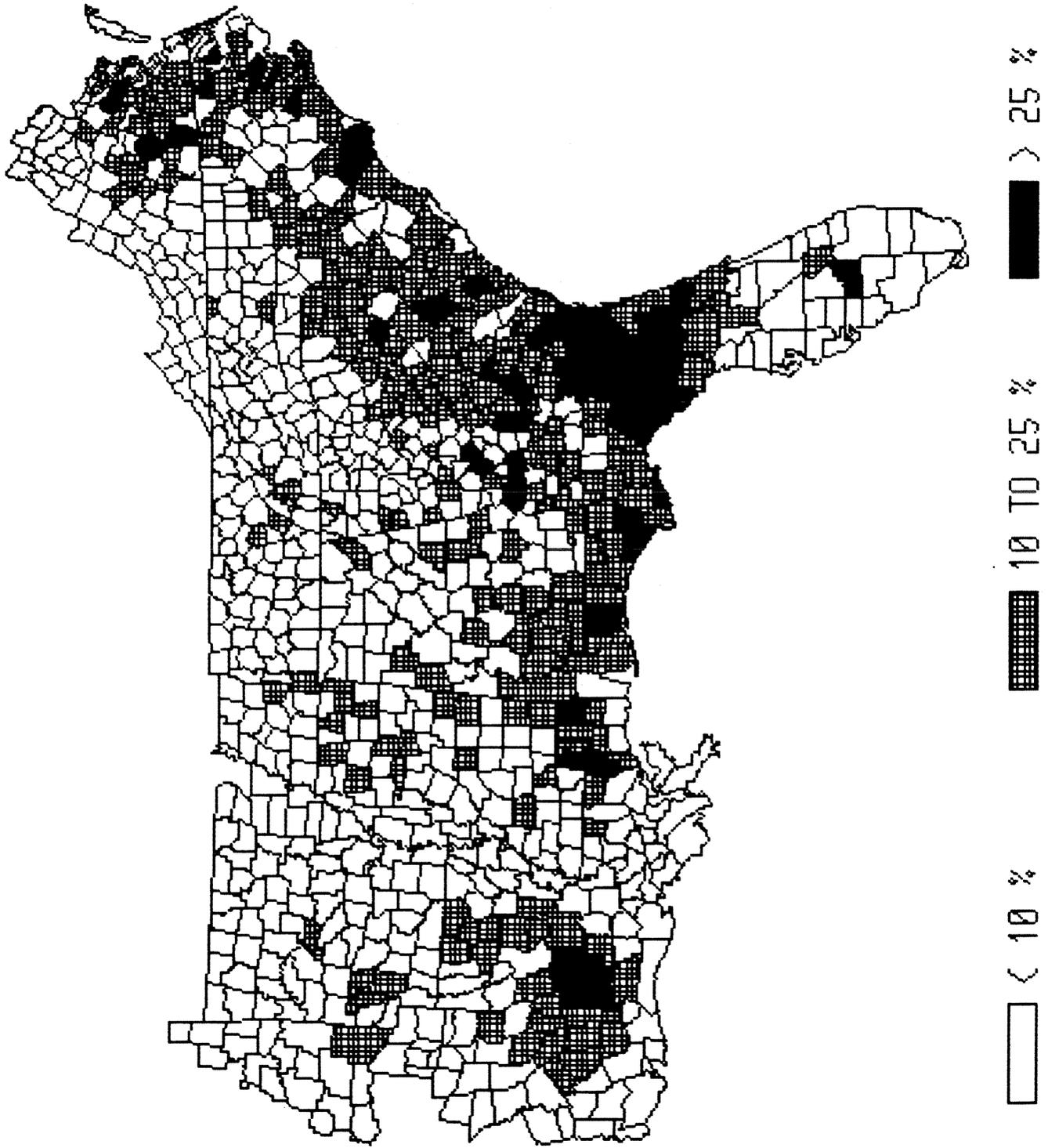
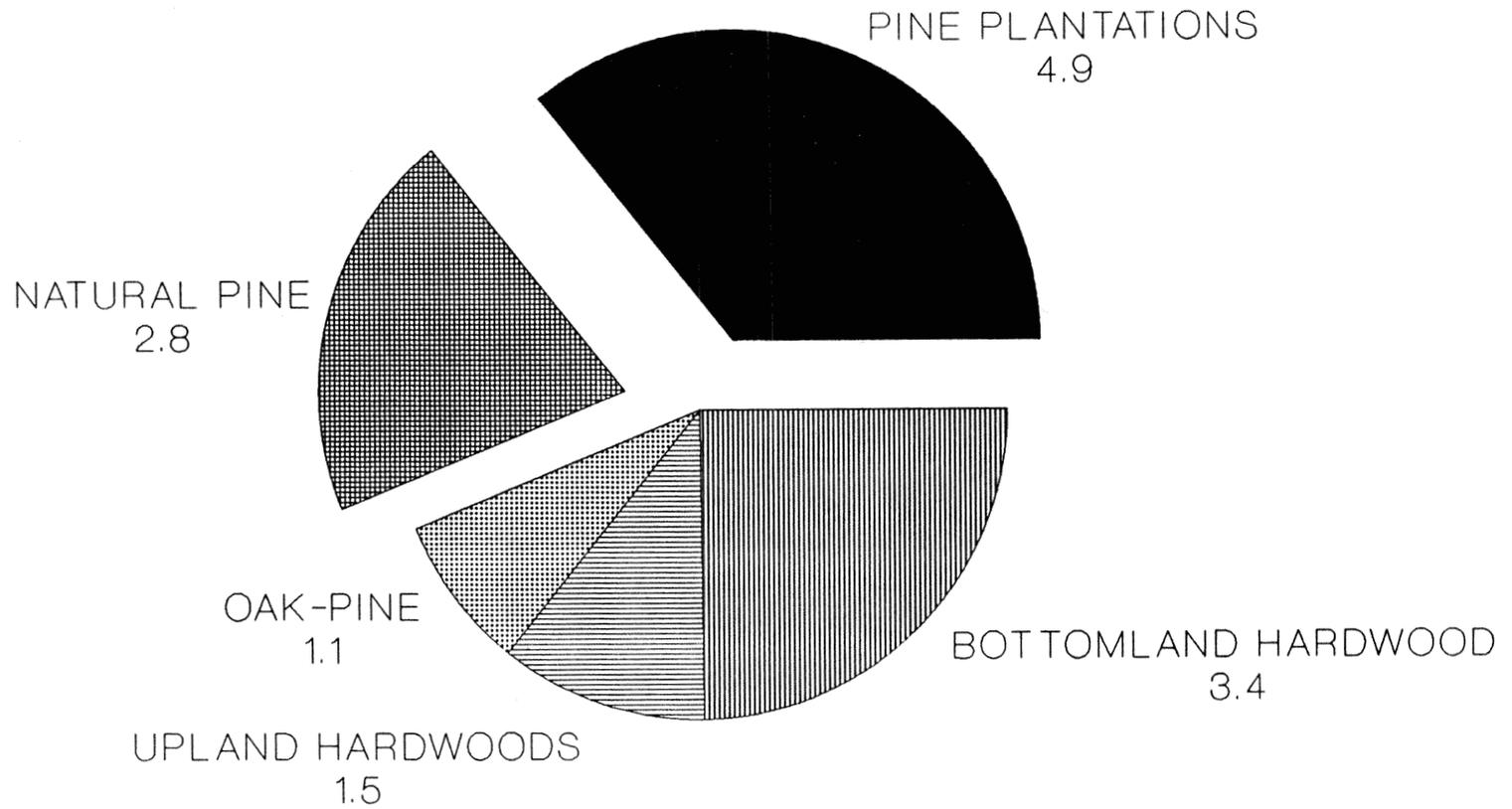


Figure 6.--Proportion of timberland in pine plantation management type, 1985.



MILLION ACRES

Figure 7.--Area of timberland in Southeast Georgia/Northeast Florida in 1987, by management type.

Volume

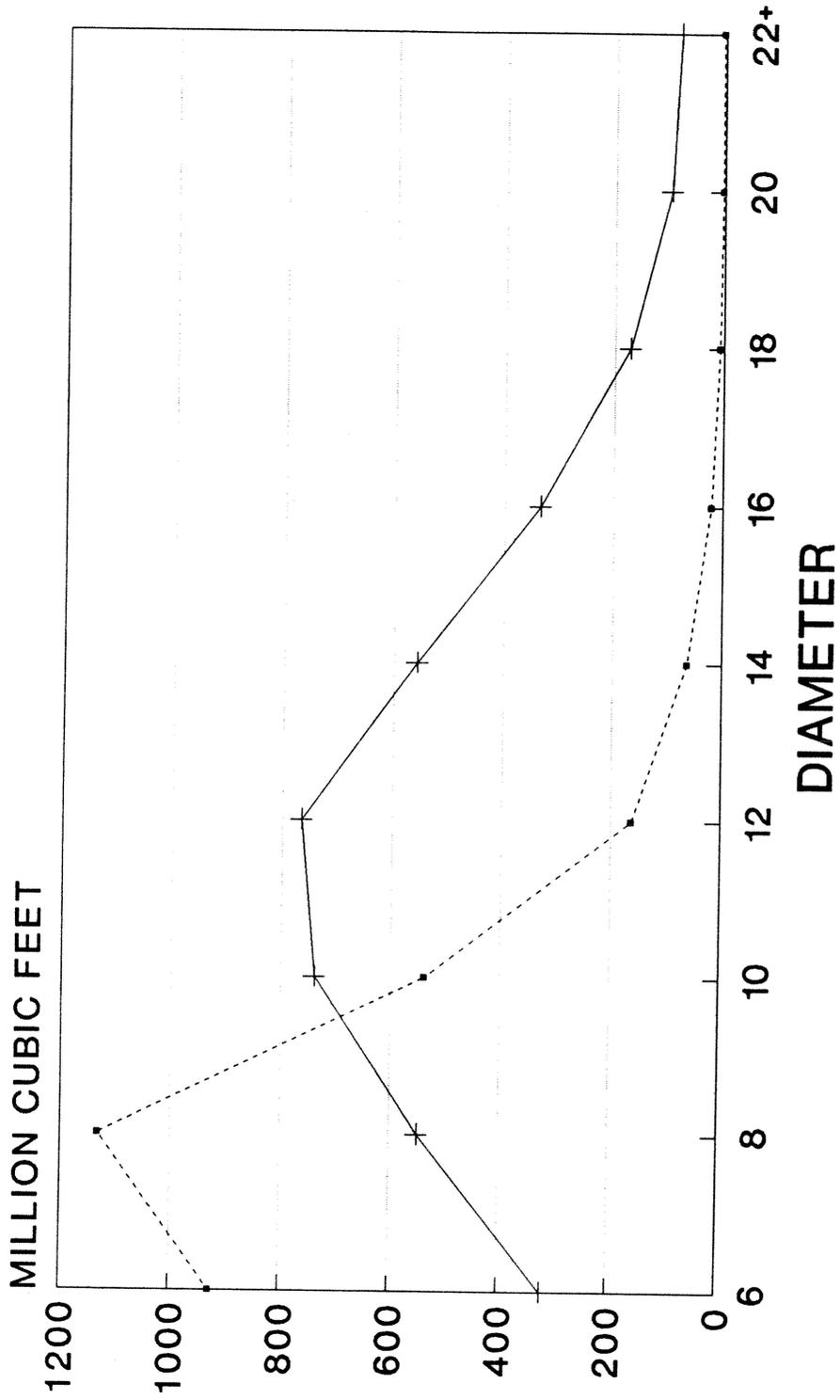
There are 6.5 billion cubic feet of softwood volume in pine stands of southeast Georgia/northeast Florida. Pine plantations currently account for 44 percent, or 2.9 billion cubic feet, of this total compared to only 19 percent Southwide. Figure 8 shows the diameter distribution of softwood volume for pine stands in this region. For pine plantations, 72 percent of the softwood volume is found in the 6- and 8-inch diameter classes. Ninety-one percent of the plantation volume is in diameter classes 10 inches and smaller. Softwood volume in natural pine stands is more evenly distributed across all diameter classes. The 10- and 12-inch diameter classes contain 42 percent of the natural pine stand volume. Almost all softwood volume in trees larger than 14 inches occurs in the natural pine stands.

Removals

Annual removals of softwood from pine stands averaged 551 million cubic feet in southeast Georgia/northeast Florida. Pine plantations already contribute 45 percent of these removals versus 18 percent Southwide. The diameter distribution of these removals reveals that 41 percent of the removals from plantations come from the 8-inch diameter class alone (fig. 9). In addition, 89 percent of the plantation removals come from the 10-inch and smaller diameter classes. Removals from natural pine stands are more evenly distributed across the range of diameter classes; the 10-12 inch classes provide 41 percent or more than two-fifths the removals from natural pine stands.

SUMMARY

What has already transpired in the pine stands of southeast Georgia and northeast Florida is indicative of the future in other pine growing regions of the South. The total area of pine stands in southeast Georgia and northeast Florida is already dominated by plantations. The volume in plantations is quickly approaching half the total volume in pine stands. Plantations now contribute nearly half of the removals. Furthermore, almost three-fourths of the plantation volume is in 6- and 8-inch trees, and 8-inch trees supply 41 percent of plantation removals. The situation in this region confirms a trend toward more plantation wood and smaller diameter trees. If more juvenile wood is not desirable, a solution would be to extend rotations and grow larger logs. But this is seemingly incompatible with the projected decline in softwood volume through year 2000. Industry may have to shorten rotations and cut more from its own land temporarily to keep its mills supplied. The emphasis on increased use of hardwoods will certainly have an impact on future timber supplies.



..... PLANTED PINE + NATURAL PINE
 Figure 8.--Softwood inventory volume by diameter class for planted and natural pine stands in Southeast Georgia/Northeast Florida, 1987.

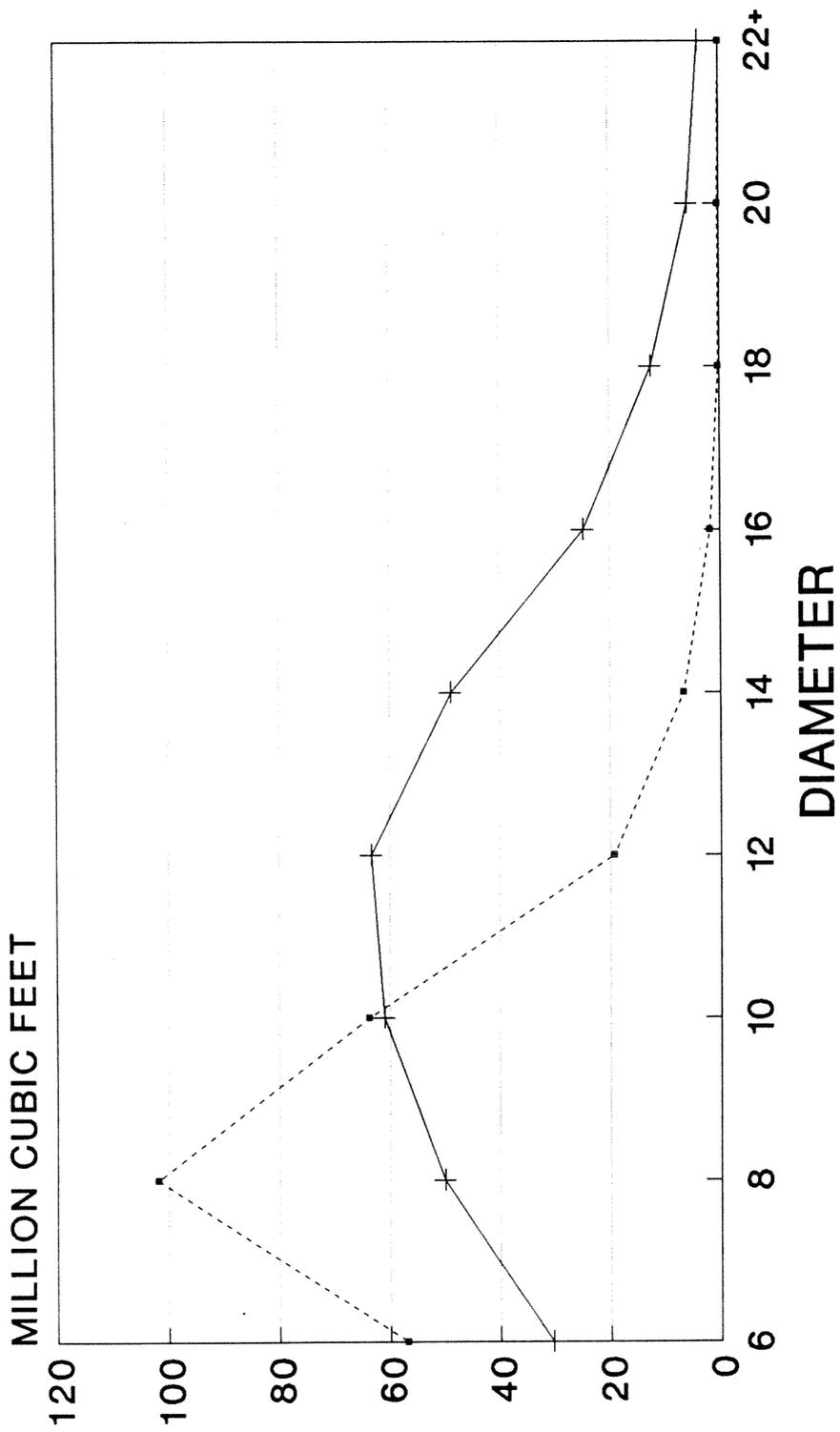


Figure 9.--Average annual softwood removals by diameter class from planted and natural pine stands of Southeast Georgia/Northeast Florida, 1980-1987.

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IMPACTS ON LUMBER AND PANEL PRODUCTS

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IMPACTS ON LUMBER AND PANEL PRODUCTS

AGENDA

- BACKGROUND

- SIGNIFICANT IMPACTS
 - RAW MATERIAL
 - CHANGES IN PROPERTIES

- CHARACTERISTICS OF PRODUCTS FROM PLANTATIONS

- RECENT TECHNOLOGICAL IMPROVEMENTS

- KEY AREAS NEEDING MORE RESEARCH

IMPACTS ON LUMBER AND PANEL PRODUCTS

BACKGROUND

- SOUTHERN PLANTATIONWOOD HAS BEEN THE SUBJECT OF CONSIDERABLE RESEARCH:
 - *ZOBEL, BLAIR, LENHART & OTHERS ON RAW MATERIAL AND PULP PROPERTIES*
 - *BENDTSEN, KOCH, PEARSON, GILMORE, ETC. IN BASIC LUMBER PROPERTIES*

- SOUTH IS RAPIDLY MOVING TOWARDS MORE SIGNIFICANT VOLUMES OF YOUNGER TREES
 - *U.S. FOREST SERVICE FORECASTS*
 - *ZOBEL AND KELLISON PAPER IN TAPPI*

- THERE ARE SEVERAL EXAMPLES OF "INTEGRATED FOREST TO PRODUCT" RESEARCH MODELS:
 - *NEW ZEALAND RADIATA TASK FORCE*
 - *CANADIAN DOUGLAS FIR TASK FORCE*
 - *WESTERN STAND MANAGEMENT COOP*

- THESE INTEGRATED STUDIES ARE CHARACTERIZED BY:
 - *INVOLVEMENT OF MANY SCIENTIFIC DISCIPLINES IN ORDER TO MEASURE AND CORRELATE ALL RESULTS*
 - *STUDY DESIGN - LINKAGE OF RAW MATERIAL TO END PRODUCT PROPERTIES*

IMPACTS ON LUMBER AND PANEL PRODUCTS

BACKGROUND (CONTINUED)

- INTEGRATED STUDY DESIGN INCLUDES:

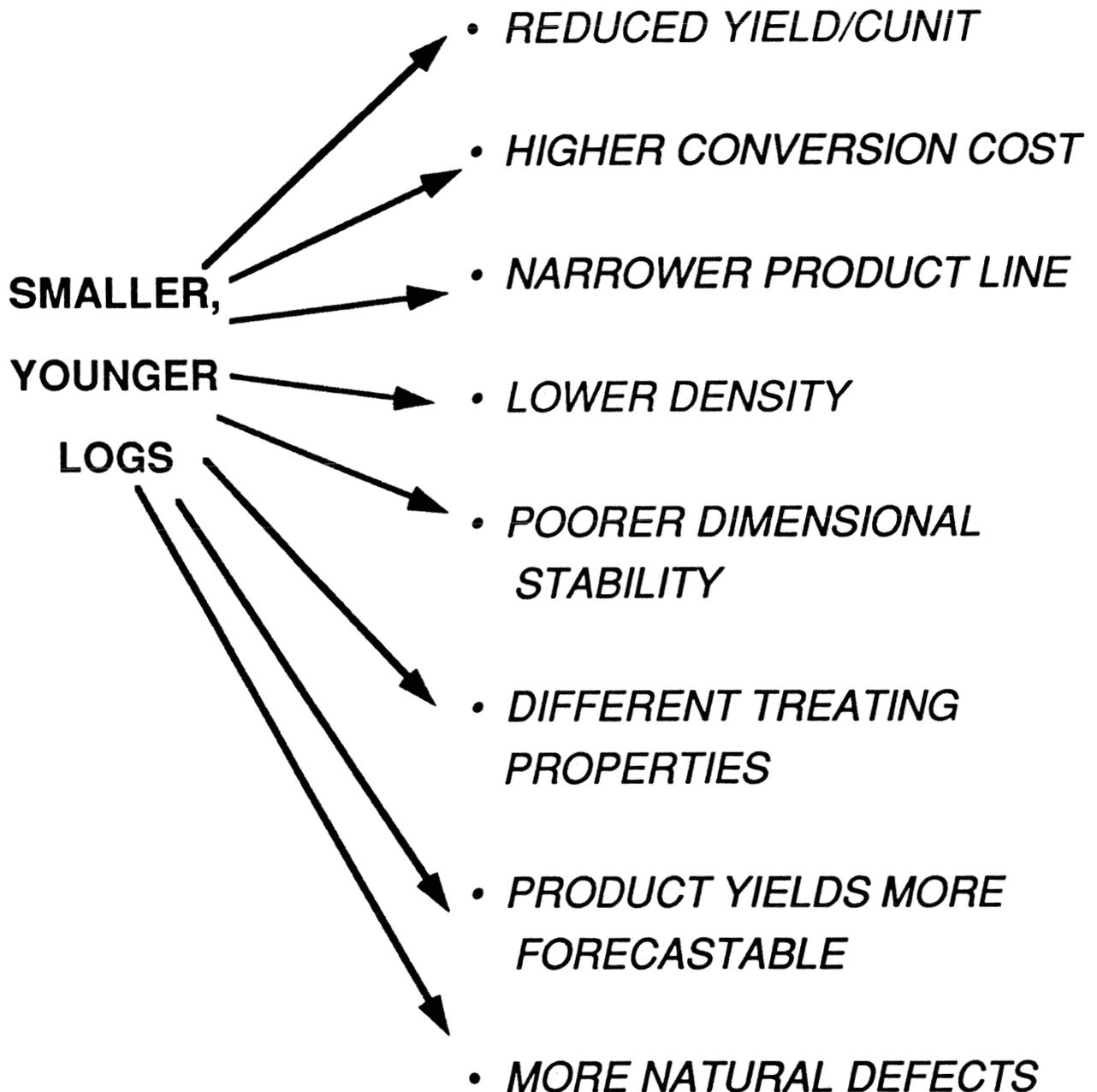
- *DETAILED TREE MEASUREMENTS*
- *PRODUCT CONVERSION & YIELD*
- *PRODUCT QUALITY MEASUREMENTS*
- *DRYING, TREATING PROPERTIES*
- *PHYSICAL TESTING, CORRELATED BACK TO TREE CHARACTERISTICS*
- *STUDY RESULTS ARE USED TO BUILD PREDICTIVE MODELS*

- PURPOSE OF THIS PRESENTATION

- *REVIEW OUR CURRENT KNOWLEDGE, (PUBLISHED RESEARCH)*
- *SUGGEST KEY AREAS NEEDING MORE RESEARCH*

IMPACTS ON LUMBER AND PANEL PRODUCTS

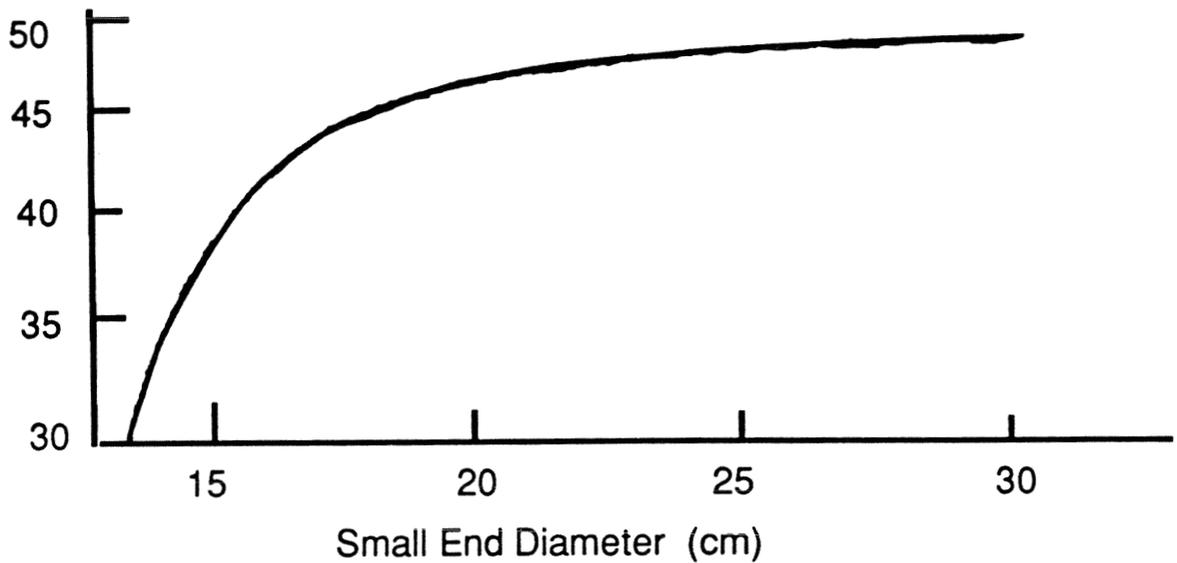
SIGNIFICANT IMPACTS - OVERVIEW



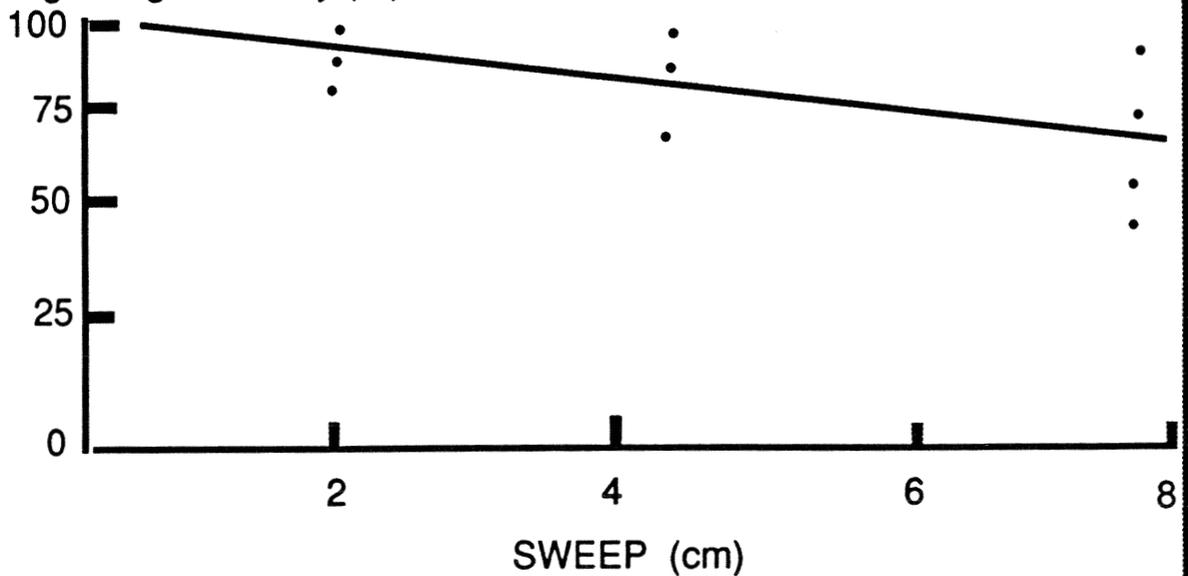
IMPACTS ON LUMBER AND PANEL PRODUCTS

RAW MATERIAL CHANGES

Volumetric Lumber Recovery (%)



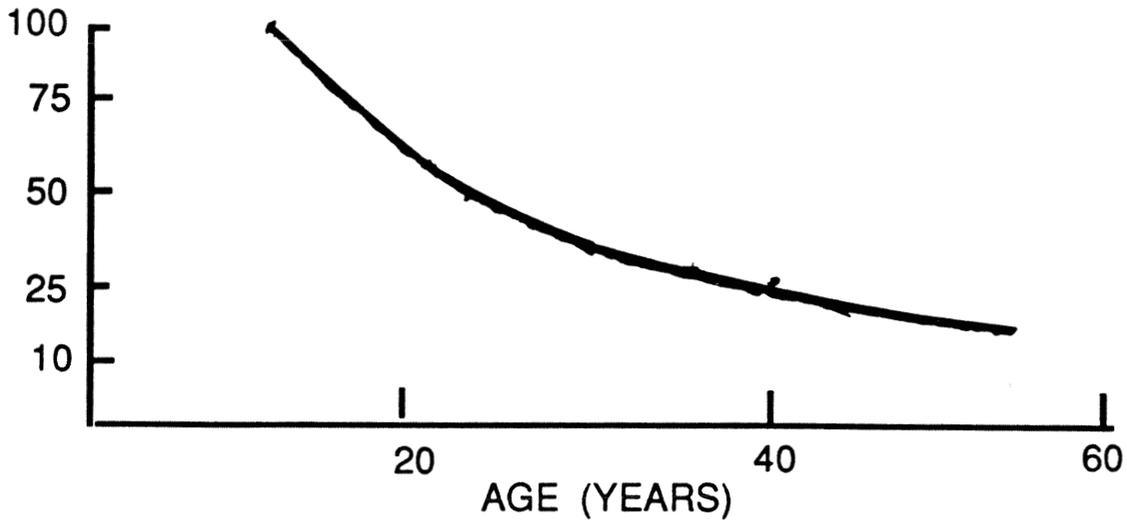
Straight Log Recovery (%)



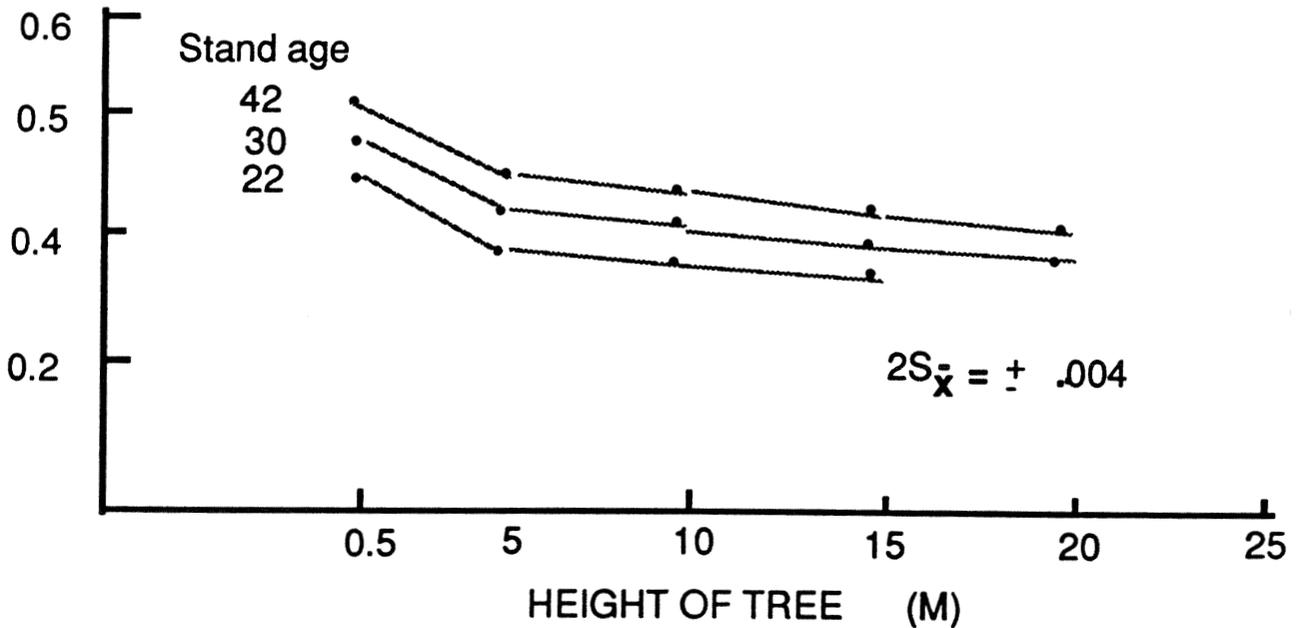
SOURCE: MATCHING PRODUCTS OF YOUNG FORESTS TO THE MARKET PLACE. BY GIB COMSTOCK. PROCEEDINGS OF THE 1983 CONVENTION OF THE SOCIETY OF AMERICAN FORESTERS IN PORTLAND, OREGON

IMPACTS ON LUMBER AND PANEL PRODUCTS JUVENILE WOOD, SPECIFIC GRAVITY

JUVENILE WOOD (%)



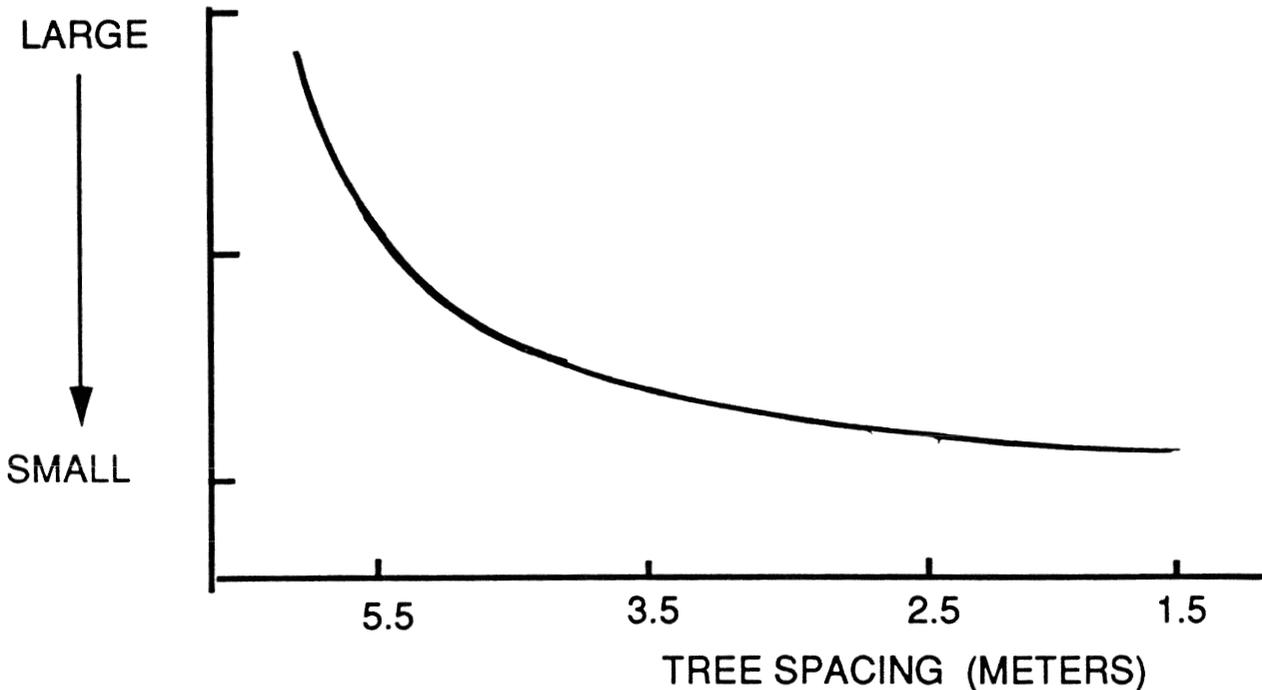
SPECIFIC GRAVITY



SOURCES: WOOD & PULP PROP. OF JUVEN. WOOD by ZOBEL & BLAIR, APPLIED SCIENCE SYMPOSIUM #28 (1976)
WOOD QUALITY FACTORS IN LOBLOLLY PINE BY MEGRAW (TAPPI PRESS)

IMPACTS ON LUMBER AND PANEL PRODUCTS LIMB SIZE AS FUNCTION OF TREE SPACING

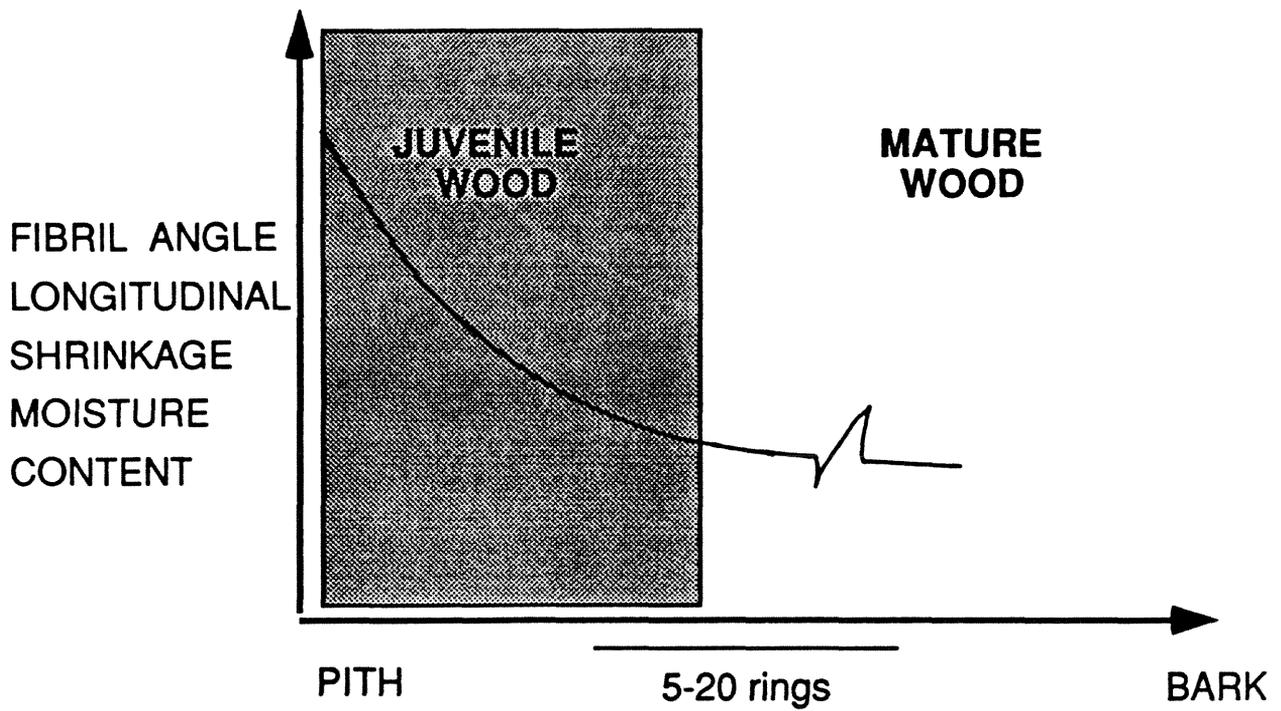
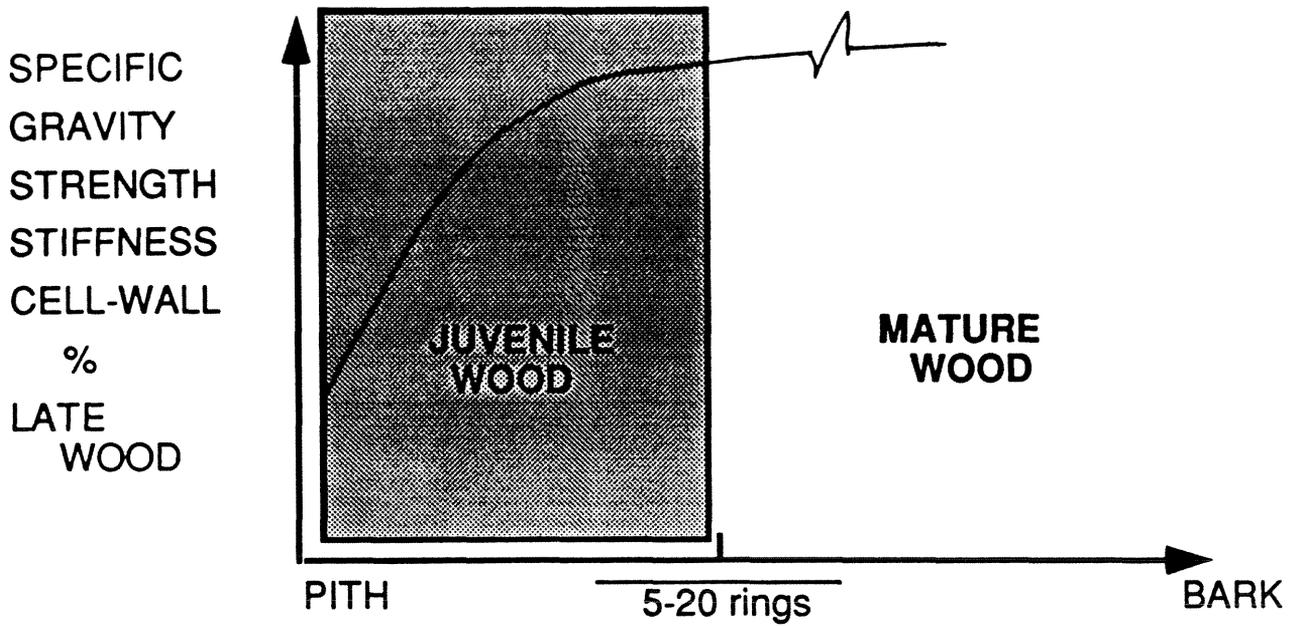
BRANCH DIAMETER



EXACT SHAPE OF THE ABOVE CURVE IS SPECIES AND SITE DEPENDENT. RESEARCH HAS BEEN DONE IN EUROPE AND AUSTRALIA. BOTH INITIAL SPACING AND SUBSEQUENT THINNING SCHEDULE IS IMPORTANT

SOURCE: EFFECT OF FOREST PRACTICES ON THE QUALITY OF THE HARVESTED CROP BY BRAZIER. FORESTRY VOL. 50 #1 (1977)

IMPACTS ON LUMBER AND PANEL PRODUCTS CHANGES IN PROPERTIES - JUVENILE TO MATURE



SOURCE: Properties of Wood from Improved & Intensively Managed Trees by
 B. Alan Bendtsen FPJour. Vol. 28 #10 pp 61-72 (1978)

IMPACTS ON LUMBER AND PANEL PRODUCTS

CHARACTERISTICS OF LUMBER - 1990'S

LUMBER PROPERTIES CHANGE AS A RESULT OF USING YOUNGER RAW MATERIAL:

- *GREATER PROPORTION OF KNOTTY WOOD WILL BE AVAILABLE*
- *LOWER STRENGTH AND STIFFNESS FOR VISUALLY GRADED LUMBER*
- *GREATER VARIABILITY OF STRENGTH & STIFFNESS, EXCEPT FOR MACHINE-STRESS RATED PRODUCTS*
- *MORE DEGRADE IF ONLY CONVENTIONAL KILN-DRYING TECHNIQUES ARE USED*
- *GREATER POTENTIAL FOR WARPAGE*
- *BETTER TREATABILITY USING WATER-BORNE PRESERVATIVES*

SOURCES:

- 1) MORE PLANTATIONWOOD MEANS QUALITY PROBLEMS BY KELLISON, DEAL, & PEARSON. FOREST INDUSTRIES, SEPT. 1985
- 2) "WEAK WOOD" BY SENFT, BENDTSEN, & GALLIGAN. JOURNAL OF FORESTRY, AUGUST 1985
- 3) CHARACTERISTICS OF STRUCTURAL IMPORTANCE OF CLEAR WOOD FROM FAST GROWN LOBLOLLY PINE STANDS BY PEARSON. PROC. OF THE SYMPOSIUM ON UTILIZATION OF THE CHANGING WOOD RESOURCE, JUNE 12-14, 1984

IMPACTS ON LUMBER AND PANEL PRODUCTS CHARACTERISTICS OF PLYWOOD PRODUCTS

PLYWOOD PROPERTIES CHANGE AS A RESULT OF USING YOUNGER RAW MATERIAL:

- **SMALLER AVERAGE BLOCK SIZE: RESULTS IN LOWER NET RECOVERY OF VENEER**
- **LOWER PANEL DENSITY (LOWER SP. GR. WOOD!)**
- **DIFFERENT GRADE OF VENEER FROM AVERAGE BLOCK**
 - **LOWER % OF CLEAR GRADES**
 - **HIGHER % OF C GRADE**
 - **LOWER % OF D GRADE**
- **IF JUVENILE WOOD IS FACE OR BACKS, LOWER PANEL STIFFNESS WILL RESULT**
- **PANELS CONTAINING JUVENILE WOOD WILL EXHIBIT GREATER LINEAR EXPANSION - MAY FAIL TO MEET APA SHEATHING PERFORMANCE SPECIFICATIONS**

SOURCE:

QUALITY, YIELD, & MECHANICAL PROPERTIES OF PLYWOOD PRODUCED FROM
FAST GROWTH LOBLOLLY PINE. by MACPEAK, BURKHART, & WELDON. PRESENTED AT
THE NATIONAL FPRS MEETING IN JUNE, 1984

IMPACTS ON LUMBER AND PANEL PRODUCTS TECHNOLOGICAL IMPROVEMENTS - LUMBER

- IMPROVEMENTS IN SMALL LOG PROCESSING AND RECOVERY OF PRODUCT:
 - *RECOVERY OPTIMIZATION THROUGH USE OF COMPUTER PROGRAMS COUPLED WITH SCANNERS, MACHINE SET-WORKS, AND TRANSPORT SYSTEMS*
 - *HIGHER SPEED, MORE RELIABLE TRANSPORT SYSTEMS*
 - *DEVELOPMENT OF HIGH TEMP DRY KILNS, IMPROVEMENTS IN SCHEDULES, AND RESTRAINT SYSTEMS*

- GROWTH OF MSR-RATED LUMBER PRODUCTS INTO STRUCTURAL END-USE APPLICATIONS

- INDUSTRY-BACKED EFFORT TO DEVELOP A RELIABILITY BASED DESIGN SPECIFICATION (RBD) * FOR STRUCTURAL LUMBER PRODUCTS
 - *REQUIRES IMPROVED GRADING & Q/C SYSTEMS*
 - *SHOULD RESULT IN LUMBER BEING EASIER TO USE & MORE COMPETITIVE IN ENGINEERED END-USES*

* LRFD for Engineered Wood Construction by James Goodman, Proceedings the sessions at Structures Congress pp736-740 1989

IMPACTS ON LUMBER AND PANEL PRODUCTS TECHNOLOGICAL IMPROVEMENTS - PLYWOOD

- PROCESSING IMPROVEMENTS
 - *PRE-ROUNDUP, X-Y CHARGERS WITH POSITIONAL SCANNERS*
 - *FASTER LATHES & SPINDLE SPEEDS - 450 RPM*
 - *DEVELOPMENT OF THE SPINDLESS LATHE*
 - *LATHE/TRAY/CLIPPER SPEED-UP*
 - *MORE EFFICIENT DRYERS, WITH VENEER MOISTURE CONTENT MONITERING SYSTEMS*
- PEELING TO SMALLER CORE DIAMETERS,
(ESPECIALLY SPINDLESS LATHES)
- GLUING HIGHER MOISTURE CONTENT VENEERS
USING MOISTURE TOLERANT GLUE MIXES

SOURCE:

SOFTWOOD PLYWOOD INDUSTRY ADAPATS TO NEW TECHNIQUES.

BY RICHARD F. BALDWIN. FOREST INDUSTRIES, APRIL 1984 pp. 28-29.

IMPACTS ON LUMBER AND PANEL PRODUCTS

NEW STRUCTURAL PRODUCTS

ORIENTED STRANDBOARD & OTHER STRAND PRODUCTS

- THIS TECHNOLOGY ALLOWS UTILIZATION OF A WIDE VARIETY OF SPECIES & SMALLER DIAMETERS
- IN THE FORM OF PANELS, OSB & WAFERBOARD SALES HAVE INCREASED FROM 1.5 BILLION SQ. FT. IN 1980 TO 4.6 BILLION IN 1988, GROWTH TO 8 BILLION BY MID 1990'S
- McMILLAN-BLOEDEL HAS INTRODUCED PARALLAM™, THE FIRST COMMERCIAL "PSL" TYPE PRODUCT
- SATCO (AUSTRALIA) IS JUST COMMERCIALIZING SCRIMBER™, WHICH USES LOW COST THINNINGS CRUSHED TO PROVIDE "SCRIMS" OF FIBER FOR BONDING WITH RESIN INTO BEAMS

OTHER STRUCTURAL LUMBER SUBSTITUTES

- LAMINATED VENEER LUMBER (LVL)
- WOOD I-BEAMS
- COM-PLY™
- RESEARCH IS UNDERWAY ON OTHER TYPES OF PSL (PARALLEL STRAND LUMBER). IN THEORY, HIGH STRENGTH PROPERTIES ARE POSSIBLE

SOURCES:

SOUTH AUSTRALIA FACTORY - FIRST SCRIMBER USER. AUSTRALIAN FOREST INDUSTRIES JOURNAL, JAN./FEB. 1988. P 32

POTENTIAL FOR STRUCTURAL LUMBER SUBSTITUTES. BY T. L. LAUFENBERG. STRUCTURAL WOOD COMPOSITES: MEETING TODAY'S NEEDS & TOMORROWS CHALLENGES. FPRS. PROCEEDINGS # 7339. 1984. PP 41-53

IMPACTS ON LUMBER AND PANEL PRODUCTS

KEY AREAS NEEDING MORE ATTENTION

- NON DESTRUCTIVE ESTIMATING OF LUMBER PROPERTIES
 - LOCALIZED SLOPE OF GRAIN RESEARCH
 - STRENGTH PREDICTION MODELING
 - ACCOUSTICAL EMISSION RESEARCH

- PROGRAMMED LAYUP OF PLYWOOD AND LVL USING HIGH PROPORTIONS OF JUVENILE WOOD

- DEVELOPMENT OF ENGINEERED PSL TYPE PRODUCTS TAILORED TO END USE APPLICATIONS
 - 1.5-2.1 million psi (MOE)
 - 1500-2800 psi (Ft)

- INNOVATIVE WAYS TO MAKE LUMBER PRODUCTS EASIER TO USE
 - "STRESS-CLASS" SYSTEM PROPOSED BY GREEN *etal.*
 - RBD METHODOLOGY APPLIED TO STRUCTURAL LUMBER

SOURCES:

FAILURE MODELING: A BASIS FOR THE STRENGTH PREDICTION OF LUMBER. by Cramer & Goodman. Wood & Fiber Science, vol. 18, #3, pp.446-459

FUTURE NEEDS IN THE NDE OF LUMBER. by W. L Galligan PROCEEDINGS / SIXTH NONDESTRUCTIVE TESTING OF WOOD SYMPOSIUM W.S.U. SEPT. 1987

LAMINATED VENEER LUMBER MADE FROM PLANTATION-GROWN CONIFERS. by Stump, Smith & Gray, FPRS Jour. 31(4):34-40.

STRESS CLASS SYSTEMS: AN IDEA WHOSE TIME HAS COME. by Green & Kretschmann. ASTM Committee D7 at Tacoma, Wash. (OCT. 1987)

STRUCTURAL WOOD PRODUCTS APPLICATION OF RBD by Suddarth. Structural Wood Composites Proceedings. #7339. (1984)

IMPACTS ON LUMBER AND PANEL PRODUCTS

KEY AREAS NEEDING MORE ATTENTION (CON'TD)

- IMPROVED DRY KILN TECHNOLOGIES FOR DRYING OF LUMBER WITH HIGHER PROPORTIONS OF JUVENILE WOOD
 - *OFF-SET TENDENCY TO WARP, CROOK, TWIST*

- IMPROVED RESISTANCE TO CREEP FOR RECONSTITUTED STRAND TYPE PRODUCTS

- REDESIGN OF COMPOSITE STRUCTURAL PRODUCTS
 - *SOME RESIDENTIAL TRUSS MEMBERS CAN USE LOWER MSR GRADES IN COMPRESSIVE MEMBERS*
 - *"E" RATED LAMINATED BEAMS, USING LOWER GRADES WHERE APPROPRIATE AND LUMBER SUBSTITUTE TENSILE PLYS (IE. LVL OR PSL)*

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ABSTRACT

Juvenile wood has always formed a portion of the southern pine raw material, but the proportion has increased as the amount of plantation pine with its shorter rotation reaches the pulp mills. As a result, both pulp and paper properties are changed. Paper made from chemical pulp with a high content of juvenile wood fiber has higher burst, tensile strength, fold endurance, sheet density and lower tear than paper from pulp with a high content of mature wood fiber; uniformity of sheet formation and printing characteristics also improve. Manufacturing costs increase as digester packing, pulp yield and byproducts decline and harvesting costs increase. Thus, the raw material change provides both benefits and limitations. Procedures for maximizing the benefits and minimizing the limitations through separation of the raw material, process manipulation and changing technology are described. Although solutions may be mill specific for many of the process manipulation techniques, raw material separation may be the best solution for most mills.

INTRODUCTION

Juvenile wood has always formed a portion of the raw material, but the proportion has increased as the amount of plantation pine with its shorter rotation reaches the pulp mills. From 1962 to 1985, natural pine acreage declined 13.5 percent and plantation pine increased 9.1 percent. At the same time, natural hardwood acreage increased 3.5 percent. Although hardwoods will become increasingly important as their acreage increases, this paper will primarily consider only the impact of the changing pine resource on paper manufacturing and properties.

As pointed out by Semke (1984), almost all commercial pulps from loblolly pine already have significant contents of juvenile wood fiber (Table 1.). The future trend will be to even higher contents.

^{1/} Reprinted with permission from the Forest Products Research Society/.

Table 1. EFFECT OF TREE AGE ON THE JUVENILE CONTENT OF WOOD AND PULP FROM TYPICAL LOBLOLLY PINE TREES

<u>Tree age, years</u>	<u>Juvenile Wood Content</u>	
	<u>Wood, % Dry Wt.</u>	<u>Pulp, % Oven-Dry Wt.</u>
15	76	75
25	50	48
40	15	14

From Semke (1984)

Juvenile wood is formed in the center of the stem and usually consists of 5 to 20 growth rings. The number of rings of juvenile wood is higher for longer-lived species than for short-lived species. Plantation grown trees with their accelerated growth reach marketable size at an earlier age than natural grown pine and therefore contain a higher proportion of juvenile wood. Thinnings from plantations younger than about 15 years old are essentially 100 percent juvenile wood. The tops of trees from both plantation and natural pine will also be comprised of 100 percent juvenile wood.

Prior to examining the effects, both limitations and benefits of juvenile wood on paper manufacturing and properties, a brief review of the anatomical, chemical and physical properties of juvenile wood is appropriate.

JUVENILE WOOD PROPERTIES

The changes that occur in some of the anatomical, chemical and physical properties of juvenile wood with increasing age are shown in Figure 1. Note the substantial and rapid change from the pith to the mature wood zone. A summary of the anatomical, chemical and physical properties of juvenile wood follows.

Anatomical Characteristics

The length, diameter, and wall thickness of juvenile wood cells are significantly different from mature wood cells. Figure 1 indicates the change in cell length and wall thickness from the pith to the mature wood zone. A quantitative indication of the change is shown in Table 2. Note that the wood source is listed in order of decreasing juvenile wood content and the cell dimensions increase with decreasing juvenile wood.

Within the cell wall, alpha-cellulose is organized in long string-like structures called microfibrils. In mature wood, the microfibrils are oriented almost parallel to the long axis of the fibers (10 to 30 degrees). However, in juvenile wood the orientation is much greater, up to 55 degrees in some species (Dadswell, 1958). Erickson and Armina (1974) found a microfibril angle change from 32 degrees in juvenile wood to 7 degrees in mature wood. As the microfibril angle increases, tensile strength in the long axis of the fiber decreases and longitudinal shrinking and swelling increase.

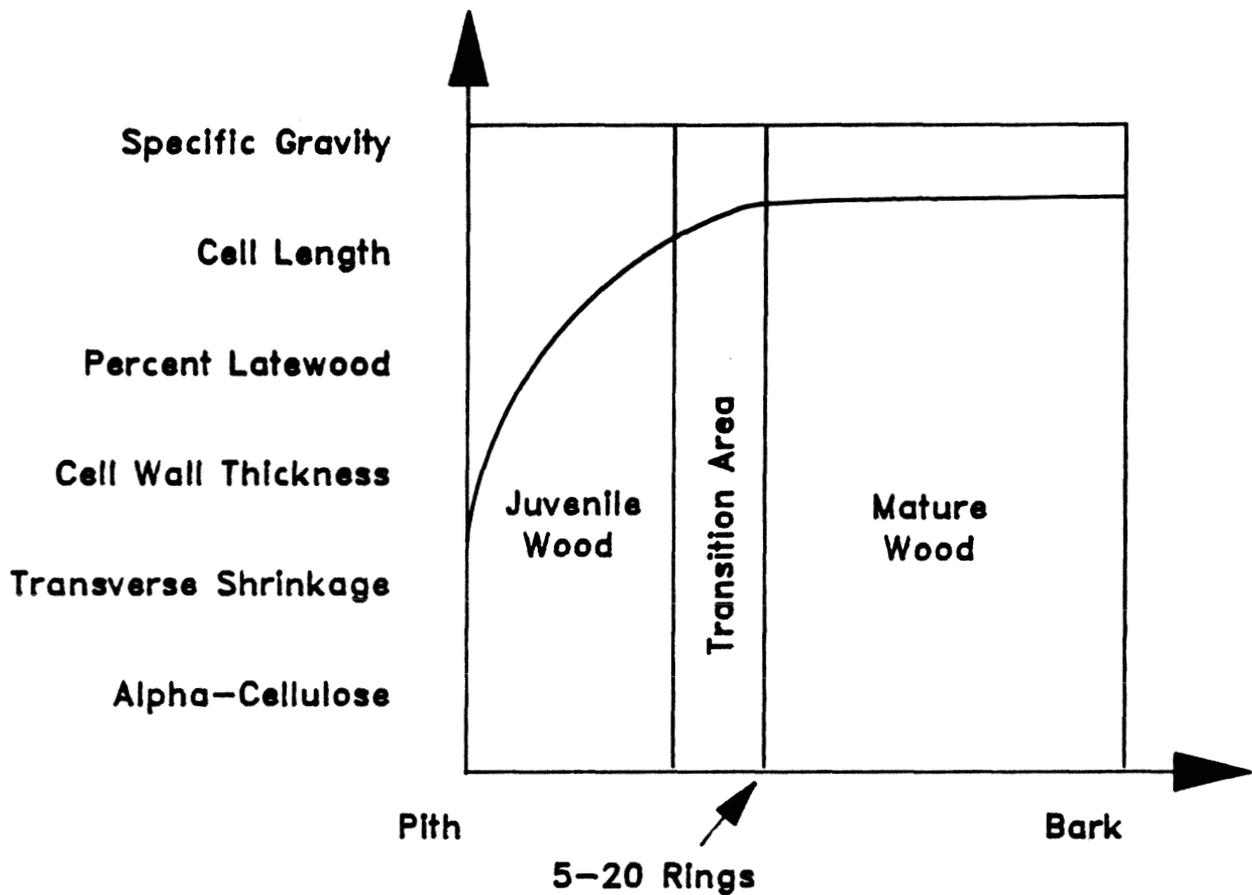


Figure 1. Change in juvenile wood characteristics with increasing age. The size of the juvenile wood zone is primarily species dependent and varies from 5 to 20 growth rings. The transition zone indicates an area within which the different properties reach maturity at different times.

Table 2. DIMENSIONS OF CELLS IN LOBLOLLY PINE PULP
FROM DIFFERENT SOURCES

Fiber Source	Average Cell Dimensions		
	Length Millimeters	Diameter Micrometers	Wall Thickness Micrometers
10-year-old trees	1.62	40.9	3.4
15-year-old trees	1.86	42.1	4.0
Topwood	2.43	42.1	4.4
Conventional roundwood	2.48	44.1	4.8
Sawmill Chips	2.80	46.7	5.3

From Semke and Corbi (1974)

Higher relative amounts of compression wood are found in juvenile wood than in mature wood (Bendsten, 1978). Compression wood has a higher lignin content, greater microfibril angle and shorter fibers than normal wood, regardless of location (juvenile or mature wood zones). The characteristics of this abnormal wood are similar to those of juvenile wood.

Another anatomical characteristic is the increase in the amount of summerwood with increasing age of juvenile wood. Taras (1965) documented an increase from 10 percent to 60 percent summerwood across the juvenile zone of slash pine. This, of course, is directly related to the wall thickness increase noted earlier.

Chemical Composition

The primary chemical constituents of softwoods and their approximate composition by weight are alpha-cellulose, 42 percent; hemi-cellulose, 27 percent; and lignin, 28 percent. Significant differences in the percentage composition exists between juvenile and mature wood. Juvenile wood has a lower cellulose and a higher lignin content than mature wood. Although these differences are quite variable, they are significant, with cellulose increases ranging from 5.7 percent (Byrd, 1964) to 13.7 percent (Cole, Zobel and Roberds, 1966) from juvenile to mature wood.

Physical Properties

The major properties within which juvenile wood differs from mature wood are strength, specific gravity, and dimensional stability as a result of changing moisture content. Although all three properties relate to the performance of juvenile wood as a solid wood or composite product, only specific gravity is directly related to the performance of paper products.

Figure 1 reveals the typical pattern of increasing specific gravity throughout the juvenile wood zone and then holding relatively constant in mature wood. This change is not unexpected since cell wall thickness is increasing rapidly compared to cell diameter (56 percent to 14 percent; Table 1) and the proportion of summerwood is accelerating rapidly.

IMPACT OF JUVENILE WOOD ON PULP MANUFACTURING AND PAPER PROPERTIES

The literature contains many references pertaining to the impact of increasing amounts of juvenile wood fiber on pulp and paper manufacturing processes and on the physical properties of the finished paper products. Some effects are beneficial whereas others are not. A summary of some of the literature pertaining to the benefits and limitations imposed on the manufacturing process and paper properties follows.

Manufacture of Pulp and Paper

The initial impact of increasing amounts of juvenile wood can be found in the increased cost of harvesting wood containing large amounts of juvenile wood. Table 3 indicates the amount of fiber obtained per cord of wood harvested from stands of varying ages. Since the cost of harvesting small stems with less fiber per unit volume is essentially the same as harvesting stems with a greater weight of fiber per unit volume, the cost per pound of fiber delivered to the mill is higher. Also, contributing to the increased harvesting cost per unit weight of fiber is the higher bark content of young stems (Table 3).

The purchase of wood by weight rather than volume is now practiced by most mills in order to avoid paying the same price for low density as for high density wood. However, the higher moisture content associated with juvenile wood partly negates this effort. Table 3 indicates the relationship between moisture content and tree age.

Also illustrated in Table 3 is a prediction of the pounds of oven-dry wood that can be obtained per ton of green wood from trees of varying ages. The differences are due to the lower specific gravity, relatively high bark content, and the higher moisture content associated with trees of young ages. According to McKee (1984) the most significant impact of high proportion of juvenile wood in a mill supply is on the delivered cost per unit dry weight of wood fiber. Zobel (1978) reported the cost of harvesting tops and thinnings from 15-year-old trees to be \$10 per cord more than from 25-year-old trees. Also, Kirk, Breeman and Zobel (1972) indicated that a ton of pulp from a 12-year-old plantation to be 84 percent higher in cost than pulp produced from 30-year-old trees. They attributed the higher costs primarily to harvesting.

Although chip configuration and method of loading can effect batch digester loading by as much as 10 percent (McKee, 1984), the loading of a high proportion of juvenile wood chips also results in a lower pulp yield per digester cook due to less fiber per unit volume. In addition, because juvenile wood has a lower cellulose content than mature wood, pulp yields at all Kappa numbers are lower. Ten year-old wood cooked to a Kappa number 50 had a pulp yield of 45.2 percent compared to 49.2 percent for 25-year-old wood (Howell, 1984). Table 3 indicates pulp yields from wood of varying ages. Thus, juvenile wood pulp yields are reduced not only due to less wood per unit volume but also because of a lower cellulose content. Howell (1984) estimated that 5.4 tons of rough green wood from 15-year-old trees is required to produce 1 ton of oven-dried pulp, whereas only 4.4 tons of 25-year-old wood is required (Table 3).

Table 3. SOME AGE-ASSOCIATED CHARACTERISTICS OF SOUTHERN YELLOW PINES

	Tree Age (years)		
	15	25	40
Per Cent Juvenile Wood ^a	85	55	19
Pounds of Dry Fiber per Cord ^b	3,590	3,805	4,122
Bark to Wood Weight Ratio ^c	.1742	.1345	.1181
% Moisture Content (Dry Basis) ^c	113	92	75
Dry Weight of Wood per Ton Green Wood (lbs.) ^c	776	896	999
% Pulp Yield (Kappa No. 50) ^c	48	49.2	49.8
Tons Green Wood/Ton OD Pulp (Kappa No. 50) ^c	5.4	4.4	3.9

^a From Zobel et al (1976)

^b Based on Juvenile Wood S.G. of .413 and Mature Wood .54

^c Howell et al (1984)

The literature also indicates that juvenile wood requires slightly more pulping chemicals to cook to a given Kappa number than is required for mature wood (Kirk et al., 1972; Hitchings, 1984).

With regard to byproduct yield of tall oil and turpentine from juvenile wood, the literature is neither plentiful nor clear. McKee (1984), Foran (1984) and Zobel et al. (1976) indicate lower yields of both tall oil and turpentine from juvenile wood than from mature wood. However, Howell (1984) noted that turpentine yield was constant with age on an oven-dry basis, but that turpentine yield decreased per ton of dry pulp with increasing tree age because less wood was required to produce a ton of pulp. He also observed that younger wood produced significantly more tall oil than older wood, probably as a result of the greater relative amount of knots associated with young wood.

Concerning mechanical pulping, Carpenter (1984) states that low density wood containing relatively large amount of juvenile wood springwood is preferred to denser wood with a relatively high summerwood content. However, problems are still encountered in the manufacture of lightweight coated grades of paper from thermomechanical pulping of juvenile wood because of poor interfiber bonding. Ten to twenty percent chemical pulp is needed in the mixture to meet the standard.

Paper Properties

A wealth of information regarding the effects of juvenile wood on paper properties exists (Barefoot et al., 1970; Cole et al., 1966; Cown and Kibblewhite, 1980; Hitchings, 1984; Kibblewhite, 1980; Kirk et al., 1972; Lobosky and Ifju, 1981; Semke, 1984; Semke and Corbi, 1974; Uprichard, 1980). The published data clearly indicate that paper derived from pulp produced from juvenile wood has higher burst, tensile strength, fold endurance, and sheet density; also noted is improved uniformity of sheet formation and printing characteristics. Tear strength, on the other hand, declines as the juvenile wood content of the mill furnish increases. Changes in paper properties influenced by tree age are shown in Table 4. Note that the strength parameter most influenced by tree age is tear.

Table 4. VARIATION IN KRAFT PAPER PROPERTIES ASSOCIATED WITH AGE OF RADIATA PINE^a

Pulp Property	Rings From Pith			
	1-5	6-10	16-25	26-35
Tear index	9	14	19	28
Tensile index	102	92	88	82
Stretch (%)	4.0	3.5	3.3	2.9
Burst index	92	88	77	73
Tensile energy (J/kg)	2630	1950	1790	1480
Sheet density (kg/m ³)	727	656	624	602

^a From Uprichard (1980)

Pulp from juvenile wood forms sheets of high density since the thin-walled fibers are more flexible and therefore are more easily collapsed and consolidated than older wood fibers. The decrease in burst and tensile strengths with increasing age of the wood is largely related to the decrease in sheet density, which in turn is related to the higher density of the older wood. It should also be noted that the strength characteristics associated with fiber to fiber bonding (burst, tensile and stretch) increase in pulps made from juvenile wood, since the more readily collapsible fibers provide a greater bonding area. Thicker walled fibers, characteristic of higher density wood, do not readily collapse and thus sheets of lower bonding area and lower density are formed. As a general rule, increased beating will result in increased sheet density and the associated strength properties. However, juvenile wood pulps are much more easily beaten to higher sheet density than mature wood pulps. This is obviously an advantage since beating requires energy. Also, the less beating required to obtain satisfactory burst and tensile strength, the smaller the decrease in the already low tear factor.

Kibblewhite (1980) showed that for radiata pine, chip or wood-density was the wood property most closely related to pulp and handsheet properties. About 80 percent of the variation in handsheet tear, burst, tensile and density properties were accounted for by chip density variation. Kibblewhite (1980) also showed a good relationship between chip density and fiber coarseness and suggested this more easily determined property as a potential for quality control procedures. Adding fiber length increased the variation accountability by another 5 to 10 percent.

Tear strength is the paper property most influenced by wood age and therefore may, depending upon end-product use, be the parameter of most concern as larger proportions of juvenile wood are used in pulp and paper manufacturing. Tear strength is directly proportional to wood density regardless of the source of the wood. Thus, the relationship between tear and wood age is the result of increasing density with increasing wood age. The blending of pulps is based on the assumption that pulp properties are additive. Uprichard (1980) showed that the tear index is an additive property. If paper tear strengths equivalent to that produced from a wood supply of natural pine, containing a small amount of juvenile wood, are required for a particular product, then mature wood with its associated higher density must be used or the blending of pulps with the requisite properties must be performed.

Tear strength is also dependent upon fiber length. For most pulp and paper products of the southern pines, however, tear strength is not a limiting factor. Of greater importance is wetweb strength. In unaltered form, tracheids of southern pines, even of juvenile wood, are sufficiently long to provide the needed wetweb strength, averaging 3.23 and 4.28 mm for juvenile and mature wood, respectively (McKee, 1984). During the chipping and pulping process, however, the cells are reduced in length to 1.62 mm for 10-year-old trees (juvenile wood) and to 2.80 mm for sawmill chips (mature wood) (Table 2). The pulp fibers of the juvenile wood are short enough to adversely affect wetweb strength and consequently sheet breakage leading to machine downtime. Similar incidents occur infrequently when using topwood, conventional roundwood, and sawmill chips.

ACTIONS TO CONTROL IMPACT OF THE CHANGING RAW MATERIAL RESOURCE ON PULP AND PAPER MANUFACTURING

Possible actions to deal with the increasing amounts of juvenile wood contained in the raw material supply fall into two categories - long and short range. Long-range activities include the development of forest management procedures with the ultimate goal of producing a raw material with less variable and perhaps even specific characteristics. Research and development programs designed to develop manufacturing processes capable of coping with raw material variability would also be long range. Short-range actions are designed to address utilization of the present raw material with current technology and minimize the impact of the raw material on both the manufacturing operations and finished product performance.

Forest Management

The land base supporting a pulp mill can have a tremendous effect on the raw wood material. Organizations with land spanning two or more physiographic

provinces will often encounter two or more pine species, each of which will have unique wood properties. Even with a province, such as the Lower Coastal Plain of South Carolina, Georgia, and Florida, mixed stands of loblolly, slash and longleaf pine occur. The extracted wood specific gravity of juvenile and mature wood of the respective species in mixed stands in South Georgia averaged 0.413, 0.439 and 0.413, and 0.540, 0.526 and 0.540 (Cole et al., 1966). Even greater differences than those among species can occur with a species from one province to another. For example, the average specific gravity of loblolly pine in the Coastal Plain is about 0.04 higher than that in the Piedmont. Such differences amount to about 77 kg/m³ of dry fiber. These differences are prima facie evidence that manufacturing efficiency could be realized by an organization owning land in a common province. Planting the entire land base to a single species, however, presents more of a problem because of the need to match species to site.

The variation in juvenile wood from one tree to another of the southern pines is sufficiently great that a breeding program, in which the wood specific gravity of juvenile wood could be made comparable to mature wood of the same tree, is feasible (Matziris and Zobel, 1973). Because of the large variation among trees for either high or low wood specific gravity, the opportunity exists to breed for either low juvenile-mature or high juvenile-mature wood.

The value of breeding for a broad-based wood property like specific gravity is that the trait is positively correlated with percent summerwood and cell wall thickness. If high yield chemical pulps are desired and if tear resistance is an important sheet property, then wood of high specific gravity would be favored. Conversely, wood of low specific gravity would be desired for paper and paperboard products requiring high burst, tensile strength, fold endurance, sheet density and opacity.

An added opportunity exists to plant the trees of a specific wood type to stands which can be separately harvested. Tree improvement programs in which the seeds from selected clones are collected are already making this option available, the onset of tissue culture of forest trees is intensifying the option.

Planting seedlings at high densities so as to restrict juvenile wood to a small core, and managing the stands to rotations of 35 to 40 years to reduce the relative proportion of juvenile wood are other advocated options (Martin, 1984). However, neither of these options is presently acceptable to the pulp and paper industry. Planting seedlings at high densities to restrict diameter growth is counter to the application of good silviculture practices, including tree improvement programs, in which the objective is to optimize volume growth per unit area per unit time. The same reasoning applies to rotation length. Financial maturity of southern pine stands managed for fiber production is from 20 to 25 years. Longer rotations can be justified by the forest industry only if sawtimber production is an objective. The forest industry of today is concentrating on fiber production to the almost total exclusion of sawtimber rotations.

Manufacturing

The changing raw material, with its higher juvenile wood content, results in increased manufacturing costs, lower digester packing, lower cellulose content, higher chemical consumption and lower byproduct yields. Also, pulping

mature and juvenile wood together results in either overcooked juvenile wood or undercooked mature wood (Barefoot, Hitchings and Ellwood, 1965). Strength losses and lower pulp yields are associated with overcooked wood. A reduction in the percentage of juvenile wood in the digester would reduce the impact of these costs.

With regard to product performance, most sheet properties are improved as the juvenile wood content increases. The one detriment is the reduction in tear strength.

Solutions to increased manufacturing costs are not readily apparent, as most of the difficulties are associated with inherent juvenile wood properties. However, a possible solution to the overcooking of juvenile wood is the processing of juvenile wood alone or in a mixture with a low percentage of mature wood. Uprichard (1980) showed that the tear index of beaten pulps is additive; thus, the blending of pulps from mature and juvenile wood or the blending of wood prior to pulping to obtain a specified tear index is possible. However, the prerequisite for blending either wood or pulp is wood separation. A thinning operation of a 15-year-old plantation would obviously produce wood containing a high proportion of juvenile wood. This wood could be pulped separately for the manufacture of printing and writing papers, or it could be held in storage for subsequent blending with other pulps for special paper and paperboard grades. Blending of chips from a Chip-n-Saw operation, or of veneer log round-up material, or slabs from a conventional sawmill with the plantation thinnings would increase the average specific gravity and subsequently increase the tear index of paper produced from the blended wood pulp. Alternatively, chips from mature wood with its associated higher density can be processed alone when products specifying even higher tear are required.

Space limitations may make separation of conventional roundwood in the woodyard difficult, but separation on arrival, based on source, would suffice. An immediate negative reaction is encountered when wood sorting is suggested. Sorting does result in an added cost, but the question is whether the benefit derived is greater than the expense. The fact that sorting is already commonly done in the woods should partly counter negative reactions. The greatest amount of sorting occurs on the log deck, where the first separation is between hardwoods and softwoods. The second separation is between sawlog and pulpwood within the hardwood and softwood groups. Since much of the timber harvested in the South is tree length, a common practice is to divert trees of sawlog quality to the merchandiser, where the sawlogs and Chip-n-Saw bolts are cut to length for further processing; the remaining timber is chipped for delivery to the pulpmill. Presently, the chips from top bolts are mixed with the outerwood chips from the sawmill and Chip-n-Saw. These fractions could be kept separate.

The potential for segregating chip flows differing significantly in specific gravity has been illustrated by Veal, Marrs, and Jackson (1984). Working with loblolly pine, they described two examples of wood segregation. In the first example, 1,000 green tons of tree-length stems were cut into 2.4 m bolts. The lowest two bolts were chipped separately from the remainder of the stem. This material averaged 0.46 specific gravity, and the tops 0.39. Their second example was concerned with sorting sawmill residual chips. Outer wood chips from Chip-n-Saw had a specific gravity of 0.46, and veneer log round-up residuals, 0.45. A third source, a mixture of core and outer wood consisting of top and butt ends trimmed from the stems and defective stem segments, had a

specific gravity of 0.43. This flow had a highly variable specific gravity in that it was comprised of a mixture of stem parts.

Veal and coworkers (1984) also illustrated a segregation by stands. Although a correlation exists between age and specific gravity, there is a significant variation between stand means at the same age. They cited an example of segregation where age alone gave a difference in specific gravity of 5.0 percent. Actually measuring the stands for specific gravity, and allocating the higher stand specific gravity material to one stream and the lower to another, the difference in specific gravity was 6.7 percent.

The three-pile chip inventory advocated by Veal and coworkers (1984) consists of a low specific gravity pile composed of stands of low specific gravity, thinnings, tops, and peeler cores (0.40 or less); an intermediate and variable specific gravity pile comprised of stands of intermediate specific gravity, segregated tops, and sawmill cull residues (more than 0.40, but less than 0.45); and a high specific gravity pile consisting of sawmill residual chips and segregated butt log wood (greater than 0.45).

Another advantage of a wood separation system would be the elimination of the difficulties imposed on the manufacturing processes when sudden and large changes in the raw material supply occur. Wood sorting would also permit the production of pulps with specified characteristics, and the subsequent blendings of these pulps to produce paper with the required properties. For example, linerboard is often produced on a dual headbox fourdrinier paper machine. The top liner, which comprises about 20 percent of the board, is usually cooked to a lower Kappa number than the base stock, because the burst strength of the duplex sheet is largely controlled by the top liner. Also, three wire machines are used to make linerboard. A machine of this design opens up numerous possibilities of manufacturing three-ply paper with the center and outer plies made from pulps with different properties designed to give particular performance properties to the final product.

Also, it has been shown that press drying of high yield chemical pulps with their associated high lignin content results in paper with higher sheet density, higher burst and tensile strength, and a tear strength essentially equal to the lower yield chemical pulps (Setterholm, Benson, Wichmann and Auchter, 1975). This suggests that juvenile wood can be cooked to a higher Kappa number, thus increasing yield, and obtaining paper with suitable strength properties.

HARDWOODS

Although the above discussion refers to softwoods, primarily southern pine, the increasing consumption of hardwood pulpwood in the South warrants comment. According to Ince (1986), during the past 30 years the ratio of hardwood in all pulpwood consumption doubled in the United States as a whole. During the same period, all pulpwood consumption more than tripled and almost quadrupled in the South. With the increasing hardwood acreage, low hardwood stumpage prices, and technological changes, hardwood pulpwood consumption will continue to increase. The technological changes that have precipitated the increasing use of hardwoods are press drying, improvements in refining, and wet-press design changes that achieve longer residence time of the sheet and higher pressures, resulting in increased sheet density (Ince, 1986).

Research at the U.S. Forest Products Laboratory, Madison, Wisconsin, confirmed that southern red oak kraft pulp can produce sheets with the same burst, tensile, and compression strengths as a sheet made from pine kraft pulp. Also, the Forest Products Laboratory showed that by separate refining of hardwood and softwood fibers, it is possible to use more than 50 percent hardwood fiber in conventional linerboard and achieve a satisfactory compressive strength.

Presently, 9 percent of the fiber in softwood-based pulps are hardwood fibers. Ince (1986) suggests that because of technological changes alone, by the year 2000 the hardwood fiber component of softwood-based pulps in the South may reach 50 percent or more. Given this increase, the hardwood component is projected to be 50 percent of total pulpwood consumption, or 47.5 million cords. These shifts toward hardwood, should they occur, will likely have an effect on products, as well as stumpage costs and forest management.

CONCLUSIONS

The fact that juvenile wood has generally an undesirable effect on pulpmill economics is obvious, particularly on byproduct yields, harvesting, and pulping costs. It is also obvious that there is essentially no prospect, at least in the short term, of reducing the juvenile wood content of the wood being delivered to many mills. One method of coping with the fluctuations in the juvenile content of the raw material is wood segregation. This segregation can very often take place prior to reception at the mill woodyard. Wood separation will permit the achievement of the benefits associated with cooking low-density and high-density wood separately. Depending upon the end product, the pulps can be directly formed into paper or blended to produce paper with specified end-product performance. The blending of wood prior to cooking can eliminate the processing difficulties associated with sudden and significant changes in the amount of juvenile wood in the raw material furnish.

Many factors, some of which may not be applicable to all mills, must be considered prior to making the decision to separate the incoming wood. Some factors to be evaluated are raw material species and source (plantation or natural stands, mill residue from Chip-n-Saws, sawmill and veneer mill operations, thinnings, tree tops, age of stands, difference in stand mean density, and end-product specifications). New technology must also be considered. Developments in refining and press drying may be directly applicable to solving some of the problems associated with utilizing the changing raw material resource.

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FOREST MANAGEMENT AND WOOD QUALITY

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ABSTRACT

Plantations currently comprise one-third of the pine forest area in the South and are projected to exceed natural stand acreage by the year 2000. Also, by the year 2000, it is projected that 50 percent of the softwood harvested in the South will be from plantations. Since fast-grown plantation pine contains a high percentage of juvenile wood, a decline in the quality of softwood timber and associated processing and in-use problems will become increasingly troublesome. This anticipated change in the characteristics of the southern pine resource has caused forest managers to re-examine those cultural practices and management options that consider not only volume growth but also the quality of wood produced.

INTRODUCTION

The South has about 22 million acres of pine plantations and USDA Forest Service (1988) projections indicate that the total will increase to 35 million acres by the year 2000. In a fraction of a rotation, or 10 years, southern pine plantations will be the dominant source of softwood timber in the region. Because of controlled growing conditions, plantation trees grow faster than those in natural stands and therefore reach harvest size at an earlier age. However, the resulting growth has a characteristically high proportion of juvenile wood--a wood generally not suitable for acceptable grades of construction lumber or plywood because of decreased strength and poor dimensional stability. High proportions of juvenile wood also reduces the value of wood from pulp.

The changing pine resource and its potential impact on softwood-based industries mandates that timber management activities not only be assessed relative to growth rate but must also include a component of wood quality. An integrated stand management/wood quality approach is needed to develop specific quantitative information on the effects of different management regimes--some of which may have interacting treatments such as planting density, thinning and fertilization on wood quality.

Some data suggests that actions in the realm of silviculture can influence the proportion of juvenile wood in tree stems but much more information is needed. The selection of planting stock, planting density, control of stocking, combinations of management treatments, and harvest schedule offer potential solutions.

SILVICULTURAL EFFECTS

Before addressing potential solutions, we must recognize certain difficulties in defining the term "juvenile wood." While its characteristics differ from that of mature wood, the change from the production of juvenile wood to production of mature wood in individual trees is gradual and barely perceptible from one year to the next. Figure 1 provides a generalized illustration of how wood properties change with age from pith at any position in the stem. Wood formed near the pith is weak, has low wood property values and is commonly referred to as crown-formed wood. As the tree matures and the crown recedes, wood properties undergo rapid change and then essentially stabilize. Wood formed during the period of rapid change is referred to as transition wood and wood with stabilized properties is mature wood. Crown-formed and transition wood together are referred to as juvenile wood. In assessing factors associated with juvenile wood formation, we have found that specific gravity is a convenient measure that strongly reflects the pattern of maturation from juvenile to mature wood.

Selection of Planting Stock

Several studies in the literature indicate that the period of juvenile wood formation in slash and loblolly pine differ--loblolly 9 to 12 years, slash 6 to 8 years, (Zobel and others 1959, Taras 1965, Larson, 1969, Pearson and Gilmore 1980). In a recent study, Clark and Saucier (1989) found that when these species are grown in the same or neighboring plantations, they display the same juvenility period or developmental pattern when measured by specific gravity changes.

Figure 2 shows specific gravity trends for the two species at four different locations ranging from the Piedmont of South Carolina to the Gulf Coastal Plain of Florida. At each location, the pattern of juvenility is similar for both species. In the Piedmont of South Carolina, both species produced juvenile wood for the first 14 rings from pith; 10 years in the Coastal Plain of Georgia and South Carolina; and 6 years in the Gulf Coastal Plain of Florida. These data show that the period of juvenility of slash and loblolly pine is less influenced by inherent species differences than by environmental differences associated with geographic location. There are indications, however, that it is possible to reduce juvenile wood production through genetic selection (Loo and others 1985). Zobel and others (1978) state that specific gravity through age 10 can be increased by 10 percent in a single generation by selection for high specific gravity.

The strong influence of geographic location on length of juvenility and specific gravity in loblolly and slash pine is shown in Figure 3. The plots of loblolly specific gravity over rings from pith show two groups of curves--one for the Piedmont locations and one for the Coastal Plain locations. As a group, loblolly pine sampled in the Coastal Plain produced juvenile wood for the first 6 to 10 rings while loblolly in the Piedmont produced juvenile wood for about 10 to 14 rings.

The length of juvenility of slash pine also varied with geographic location. In these data, the distinction between locations is clearer. In Florida, slash pine produced juvenile wood for 6 years, for 10 to 12 years in the Coastal Plain of South Carolina and Georgia, and for 14 years in the Piedmont of South Carolina.

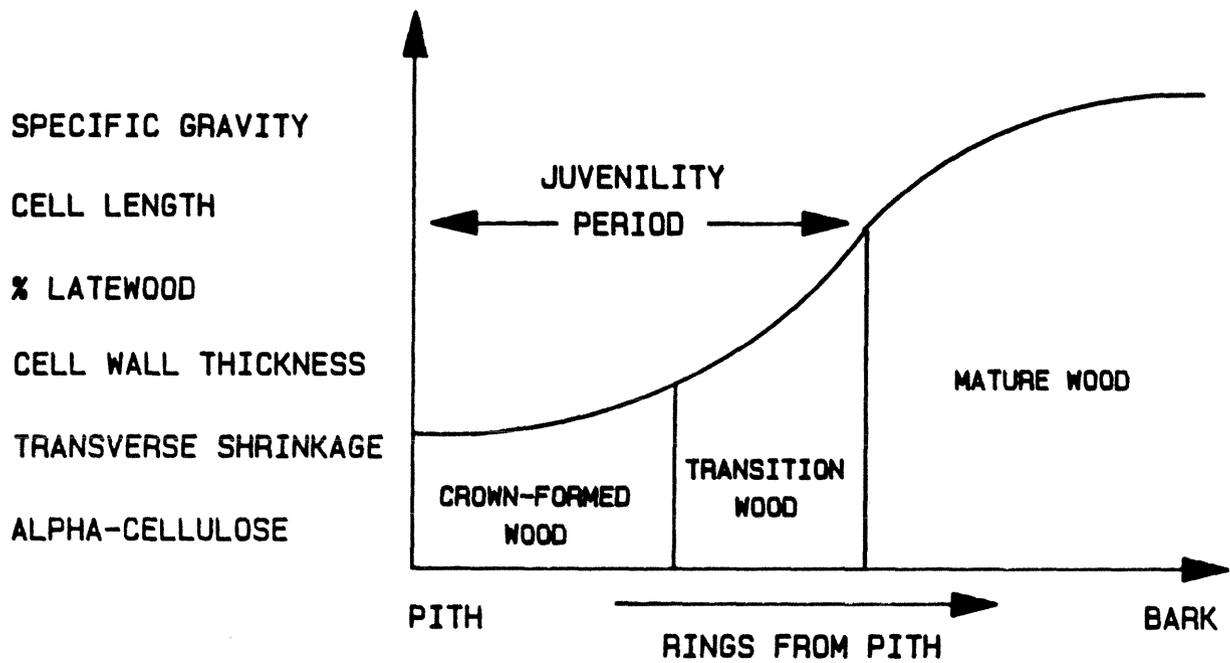


Figure 1.--Schematic diagram of radial change in wood properties with age from pith and the pattern of maturation.

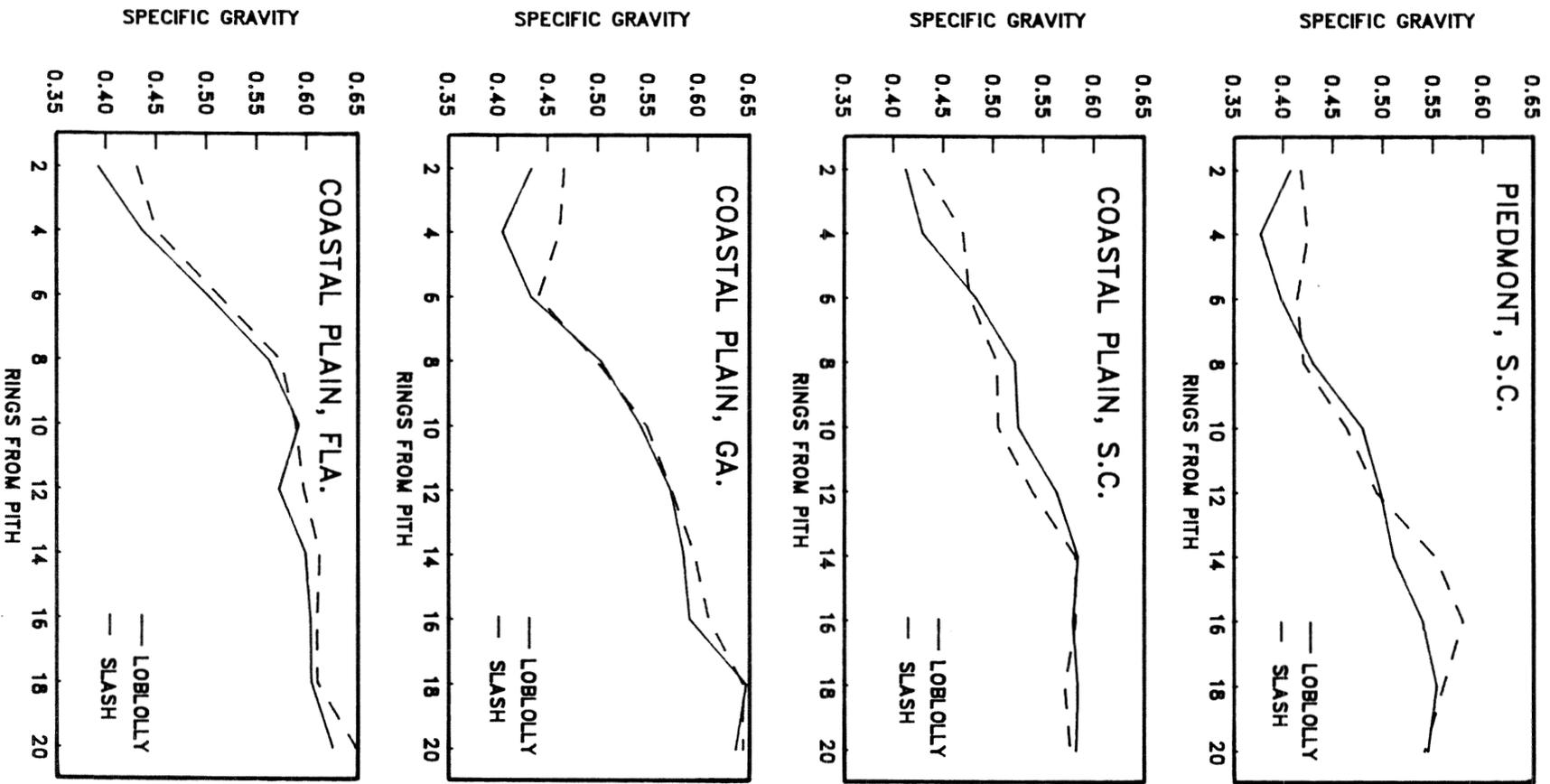


Figure 2.--Comparison of juvenile wood patterns of slash and loblolly pine when grown together at four different geographic locations.

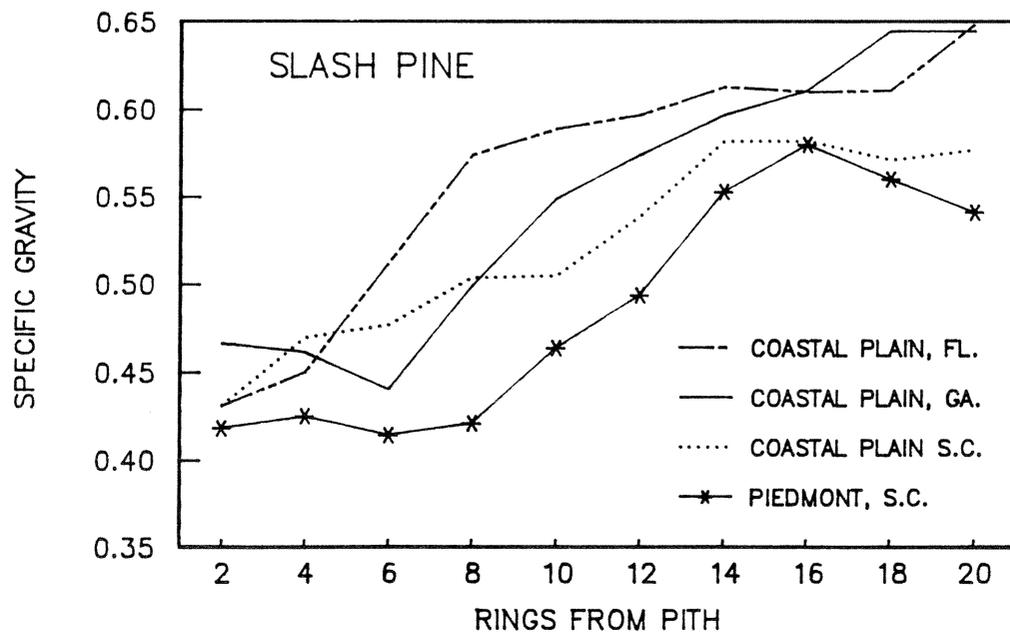
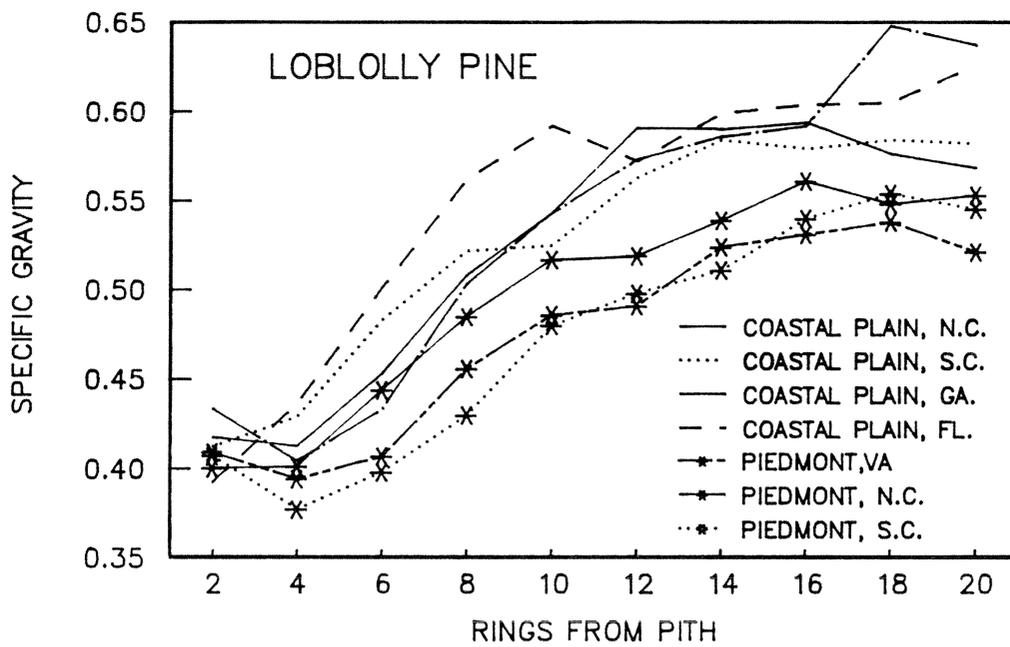


Figure 3.--Comparison of juvenile wood patterns at different locations of loblolly and slash pine.

Planting Density

The size of the juvenile core in plantation trees is related to the rate of growth which, in turn, is influenced by initial planting density. We were interested in looking at planting density as it might influence the period of transition from juvenile to mature wood as well as the proportional volume of each wood type. A 30-year-old loblolly pine spacing study in the South Carolina Piedmont was sampled. Plots had initial planting densities of 6 by 6, 8 by 8, 10 by 10, and 12 by 12 feet and were unthinned. Results presented in figure 4 show that the period of juvenility or the pattern of wood maturation is unaffected by initial planting density even though there were large differences in the rate of growth amount spacings as shown in table 1.

Table 1.--The influence of spacing on growth rate and the proportional basal area in juvenile wood of 30-year-old loblolly pine

<u>Spacing</u>	<u>Average d.b.h.</u>	<u>Diameter of juvenile core</u>	<u>Proportion of BA in juvenile wood</u>
<u>Feet</u>	<u>Inches</u>	<u>Inches</u>	<u>Percent</u>
6 x 6	8.0	5.2	42
8 x 8	9.0	6.0	44
10 x 10	9.7	6.6	46
12 x 12	11.2	7.7	47

Planting at close spacing such as 6 by 6 feet did restrict the size of the juvenile core but in the absence of thinning the proportional area in juvenile wood is only slightly less than that planted at wider spacing and growth of individual trees was significantly reduced.

In another study with loblolly pine, thinning was done beginning at age 17 and at subsequent 5-year intervals that maintained the thinning treatment of unthinned control and basal areas of 100 and 60 square feet. Figure 5 shows the radial growth profile of earlywood and latewood for the 6 by 6 feet spacing and for the three thinning levels. It is obvious that growth responses were roughly proportional to the degree of thinning, but the significance is that thinnings beginning at or near mid-rotation stimulated both earlywood and latewood growth. This resulted in wood of relatively uniform properties which is important from a wood quality standpoint. The dips in 78 and 80 are the result of severe droughts in those years and not treatment effects.

Control of Rotation Length

Increasing the length of rotation is probably the most effective action that can be taken to increase the proportion of mature wood in stems at final harvest. Table 2 shows that slash pine growing in the upper Coastal Plain on a 22-year rotation has approximately 40 percent of its basal area in juvenile wood. On a 32-year rotation, the proportion is reduced to about 25 percent.

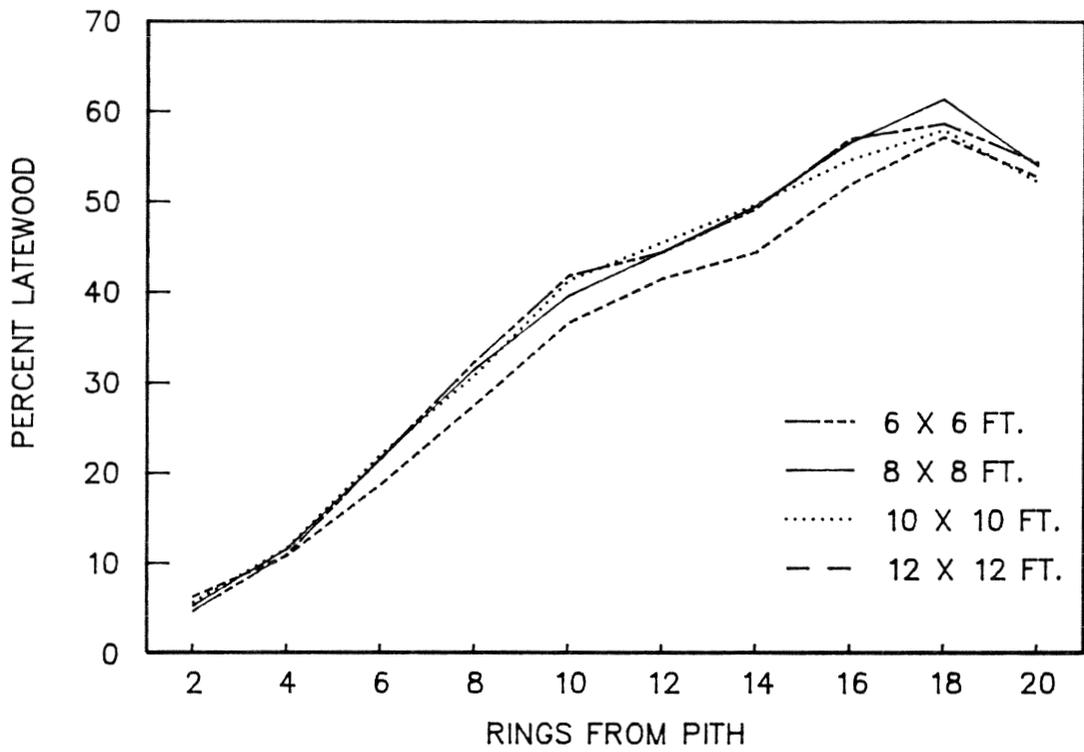


Figure 4.--Comparison of juvenile wood patterns at four different planting densities.

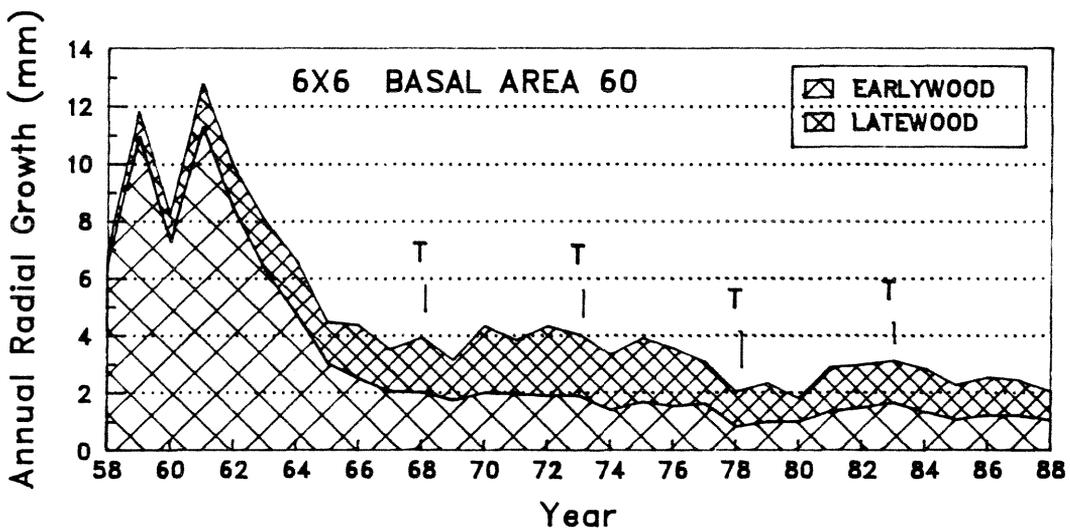
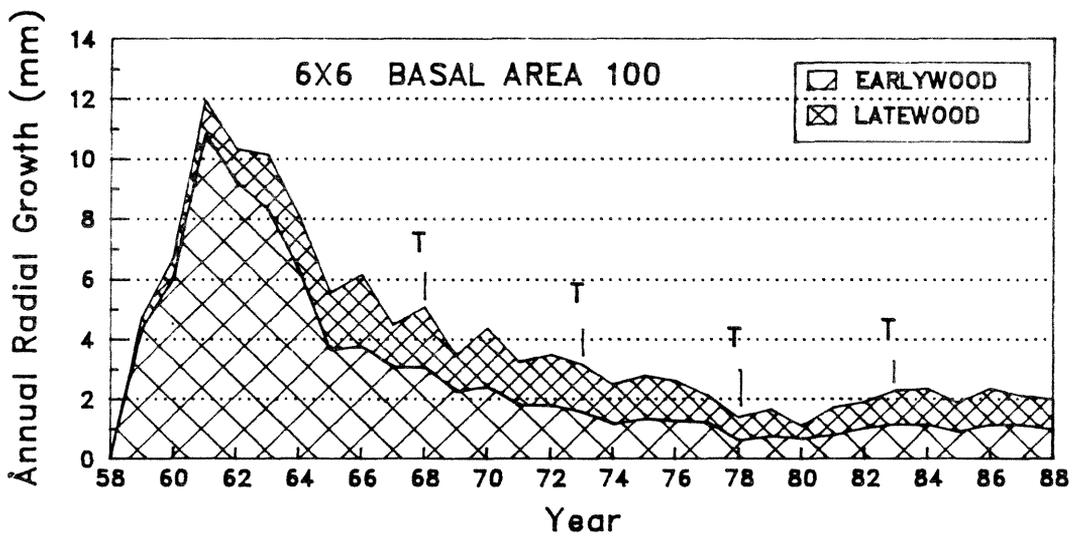
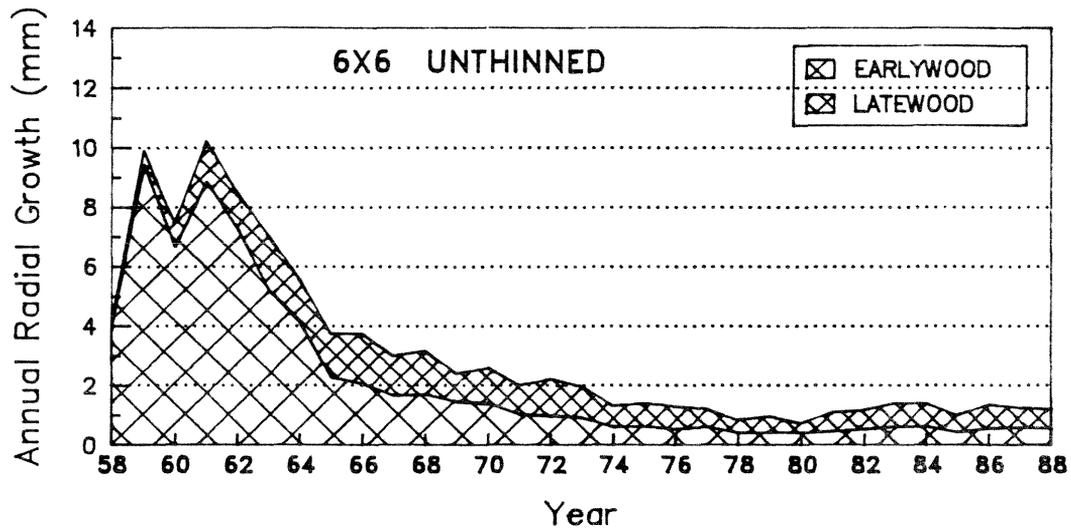


Figure 5.--Growth response of earlywood and latewood of loblolly pine to intermediate thinnings and maintained basal areas of 100 and 60 square feet per acre.

Table 2.--The influence of spacing and rotation age on the proportion of basal area in juvenile wood of slash pine

Spacing	Average d.b.h.	Diameter of juvenile core	Proportion of BA in juvenile wood
<u>Feet</u>	<u>Inches</u>	<u>Inches</u>	<u>Percent</u>
Rotation Age 22			
6 x 6	6.2	4.0	42
8 x 8	7.2	4.6	41
10 x 10	8.7	5.5	40
15 x 15	10.4	6.3	37
Rotation Age 32			
6 x 6	7.3	4.0	30
8 x 8	8.9	4.6	27
10 x 10	10.7	5.5	26
15 x 15	12.9	6.3	24

Determination of an appropriate length of rotation is complex and includes many biological and economic variables. The quality of the wood that is produced is only one of these variables, but too often it is not included in the assessment. As plantations become increasingly important sources of wood for manufacture, forest managers will have to give greater consideration to the quality of wood produced from plantations.

SUMMARY AND CONCLUSIONS

1. Slash and loblolly pine, when grown in the same location, have the same period of juvenility or developmental pattern.
2. Large differences in the length of the transition period from juvenile to mature wood is geographically related. There is a north-south trend of decreasing juvenile period for both loblolly and slash pine that is related to differences in seasonal precipitation.
3. Spacing in the absence of thinning does not influence or change the pattern of wood maturation but does influence the proportional volume of juvenile wood in stems.
4. Thinning done at mid-rotation and beyond stimulates both earlywood and latewood growth, and with proper timing, can be used for maintenance of uniform wood properties.
5. Rotation length is probably the most effective tool available to forest managers for effecting the proportion of mature wood in stems at harvest.

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ECONOMIC IMPACTS OF SOUTHERN PINE WOOD QUALITY CHANGES

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INTRODUCTION

One-third of the South's pine timberlands currently consist of plantations, and the shift from natural pine stands to either plantations or mixed pine-hardwood stands continues. Currently, pine plantations contribute only about 15 percent of the total pine fiber supplies used in the South. By the year 2000, however, they are projected to comprise 50 percent of the total pine harvest volumes (U.S.D.A. Forest Service 1988). This change has many implications for timber utilization and timber requirements, product manufacturing and grading, and consumer demands for forest products. These impacts will affect the profitability of timber forest products firms and influence the desirability of intensive forest management practices.

This paper evaluates the economic impacts of this changing resource base on the forest industry. It outlines a production economics framework for making an evaluation of the costs of the changing pine resource. Then it makes use of the framework to some preliminary cost assessments of the changes for the industry as a whole and for hypothetical individual firms. Based on these economic evaluations, general implications for the forest industry are discussed.

PLANTATION JUVENILE WOOD QUALITY

Timber grown in plantations tends to have greater amounts of juvenile wood than does that grown in natural stands. Juvenile wood consists of the annual growth rings nearest the pith of a tree, extending from the base to the top of the bole. Juvenile wood of southern pine is usually contained in the first 10 rings from the pith, but may range from 5 to 20 rings. In plantations, trees usually grow faster in the early years than they do in natural stands, which is one reason that plantations are becoming more common. Thus, trees from plantation wood will generally have a greater percentage of juvenile wood than trees from natural stands of the same diameter.

The principal forestry concern with juvenile wood is that it often has inferior structural properties and lesser product yields compared to mature wood (Kellison and Zobel 1978). Juvenile wood is characterized by low specific gravity, high moisture content, short, thin-walled tracheids, higher hemicellulose content, and increased amounts of compression wood compared to the characteristics of mature wood (Bendtsen 1978).

Lower yields, opacity, and tear are obtained from pulping and paper manufacturing with juvenile wood compared to mature wood. Because of lower specific gravity of juvenile wood, less dry matter content can be included in the digester than could be contained with mature wood, decreasing yields. Additionally, pulp yields from equal weights of the two types of wood cooked under identical conditions are less for juvenile wood than for mature wood. Widely varying mixes of mature and juvenile wood at different times may also decrease digester efficiency. Pulp by-product yields are also less with juvenile wood. Ground wood newsprint pulping is, however, much better with juvenile wood than mature wood.

Plantation-grown trees also make inferior lumber because of their greater amounts of juvenile wood. They have a lower lumber recovery than larger older-growth natural trees, as well as lower strength. Lumber yields decrease because of smaller diameters, more defects from edges and trim, more damage in the kiln and the planer mill, and more lumber degrade (Senft et al. 1985). Juvenile wood is highly porous, so can withstand high drying temperatures under pressure. However, such drying is expensive. Juvenile wood may also be acceptable for oriented strand board.

PRODUCTION ECONOMICS

Production economics is a form of microeconomics that involves determining the optimal mix of physical inputs into a production process in order to maximize the net return from producing one or more products. It involves determining the physical input-output relationships (production functions), the costs for the inputs and the price for the outputs, and the best use of inputs to maximize profit, minimize costs, or meet some other economic criterion.

In the case of juvenile wood, our concern with economics then relates to the use of such wood for production of traditional forest products. The first step required in the analysis is to determine the production function for juvenile wood, particularly compared with the production function for mature wood. What are the comparative product yields for lumber pulp, or other products for juvenile and mature wood? There are no doubt gradations of "juvenile" and "mature" wood, but for this analysis, let's just use the two distinct categories. To make things even simpler, this analysis will generally just make assumptions about possible yield decreases that might be expected from use of juvenile wood.

The second step in the analysis will be to estimate the price effects of these yield reductions. At least three price effects seem relevant. First, and most obvious, reduced product yields will translate into a cost for firms equal to the amount of yield reduction that occurs times the price of each product. This will include direct losses from decreased yields and secondary losses in lumber due to warpage, product degrade, and similar problems. Second, use of juvenile wood for lumber is apt to also translate into losses in market share,

particularly if grading standards are loose enough that inferior juvenile wood lumber may be marketed in place of mature wood lumber. Lumber that either actually is or is perceived to be of inferior quality will lose market share, and may even cause further price reductions for the product. This may also occur to a lesser extent with other wood products.

In contrast to these costs of using juvenile wood, one must consider its obvious price advantage. The reason we have so much juvenile wood is because there is a significant, economic advantage in short rotations. The southern forest industry has already implicitly decided that it is better to grow large volumes of wood swiftly, no matter what the quality, than to worry about juvenile wood problems. Hopefully, this advantage is real. If not, it may cost the South a large amount of market share in solid wood products mostly for the benefit of pulp and paper production.

Most industrial forest management practices are geared to increasing wood volume produced per year. The large amount of old growth natural pine grown on nonindustrial private forest lands is also rapidly being liquidated, and much of it will be replaced with planted pine. These factors will increase the amount of juvenile wood produced. These trends are caused by economic factors. The capital cost of growing trees for a long time so that they are composed of mostly mature wood are immense. Give the intense competition facing the industry, firms cannot afford to over-invest in growing stock. Non-industrial owners are also becoming more astute managers of capital. Thus it will be left to wood and paper technologists to develop new ways to use existing wood. Otherwise, we will be inundated with mature lumber from Canada or elsewhere, even if tariffs are imposed. This paper does not consider the benefits of short rotations; rather it focuses on possible costs from use of juvenile wood.

POSSIBLE AGGREGATE INDUSTRY EFFECTS

Accurately quantifying the difference in yields when using juvenile rather than mature wood is difficult. Since the precise effects of juvenile wood on pulp yield and lumber yields depend on many factors, we will just examine several scenarios to determine the potential impacts. Essentially each of these requires determining the amount of yield decrease involved with using juvenile wood, the price of the product involved, and the total volume of the product made. To avoid antitrust concerns, this paper uses historical production and price data to illustrate possible juvenile wood impacts.

Pulp and Paper

For pulp and paper production, let's assume a uniform pulp product is being produced from southern pine pulpwood. In 1984, pulp mills in the South used about 42,000,000 cords of pine pulpwood or chips

(American Pulpwood Association 1986). Even if this mix were currently one-half juvenile wood and one-half mature wood, increasing the amount of juvenile wood in the future would have significant cost impacts. First, since it takes more timber volume to make the same amount of net fiber volume, then the pulpwood furnish would have to increase, which would increase procurement purchase, harvest, storage, and handling costs. Second, since the actual pulp yield from equivalent volumes of fiber may decrease, this would also represent a cost. Third, the greater wood volume required with low specific gravity juvenile wood to equal the same amount of wood fiber content of higher specific gravity mature wood also effectively reduces digester (and plant) capacity.

More juvenile wood will require that more pulpwood be bought to get the same amount of net fiber in the boiler. Using a conservative yield difference, at least 10% more pulpwood will be needed with juvenile wood compared to mature wood. The historical components of this estimated costs are shown in Table 1, assuming that the estimated 50% mature wood furnish will be replaced with varying amounts of juvenile wood. The table could be updated for current costs if desired.

Pulp yield decreases and reduced plant capacity also will be significant. Using 42,000,000 cords of pine pulpwood would yield about 28,000,000 tons of wood pulp. If yield from the digestors were decreased 1 to 2% as more juvenile wood were used, costs would be as follows:

14,000,000 tons of		Replacement with		Pulp
mature wood pulp/yr	x	Juvenile pulp	x	Yield Decrease
				x Price
				(\$320/ton)

This would equal the following yearly amounts, assuming juvenile wood displaced varying amounts of existing mature wood furnish, ranging from 25% to 75%:

1% decrease in pulp yield--	
25%	\$11,200,000
50%	\$22,400,000
75%	\$33,600,000

2% decrease in pulp yield--	
25%	\$22,400,000
50%	\$44,800,000
75%	\$67,200,000

Assumptions cannot be made as easily to estimate the costs of reduced plant capacity because less juvenile wood can be processed in a digester than mature wood. The net effect of this problem is that effective plant capacity per day or year is reduced. For instance, a 1000 ton per day pulp mill using an equal mix of mature and juvenile wood might become a 950 ton per day mill if juvenile wood increased to 75% of the mix. One might think that a mill could just increase digester capacity by 10% or so to make up for the difference, but this is of course not possible. Instead, incremental expansions must take

Table 1. Estimated Annual Costs of Procuring Increased Amounts of Juvenile Pulpwood, 1984

<u>Procurement Phase</u>	<u>Approximate Cost Per Cord</u>	<u>Possible Volumes Required at % Replacement of Mature Wood Furnish</u>	<u>Total Cost of Juvenile Wood</u>
Purchase	\$15	---Cords---	---Thousand---
		525,000 (25%)	\$ 7,875
		1,050,000 (50%)	\$15,750
		1,575,000 (75%)	\$23,625
Harvest & Handling	\$30	525,000 (25%)	\$15,750
		1,050,000 (50%)	\$31,500
		1,575,000 (75%)	\$47,250
Storage, Planning	\$ 5	525,000 (25%)	\$ 2,625
		1,050,000 (50%)	\$ 5,250
		1,575,000 (75%)	\$ 7,875
Total	\$50	525,000 (25%)	\$26,250
		1,050,000 (50%)	\$52,500
		1,575,000 (75%)	\$78,750

into account new boiler capacity as well as chemical recovery capacity, and energy balances, which are available only in large (lumpy) units. Thus, expansion would require substantial redesign and exceedingly large investments. Even a gross approximation of this cost is impossible to measure, but it must at least equal or exceed increased wood procurement and decreased pulp yield costs.

Decreased Lumber Yields

Lumber yields undoubtedly decrease as more juvenile wood is used, but percentage reductions are hard to find in the literature. For purposes of approximation, we will just assume that juvenile wood lumber has yield decreases of 10% to 20% of that from mature wood of a similar size tree. Southwide pine lumber production in 1985 was about 13 billion board feet (Resource Information Systems 1985). If 25% of this production came from juvenile trees, and lumber sold for a price of \$180 per MBF, the following annual cost estimates could be made:

$$13,000,000 \text{ MBF} \times 0.025 \times \$200 \times 0.10 = \$ 65,000,000$$

$$13,000,000 \text{ MBF} \times 0.025 \times \$200 \times 0.20 = \$230,000,000$$

Again the magnitude of these estimates indicates substantial losses for the industry by the use of juvenile wood rather than mature wood. Procurement costs for obtaining additional lumber fiber supplies would also increase somewhat, though probably not as much as pulpwood costs.

POSSIBLE FIRM COSTS

The possible industry-wide cost increases from the shift to plantation wood are substantial. These costs also could be significant for an individual mill.

Pulp Mill

For a 2000 ton per day mill, total wood requirements in 1984 would be about 3000 cords of wood per day. Use of plantation wood with a high juvenile wood content would reduce the effective capacity of the pulp mill and require more wood furnish.

If 10% more plantation than mature wood were needed, then the mill added annual costs would be:

$$\$50/\text{cord} \times 3000 \text{ cord/day} \times 350 \text{ days/year} \times 10\% \text{ more wood} \times 35\% \text{ of mill furnish} = \$1,850,000 \text{ per year.}$$

If the mill pulp yield decreased by 1% for the same volume of wood in the digester, then annual costs would be:

$\$400/\text{ton} \times 2000 \text{ tons/day} \times 350 \text{ days/year} \times 1\% \text{ loss} \times 35\% \text{ of mill furnish} = \$700,000 \text{ per year.}$

There also would be some cost for reduced digester capacity, which would reduce the mill rated capacity. These individual pulp mill costs would then total at least \$2.5 million per year at 1984 prices and utilization levels. Less pulpwood is needed to produce pulp now than in 1984, but market pulp prices also have increased recently. Thus this cost estimate is probably conservative.

Sawmill

Possible losses from increased use of juvenile wood at a typical sawmill also are substantial. A moderate-sized pine sawmill would produce about 40 million board feet of lumber per year. If 10% of its output were lost due to milling and drying problems from changing the furnish from mature to plantation wood, then approximate costs would be:

$4 \text{ million bd. ft.} \times \$200/\text{MBF} \times 35\% \text{ of mill furnish} \times 10\% \text{ loss} = \$280,000 \text{ per year.}$

Due to the increased losses, a mill would also need more timber to produce the same volume of output. If rigorous grading standards were not maintained, a mill also could lose market share due to perceptions of poor quality.

MARKET IMPACTS

Estimating the market impacts of the use of juvenile wood for wood products is also problematical. Quite simply, we don't know how much production of inferior-quality wood products does cost in terms of market share. At the moment, the probable effects seem most apparent in the increasing use of old-growth Canadian spruce-hemlock-fir softwoods for structural timbers. According to some estimates, Canadian lumber has captured 1/3 to 1/2 of the southern market, and probably a large share in other regions of the U.S. as well. It may well be this market penetration is due to low costs of wood that is subsidized by Canadian stumpage pricing policies. But to a large degree, old growth spruce-hem-fir is perceived as a better product than young growth pine chip-n-saw, which must also contribute to loss of market share for southern pine.

Even if both Canadian stumpage subsidies and consumer (builder) preference for spruce-hemlock-fir contribute to loss of market share for southern pine, the juvenile wood problem cannot be ignored. Many consumers would prefer light, uniform straight hem-fir for construction rather than heavy, variable, and lower-grade southern pine. The

predominance of chip-n-saw mills that produce lumber exacerbates the problem. They produce chips from mature wood at the outside of the log and lumber from juvenile wood at the inside of the log. The result is frequently not a good lumber product. And in fact, an old economic adage tends to operate--bad goods will drive out good ones. In this case, poor quality southern pine lumber produced from young growth has given all southern pine lumber a bad reputation. Consumers have begun to equate southern pine 2x4's with low quality, despite the fact that the lumber may have structurally superior properties when sawn from mature wood.

In a limited survey of retail lumber retailers and builders in Athens, Georgia, it was found that most builders chose to use Canadian lumber regardless of price. In fact, many bought it rather than southern pine of the same dimensions despite a greater price. If this is the case throughout the South, one could surmise that product desirability contributes a large share to the spruce-hem-fir market penetration. Accordingly, this represents a cost for the use of juvenile southern pine wood.

The magnitude of the costs of using juvenile southern pine can be examined using various assumptions. Total southern softwood lumber consumption in 1985 was about 16.4 billion board feet per year (Forsim 1985). Canadian lumber imports have been estimated to have one-fourth to one-half the southern market share. Assuming that product preference (not price) explains various shares of the market share captured by Canada, this opportunity cost for southern pine lumber producers might be calculated as shown in Table 2.

These estimates are conjecture, but they indicate the magnitude of the costs of extensive use of juvenile wood. No one has empirically tested the causal factors for consumer's use of Canadian wood. But product preference is no doubt contributing, if not determining. The forest industry as a whole must consider these costs in their products made of juvenile wood.

INTEGRATED ECONOMIC EVALUATIONS

The preceding review provides an overview of the potential changes in southern forest industry we can expect as we move from a predominantly natural pine resource to a largely planted pine resource. Wood characteristics will undoubtedly change with more plantation wood, usually harvested from shorter rotations. While wood from plantation stands will undoubtedly be different, we can affect product composition and quality of existing and future stands by the forest management actions we select.

As indicated by the preceding review, many studies of southern pine wood quality and utilization characteristics have been conducted in the past. But this research still does not provide us with enough economic information for optimal stand management and timber processing decisions. We need to integrate timber management, harvesting,

Table 2. Possible Annual Cost Impacts of Use of Southern Pine Juvenile Wood as Measured by Loss of Structural Lumber Market Share.

<u>Approximate 1985 Southern Lumber Consumption</u>	<u>Average Price Per Thousand</u>	<u>Approximate Canadian Share of Southern Market</u>	<u>Share Attributable to Preference for Spruce-Hem-Fir</u>	<u>Approximate Market Cost to Southern Pine Industry</u>
---MBF---				
16,440,000	\$200	33%	10%	\$108,504,000
			33%	358,063,200
			50%	542,520,000
16,440,000	\$200	50%	10%	164,400,000
			33%	542,520,000
			50%	823,000,000

processing, and marketing analyses and decisions. We need to know more about all of these components of the forest business process.

Fight et al. (1986) suggest needs for better wood quality evaluations. More production function data are needed about the effects of forest management practices on pine wood quality--effects of stocking, species, fertilization, vegetation control, thinning regimes, and rotation lengths on the yields of fiber used for solid wood and pulp and paper products. Second, we need more information on costs of implementing various silvicultural practices and the marginal returns received from those practices. This would include costs of initial and intermediate treatment of forest stands, costs of harvesting and transporting different sized timber, and the mill value of timber with a specified size, density, fiber length, or other characteristics. Third, we need to know more about the market impacts (salability or demand and price) that the use of various types of wood fiber will have on final products. These individual needs must be integrated into a holistic analysis that looks at the effects of wood quality on costs and returns in timber production, logging, manufacturing, and marketing.

Fight et al. (1986) also discuss four components that are needed for an integrated analysis of silvicultural regimes, including growth and yield data, timber management costs, logging costs, and net product values. Each of these subjects requires detailed information for thorough analyses. Figure 1 enumerates some of the possible topics that are involved in each of the four components.

Growth and Yield

Detailed growth and yield data on timber volume and weights, form, limbiness, and other factors are needed for integrated economic evaluations. These requirements considerably exceed the data customarily provided in growth and yield studies. But they are needed to determine the best product usage. Yields for different management practices such as thinning and other timber stand improvement practices are also needed.

Furthermore, integrated economic evaluations will require utilization data on the amount of juvenile and mature wood in trees grown in various stands. Data on specific gravity, fiber length, and fibril angle by type of management practice would be helpful as well. Generalized studies that investigate these questions would be useful.

Management Economics

Data on management economics should be obtained for integrated analyses. In fact, economic analyses have traditionally been the criteria used to determine timber rotation ages used today. These analyses use stand establishment and management costs, anticipated yields and stumpage returns, and discounted cash flow analyses in order

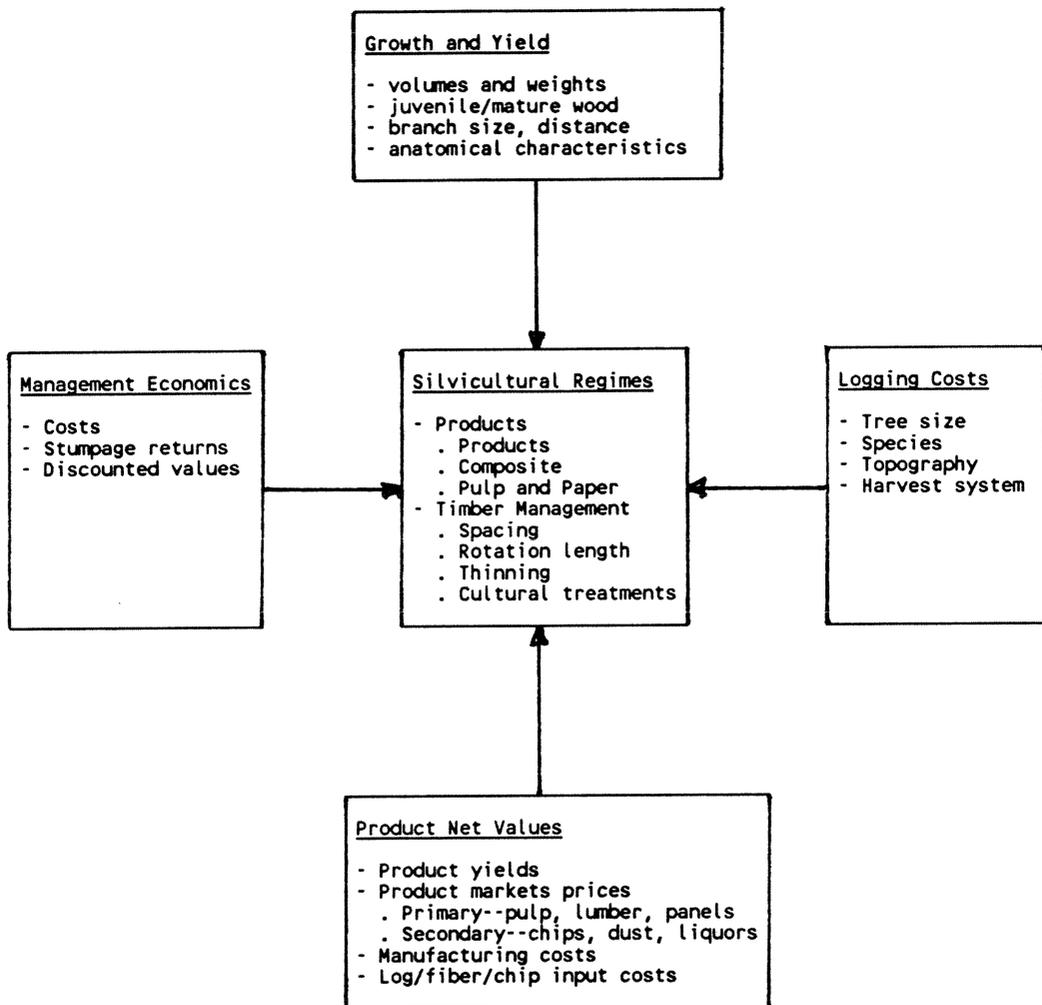


Figure 1. Important Components of an Integrated Analysis of Silvicultural Regimes (Adapted from Fight et al. 1986).

to determine the rotation age and management regimes that will maximize present values or rates of return. These types of analyses are used by corporation and individuals in evaluating other type of financial investments also.

A crucial component in an integrated economic approach will be improved estimation of stumpage values as determined by product end use and yield. Increased (or decreased) values due to greater proportions of mature wood, higher specific gravities, or longer tracheid lengths must be quantified. These price data may come from stumpage values that companies pay for desirable timber, or they may be derived using a residual value approach from the final products. In either case, estimates of differential values for different products is one of the most important improvements that must be made over current generic analyses that ignore wood quality considerations.

Logging Costs

Logging costs also are necessary for integrated economic evaluations of alternative silvicultural regimes. Logging costs vary by harvest system used, tree size, topography, species, and other factors. These costs could be estimated using results available from harvesting time studies and various equipment fixed and operating cost data. We at the University of Georgia have estimated some of these types of costs for the harvest systems common in the South. They could be used in integrated economic evaluations fairly easily.

Product Net Values

The last component that influences selection of silvicultural regimes is the final product for which the wood will be used. One would logically believe that end use would be most important in determining silvicultural regimes. In fact, this is often not the case. Foresters are fond of trying to grow the maximum amount of volume per acre, assuming that technology will provide a means to utilize whatever is grown. Technology can handle many problems, particularly if enough energy and dollars are available. But a premium will be paid to those who produce wood that is better suited to the needs of forest products manufacturers.

To determine the net value of products, information will be needed on product yield by grade and according to type of wood source. This will include both the value of the primary product and of any secondary or by-products of the manufacturing process. Estimates of manufacturing costs will also be helpful; these can be used to derive input fiber costs that should be paid for the raw material. Economists refer to this as factor demand.

Another piece of helpful information might be estimates of market demand for the final products and how demand varies with the quality of

the inputs. For example, how has demand for southern pine framing lumber been affected by use of more juvenile wood in making that lumber? These market questions are difficult to answer, but important. It will also be difficult, but necessary, to estimate the product prices that are relevant to future markets, and different grades of material.

CONCLUSIONS

Without any solid data to provide a foundation for positive analysis, one must base an assessment of the economics using of juvenile wood for southern pine products largely on conjecture and assumptions. This paper outlines a method for such an analysis, and makes some assumptions to at least provide rough estimates for their costs.

Using the conservative cost estimates for increased pulpwood procurement, pulp production decreases, lumber yield decreases, and loss of market share, and ignoring pulpmill plant costs and sawtimber procurement costs, increasing use of juvenile wood will cost the southern forest products industry \$102,450,000 in production losses and \$108,504,000 in lumber market share losses each year. Using the highest costs estimates, these costs would be \$275,950,000 and \$822,000,000 respectively. Costs for a large pulpmill could exceed \$2.5 million per year; for a large sawmill, \$280,000 per year. If these estimates are even remotely close, one can conclude that the use of juvenile wood is extremely costly to the southern forest products industry. Additionally, the question of whether the benefits outweigh these costs has not even been examined, or maybe even asked.

It is unlikely that we will return to favoring natural stands, but we can manage planted stands for the highest value products. Most other major softwood producing sectors in the world have realized that their changing resource base requires strategic planning. New Zealand (Sutton 1987), western Canada (Kellogg 1987), and the western U.S (Fight et al. 1986) have all initiated major, comprehensive, expensive task force efforts to evaluate the growth and utilization of their second-growth softwood forest resources. To a large extent, they have identified the characteristics of their resource, planned alternative utilization strategies, and developed sophisticated models to analyze timber management regime alternatives. Doubtlessly, the Scandinavian countries have done this on an ongoing basis as well. The South, on the other hand, has initiated no coordinated research efforts at all, despite being faced with the most imminent change in their forest resource. Some individual studies on plantation wood utilization are being performed, but we need much more to maintain our competitive position.

Overall, we have performed a considerable amount of research on wood quality. We have not, however, answered many crucial questions. Nor have we developed broad-based regional models to evaluate resource changes or developed any coherent regional strategies to deal with these changes. The challenge for our industry will be to work cooperatively and act quickly to develop analytical tools to implement and forest management practices that will help us maintain our world competitiveness, in forest products manufacturing and marketing.

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THE PACIFIC NORTHWEST STAND MANAGEMENT COOPERATIVE

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The Stand Management Cooperative is a research and development organization created to provide a continuing source of high-quality data on the long-term effects of silvicultural treatments and treatment regimes on stand and tree development and wood quality. The program will link silvicultural and yield research with wood quality and utilization research, with emphasis on forest plantations. Results will provide an improved basis for evaluating stand management practices and regimes for the future.

BACKGROUND

Most of our present knowledge about effects of treatments in forest plantations, in terms of effects on long-term growth and wood properties, is derived from natural stands. To fill gaps in the existing data base, the Cooperative will install plots, apply treatments, and collect and analyze data. The integrated program aims to define quantitative effects of treatments on growth, yield, and wood properties, and to forecast more accurately the consequences of alternative management regimes. Although initial emphasis is on plot establishment and data collection, in the future the program will also provide improved stand simulators, yield estimates, and stand treatment guidelines.

Initial activities focus on two species, Douglas-fir and western hemlock, in the coastal regions of Oregon, Washington, and British Columbia. In the future other species may be included.

THE CHANGING RESOURCE

Managed stands are replacing the natural forests of the Northwest. Today's planted stands will be influenced by regimes that may include many interacting treatments, such as thinning and fertilization. Current thinking in the region favors much wider tree spacings than have been common in the past, and a particular need is for specific quantitative information on the effects of such regimes on wood quality. Available information suggests that wood and product quality is likely to be a major factor determining acceptable management regimes.

Effective management of future stands will require information on:

- effects of wide planting spacings on stand development and yields
- responses to thinning in stands with prior stocking control
- effects of combining stocking control with fertilization, vegetation control, and genetic improvement

Only limited information is available specifically applicable to these conditions.

THE CHANGING PRODUCT

As the characteristics of northwest timberlands change, so will the characteristics of wood products. Wood quality studies of western species have rarely included examination of the effects of silvicultural regimes on wood properties and product quality. These effects need to be evaluated and incorporated in decisions about management practices to be applied to new forests.

Three problem areas will be addressed:

- effects of silvicultural practices on basic wood properties
- relationship of basic wood properties to product quality
- effects of stand treatments on product yields and quality

The Stand Management Cooperative is conducting product recovery studies and laboratory evaluations of basic wood properties. Results will provide an improved basis for models to evaluate effects of silvicultural treatments on wood properties and product quality.

INVOLVEMENT

The Stand Management Cooperative was formally established in January 1985. Currently, 22 organizations participate in the cooperative, including five universities. Sixteen forest industry companies and federal, provincial, and state agencies provide support and direction for the project. The six institutional members furnish technical expertise and research support. Cooperative headquarters at the University of Washington provides program administration and staffing.

Member organizations:

Bohemia, Inc.
British Columbia Ministry of Forests
and Lands
Cavenham Forest Industries
Champion International Corp.
Forintek Canada Corporation
Georgia-Pacific Corporation
International Paper Company
Longview Fibre Company
MacMillan Bloedel Ltd.
Municipality of Metropolitan Seattle
Oregon State University

Port Blakely Tree Farms
Simpson Timber Company
University of British Columbia
University of California, Berkeley
University of Washington
USDA Forest Service
USDI Bureau of Land Management
Washington Department of Natural
Resources
Washington State University
Weyerhaeuser Company
Willamette Industries

ORGANIZATION

The Cooperative includes two projects: Silviculture and Wood Quality. Each has a Project Leader, supported by Technical Advisory Committees composed of individuals from member organizations with specific skills and interests. Program and study plans are prepared jointly by the Project Leaders and Technical Advisory Committees. A Policy Committee representing all members meets annually to review plans and accomplishments and approve work plans and budget. Overall program coordination is

provided by the Director, working with the Project Leaders and the Policy Committee Chairman.

Field work and data management are coordinated by Cooperative staff at the University of Washington. Plot establishment, treatments, and data collection are done jointly by Cooperative staff and the landowner. Studies in both projects will be joint efforts, drawing on the skills of individuals in member organizations best suited and available for the specific data analyses and interpretations.

PLANS

Five-year Plans have been developed for the Silviculture Project and the Wood Quality Project.

Silviculture Project field installations are established with the primary aim of obtaining data suitable for fitting regionally applicable response surfaces. About 60 field installations are planned for establishment over a 5-year period, with planned durations of about 30 to 50 years.

The Wood Quality Project will conduct a series of coordinated studies in the five year planning period, beginning with a major product recovery study and a series of follow-up studies. Other work will involve forest, mill, and laboratory measurements, and will increasingly be directed toward linkage with Silviculture Project field installations.

IN SUMMARY

The Stand Management Cooperative emphasizes studies on effects of silvicultural treatments on wood and product quality, which is likely to be as important to future regional competitive position as is volume production. Linkage between silviculture and yield research and wood quality and products research promises to be an enduring benefit of the program. Also, the field installation design was developed to overcome some of the difficulties that have plagued past long-term studies of silvicultural regimes in the Pacific Northwest.

Cooperative efforts such as the Stand Management Cooperative are the most promising means -- and perhaps the only feasible means -- for providing a continuing source of high-quality treatment response data. These data are needed for construction of reliable models that can guide owners in evaluating alternative management regimes. The costs to an individual owner are far less than those of an independent effort, and the range in both the conditions represented and the expected sample size is far greater.

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AN INTEGRATED FOREST MANAGEMENT AND RESOURCE QUALITY
RESEARCH EFFORT FOR COASTAL DOUGLAS-FIR IN CANADA

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Introduction

The forest industry in Canada, as elsewhere in the world, will become increasingly dependent on managed second-growth timber for its wood supply. The future of the forest industry will depend upon the successful conversion of this resource into forest products. In order to plan new investments and to assess stand management practices, industry urgently needs information ranging from the effects of silvicultural regimes on volume production and wood value, to the properties and quality of end-products produced from the resource. A program of research into managed second-growth coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) timber values has been undertaken by Forintek Canada Corp. in cooperation with the Pulp and Paper Research Institute of Canada and the Research Branch, B.C. Ministry of Forests. This research group called the Douglas-fir Task Force had the following main objectives:

1. To estimate the physical, mechanical and chemical properties of the intensively managed coastal Douglas-fir resource of the future.
2. To determine the value of this resource for conversion to dimension lumber and pulp.
3. To develop a computer model capable of evaluating the effects of silvicultural treatments in terms of end-product value.

Formation of the Douglas-fir Task Force

Securing the active support and participation of industry was an absolute necessity in order to ensure the success of the task force. Initial contact was made through two committees of the Council of Forest Industries, the Sawmill Operations Committee, and the Forest Management Committee.

Six of the coastal companies, B.C. Forest Products, Crown Forest Industries (now both under the name Fletcher Challenge), Canadian Forest Products, MacMillan Bloedel, Western Forest Products and C.I.P. Inc. (now called Canadian Pacific Forest Products) all offered to locate suitable stands, fell trees and transport logs to the mill. Canadian Pacific Forest Products made their Ladysmith mill available for the conversion study. Representatives from each company and the Ladysmith mill manager joined the nine project leaders to form the Douglas-fir Task Force.

Site and Tree Selection

Six stands were sampled. The age of these stands was approximately that of the anticipated rotation age of future managed stands of Douglas-fir, that is, about 50 years. Intensively managed stands of that age do not exist in coastal British Columbia, but 50 year old stands do exist on medium to good sites where stocking densities are not too high and productivity has been at levels that foresters would hope to achieve under intensive forest management conditions. It was this type of stand which was sought for study. In addition, it was decided to obtain as wide a geographic distribution of sites as practical and to represent both the wet and dry regions on the West and East coasts of Vancouver Island as well. The flow of trees, logs, and material selected for each of the study projects is illustrated in Figure 1.

It must be kept in mind that the material sampled, and therefore the results, do not describe the present coastal Douglas-fir resource being harvested and marketed today. The results of the basic wood property, pulping, and juvenile-mature wood transition studies do not truly describe the entire stands from which they were obtained since only dominant and codominant trees were selected. It is expected that the trees selected for study represent the range of characteristics which will be produced in future managed stands of this species.

Sampling of the stands for the conversion study was more comprehensive in that the full range of tree diameters was sampled. The sampling plan called for an equal number of trees in each diameter class so that estimates would have equal precision over the full range of stem diameters. However, the results do not properly describe these stands since the sampling was not random. That was not the objective of the study.

Results and Discussion

Wood Characteristics

The results of this study show that, largely due to the high proportion of juvenile wood, second-growth coastal Douglas-fir harvested in 50 to 70 years will have physical, mechanical and chemical properties substantially different from the old-growth resource harvested today. Juvenile wood volume may be as high as 50 percent of total volume at these rotation ages. Juvenile wood, which in this study material comprised on average the first 23 rings from the pith, has an average relative density of 0.46. The average stemwood relative density of the study trees is 0.48 while the best estimate of average old-growth relative density is about 0.51 to 0.52.

A great deal of tree-to-tree variation in longitudinal shrinkage exists, but on average the longitudinal shrinkage of the innermost juvenile wood is more than twice that of mature wood. No sharp distinction can be observed between juvenile and mature wood based on longitudinal shrinkage, but it appears that the most serious levels are generally confined within the first five rings from the pith. In contrast, the fiber length increased dramatically from between 1.0 and 2.0 millimeters at the pith to between 3.0 and 4.0 millimeters in the mature wood. These mature wood values were not attained for approximately 30 rings from the pith, so it can be anticipated that the average fiber length of short rotations stands will be substantially less than that of old-growth material.

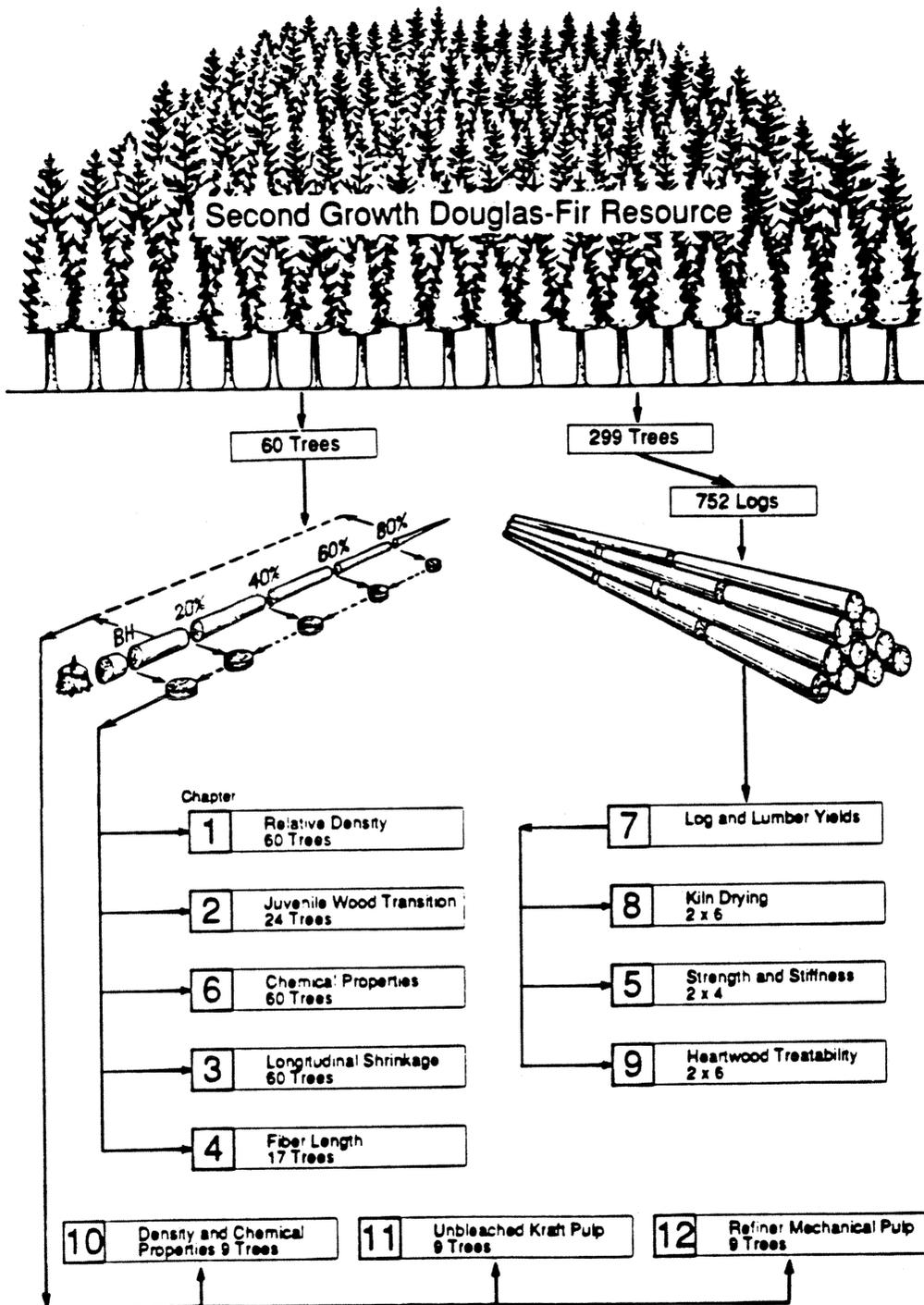


Fig. 1 Source and Distribution of trees and material in study projects

In terms of chemical properties, lignin content of juvenile wood is higher than that of mature wood, but a comparison of the mean second-growth values with those available for old-growth shows that they are not appreciably different. A similar comparison shows total extractive content of second-growth is lower than that of old-growth.

Conversion to dimension lumber

The factor primarily determining lumber value is tree and log size. Grades No. 2 and Better accounted for a relatively constant average of 82 percent of all lumber. Increased yields of Select Structural that were obtained as log diameter increased were largely at the expense of reductions in the yield of No. 1 and No. 2 lumber. Clearly, differences in lumber value related to log quality depend on a premium price for Select Structural. Without this premium for grade the effect that logs size has on value would become even more important, because premium prices are usually paid for the widest lumber widths.

Although knots were a major determinant of visual lumber grade there is no direct linear relationship between knot size and visual grade. This results from the fact that an acceptable knot size for a given lumber grade is defined by the size of the lumber piece and by the location of the knot within the piece.

Lumber grade and value considerations of second-growth material will have to include the impact of juvenile wood on lumber drying and strength characteristics. Warp, particularly twist, was a major drying degrade factor with a strong tendency for warp to increase with increasing proportion of juvenile wood.

Of greater concern is the magnitude of potential grade and value reduction resulting from the reduced strength and stiffness of lumber with high proportions of juvenile wood. These results do not reflect the design values that could currently be assigned to random samples of visually graded lumber as typically marketed in British Columbia. Rather, they bring industry's attention to a potential value problem should there be a significant change in log sorting strategies, proportion of second-growth being harvested or a change in forest management strategy that increases the production of lumber of lower density.

There is a substantial proportion of the lumber from second-growth trees with high strength and stiffness properties that are not recognizable by means of visual grading. By contrast, machine stiffness rating systems provide a direct method of assessing the structural performance capability of each piece of lumber. In a similar sense, conventional kiln-drying schedules and practices may result in appreciable drying degrade in second-growth Douglas-fir lumber containing a high proportion of juvenile wood. Methods have been developed elsewhere in the world to deal with similar drying problems and these should be examined to develop a cost-effective means of reducing degrade losses in this material.

Perhaps one of the greatest values in the information obtained in this study is the recognition of potential quality problems so that methods can be developed to deal with them effectively before this type of wood becomes a significant component of the harvested coastal Douglas-fir resource. The results should suggest ways in which second-growth can be converted, graded or marketed in order to realize its highest potential value.

Conversion to pulp

If the second-growth coastal Douglas-fir resource or sawmill residuals from that resource are converted to kraft or refiner mechanical pulp certain observations can be made on the characteristics of those pulps based on the results of this study. Yields of both bleachable-grade and linerboard grade kraft pulps were consistently lower for juvenile wood relative to mature wood while the yields of top wood was intermediate. Presumably due to interfiber bonding, the juvenile wood and top wood pulps had higher tensile and burst strength, a greater stretch and stress-strain factor than those from mature wood. On the other hand the juvenile wood and top wood pulps were substantially lower in tear strength than the mature wood pulps. The wide ranging properties of bleachable-grade kraft pulps made from the different components from the second-growth Douglas-fir resource were predictable on the basis of wood or chip density, fiber length and fiber coarseness.

An increase in the proportion of juvenile wood will adversely affect the tear index of kraft pulps of coastal Douglas-fir to a point where they are more comparable with the tear strength of other Canadian softwoods. This drop in tear is offset to some degree by increased tensile strength and sheet density. In short, future resource can be expected to produce a more balanced kraft pulp. It appears that there is the potential for an increased range of properties from kraft pulps of second-growth Douglas-fir which offers a broader range of utilization options. Other softwoods may not be capable of providing a comparable range in properties.

Fibers from mature wood refiner mechanical pulps were longer and coarser than those from juvenile wood and top wood pulps. As a result mature wood pulps were stronger in both tensile and tearing strength.

It has been found that the properties of refiner mechanical pulps can be predicted and explained primarily on the basis of fiber length, fiber strength and Klason lignin content of the wood. Wood density is also important, but unlike the models developed for kraft pulps, plays a less dominant role. Consideration of available options for utilization of second-growth Douglas-fir refiner mechanical pulps suggests that there is a good potential for the production of mechanical pulps with a distinctive range of properties.

Evaluation of Silvicultural Strategies

The second major contribution of this study has been the development of a model called SYLVER which can relate silvicultural strategies to standing yield, product recovery and financial return. Initial validation shows that SYLVER has successfully integrated the results of the Task Force studies into a system sensitive to environmental variables, silvicultural practices, wood properties, product quality, financial return and management opportunities. The flow of information from the Task Force Project to the SYLVER model is illustrated in Figure 2.

The model suggests an increased return on investment through the establishment of coastal Douglas-fir plantations at stocking densities of 400 to 500 trees per hectare as opposed to the current practice of 900 trees per hectare. On highly productive sites the highest return would be realized with a harvest rotation of 50 to 60 years when conventional visual grading procedures are applied.

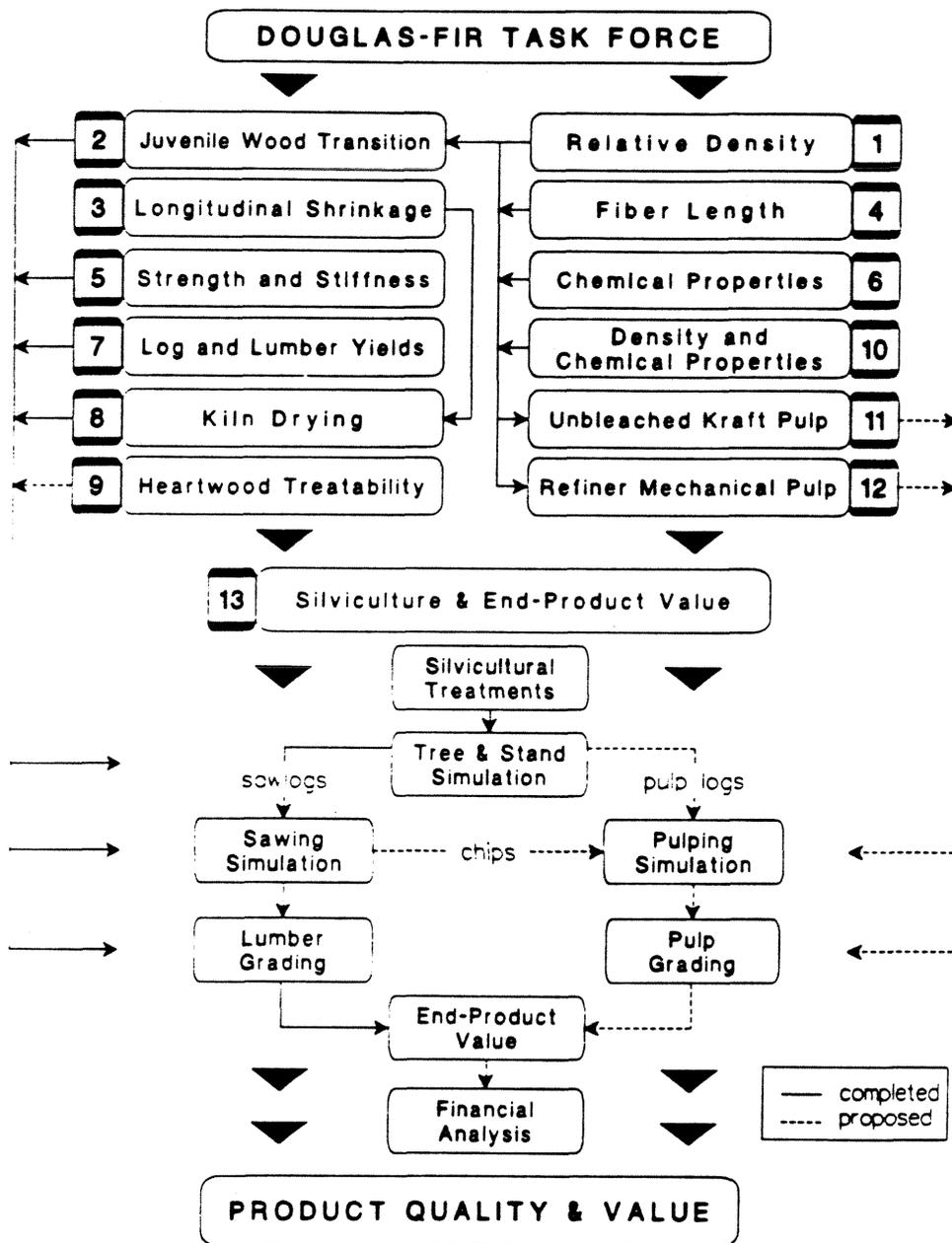


Fig. 2 Information flow between Douglas-fir Task Force projects

Recognition of the potential end-product quality problems resulting from the high proportion of juvenile wood resulting from this strategy results in a marked reduction in the net present value, expands the range of optimum planting densities (500-700 trees per hectare) and delays harvesting until age 90. Defining the magnitude of these effects provides the forest industry with some sense of the potential value losses against which the investments in either technological or biological solutions to the problem can be compared. The optimum planting density and harvest age depends on an organization's objective.

A policy that strives to maximize the merchantable volume of standing timber, or logs, encourages relatively high planting densities (1110 trees per hectare). Emphasizing lumber value has a similar effect. The attractiveness of high establishment density and long rotations vanishes when planting and carrying costs are considered through net present value analysis.

The results from the simulated experiment with different planting densities may encourage the forest planner to look for other opportunities to increase net revenue. Pruning is a likely choice with clear lumber presently demanding a price premium in excess of 300 percent relative to No. 2 and better, and the realization that short rotation unpruned stands will produce essentially no clear lumber. The model suggests that pruning will increase the net present value by as much as \$400/ha. It is predicted that a single lift pruning to 6.5 meters at age 20 would result in clear lumber accounting for 14 percent of the volume and 33 percent of the lumber value. This striking increase in the net present value of pruned stands illustrates the dynamics of financial yield and the insight that SYLVER can provide when adequately validated.

Integrated efforts like the Douglas-fir Task Force provide a means of developing a knowledge of the wood characteristics that determine end-product value. This is essential information for tree improvement planners who may want to consider the potential they have to offset some of the negative wood quality features expected in the managed second-growth resource. Models like SYLVER offer the potential of evaluating the effects of genetic manipulations of the wood characteristics which are critical in determining end-product value. The model should be able to consider the costs of genetic manipulation and trait measurement in tree improvement programs so that assessments of overall financial return of potential investments can be made in terms of net present value. These options are just beginning to be explored.

As part of the effort to remain competitive on the world market, Canada's forest industry must maintain a high quality resource which will permit the greatest flexibility in the manufacture of a variety of high quality value added products. Information of the type gathered from this integrated research effort should go a long way in helping to achieve that goal.



Southern Plantation Wood Quality Workshop

Facilitated Group Meetings

Attendees participated in one of four commodity group breakout sessions. The groups were **lumber, composites, pulp and paper, and forest management**. Each group was asked to respond to these two trigger questions:

1. What are the most pressing information needs to most efficiently utilize the South's changing softwood resource?
2. If an organization is needed to deal with the changing softwood resource, how should it be structured?

The following lists provide responses to these questions. For the first question, each group ranked information needs by classes and then prioritized needs within classes. Responses to the second question are not ranked.

LUMBER GROUP
High-Priority Information Needs

1. Resource

- Determine effects of cultural practices on grade and volume yield of logs and trees.
- Develop new weight scaling and conversion factors.
- Assess resource and build predictive models.
- Conduct genetics--research to reduce problems; e.g., wood fibril angle.

2. Conversion

- Merchandize total-tree to optimize value.
- Identify juvenile wood in furnish and solid products so that it can be segregated in the yard or mill.
- Reduce degrade through drying processes.
- Adjust processing procedures in the mill to reduce problems.

3. Grading

- Revisit the whole grading process--
 - machine stress rating
 - visual system and modifications
 - segregate juvenile wood and possible grade separately
- Furnish reliable strength values for lumber with juvenile wood.
- Determine yields of machine stress-rated lumber and for any "new" approach for segregating grade.

4. Markets and Marketing

- Understand problems of juvenile wood in major southern pine markets--
 - strength
 - treated wood-warp
 - other
- Conduct market research to find deterrents in residential and developing (new) applications.
- Determine in-use stability of material; e.g., redried treated wood.
- Quantify dollar loss due to juvenile wood.

LUMBER GROUP
Additional Information Needs

1. Resource

- Conduct research on tree genetics and biotech to reduce juvenile wood.

2. Conversion

- Determine the future product mix for industry.
- Determine the treatability of juvenile wood.
- Determine the effect of juvenile wood on mill recovery.

3. Grading

- Estimate the rate of change in the resource as it affects design values.
- Create a separate grading category for juvenile wood.
- Estimate the effect of slope of grain on lumber quality.
- Estimate the effects of crook on lumber quality.

4. Markets and Marketing

- Develop new connectors for low-density wood.
- Explore the possibility of redrying treated wood.

COMPOSITE PRODUCTS GROUP
High-Priority Information Needs

1. Forecasts of Raw Material Supply

- Continue and improve forest inventory and analysis efforts so that the quantity, distribution, quality, and grade mix of timber are known. This information must then be related to industrial needs.
- Develop data base to relate resource characteristics to product yield, quality, and costs.
- Determine the impact of expanded hardwood usage.

2. Technology

- Develop technology to use juvenile wood for specific purposes.
- Assure that products have predictable and reliable performance.
- Test methods for sorting and grading raw materials to avoid large variations in the quality of final products.

3. Markets and Products

- Explore opportunities to use wood for nonresidential products.
- Explore opportunities to use wood in combination with other materials.
- Stimulate export by determining the most desirable mix of southern panel products in world markets.

4. Education

- Provide training and education for industry on topics like in-woods processing and sorting.
- Provide information on stand management practices that improve product quality.
- Determine and disseminate information on budget needs for utilization research.
- Present a unified message to the public on multiple use forest management and utilization.

COMPOSITE PRODUCTS GROUP
Additional Information Needs

1. Forecasts of Raw Material Supply

- Determine from nonindustrial private forests how much timber is available.
- Help industry to decide whether it should lengthen rotations to meet customer needs.
- Define standards of quality.

2. Technology

- Determine how juvenile wood affects the characteristics and properties products like laminated veneer lumber and oriented strandboard.
- Develop processing technology for controlling stiffness of plywood.
- Develop technology to utilize the timber that will be available in the year 2000.
- Improve tension and other testing methods.
- Explore the possibilities of intermediate harvests for various products to allow longer rotations.

3. Markets and Products

- Determine market needs for specific products.
- Define customer needs for product quality.
- Make long-term forecasts of technology and products.
- Explore opportunities to develop markets for the kinds of products and materials that can be produced in the short term.
- Determine demographic makeup of southern consumers.
- Devise short-term as well as long-term (20+ years) solutions.

4. Education

- Inform lawmakers on benefits of tax laws that promote longer rotations.
- Communicate importance of research on juvenile wood problem.

PULP AND PAPER GROUP
High-Priority Information Needs

1. Integrated Production and Economics Studies

- Develop widely applicable economic models that include both the economic consequences of high-volume-per-acre fiber production and bottom-line impact on mill profitability within limits of antitrust.
- Develop integrated systems to study forest management and pulping processes from start to finish--from seed to pulp.
- Develop effective communication among all parties--forestry and manufacturing.

2. Resource

- Relate wood properties to silvicultural treatments--identify relative importance of factors affecting wood quality.
- Develop growth and yield models that include wood property information.
- Develop trees with high specific gravity or smaller juvenile cores.
- Develop nondestructive measurements for specific gravity.
- Consider industry-wide use of dry weight as substitute for cubic volume or green weight.

3. Manufacturing

- Establish alternative papermaking products or processes using juvenile wood.
- Develop effective on-line measurements of fiber quality in the chip stream.
- Explore feasibility of sorting wood into quality classes in the woods, in the woodyard, and at the mill--both roundwood and chip sorting.

4. Marketing

- Compare plantation woodpulp quality and price with other major world competitors.
- Conduct a marketing study of Southeast pulp and paper versus the world.

PULP AND PAPER GROUP
Additional Information Needs

1. Integrated Production and Economics

- Gather data needed to make economic evaluations for new production and processing for the changing southern pine resource
- Develop mutually acceptable strategies for dealing with a changing resource, then identify means to fulfill.
- Estimate yield and cost of pulp and paper from different mixes of plantation and natural timber.
- Compare cost of increasing rotations with the cost of pulping wood from short rotations. Include product quality and byproducts in the analysis.

2. Resource

- Develop means to value stumpage or mill wood based on quality.
- Relate pulp yields to utilization (harvesting) practices.
- Obtain timely sophisticated inventory data, by procurement areas.
- Assess wood-quality impacts on the timber projections in "The South's Fourth Forest: Alternatives for the Future."

3. Manufacturing

- Develop systems to reduce variability in wood quality as furnished to the mill.
- Project wood quality and quantity of mill residues in the future.
- Develop technology to handle small material in the woods and at the mill.
- Examine manufacturing techniques that are tolerant of wide variations in fiber quality.
- Explore processes and products that take advantage of characteristics of juvenile wood.

4. Marketing

- Determine consumer preference impacts of changing resources on final product demands, if any.

FOREST MANAGEMENT GROUP
High-Priority Information Needs

1. Management Information

- Improve communication of existing information.
- Find market niches for the wood we are growing (alternate products?).
- Conduct frequent timberland surveys to determine trends in ownership and management and how these trends affect resources and their availability.

2. Silvicultural Treatments

- Determine the effects of cultural treatments on the quantity and quality of forest products.
- Identify management activities that most strongly affect juvenile wood formation.
- Identify specific wood characteristics related to site quality.
- Determine the characteristics of wood growth under a range of silvicultural practices.

3. Modeling

- Develop a general model that integrates the major factors influencing net product value.
- Develop better biological process models to predict treatment effects on wood quality.

4. Basic Biology

- Understand physiological process of maturation.

FOREST MANAGEMENT GROUP
Additional Information Needs

1. Management Information

- Determine the demographics of impending impacts of plantation wood--when and where.
- Develop low-cost management systems for nonindustrial private forest owners that will increase production without increasing problem.

2. Silvicultural Treatments

- Determine the impact of pruning on growth and wood quality.
- Develop economic thinning systems.
- Determine what management practices can be used to improve mill production.
- Identify the juvenile wood characteristics of geographic seed sources and specific parents.

3. Modeling

- Develop additional models relating plantation to natural pine.
- Develop yield models that relate product grades to branchiness, the amount of juvenile wood in the tree, and the location of juvenile wood in the tree.

4. Basic Biology

- Characterize genotype X environment effects on the characteristics of juvenile wood and mature wood.
- Gather information on crown structure and growth and wood quality.
- Find ways to change the population through breeding.



Suggested Organizational Structure
for Dealing with a Changing Pine Resource

Lumber Group

- To focus on and recommend research funding.
- To provide a forum.
- To transfer technology.
- To organize research effort, get dollars for research, and organize political support.
- To come up with a predictive tool (similar to FORINTEK).
- To use interdisciplinary approach to solving changing resource problems.
- To organize effort through existing organizations.
- Segment organization by major interests (lumber, panels, etc.).

Composite Products Group

- Needs industry commitment.
- Participation by industry, academia, and government.
- Plan and prioritize research needs.
- Fund and execute planned research.

Pulp and Paper Group

- Use task force approach.
- Interdisciplinary--growth and yield, economics, foresters, mills, managers, trade associations.
- Educate and communicate the future raw material supply and quality (softwood) situation in the Southeast and its economic impacts.

Forest Management Group

- Coordination needed.
 - Make sure research is coordinated
 - Identify where data bases are
 - Identify where the people are
 - Determine what the questions/goals are
 - Improve communication
 - Gain support--money, technical, political
- Some type of focused process needs to be established--not a co-op but a council or task force.

SOUTHERN PLANTATION WOOD QUALITY WORKSHOP -- LIST OF ATTENDEES

NAME	STREET	CITY	STATE	ZIP	ORGANIZATION
ALBRITTON, RON	PO BOX 329	NEW AUGUSTA	MS	39462	LEAP RIVER FOREST PRODUCT
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HUNDLEY, GENE	PO BOX 1990	SUMMERVILLE	SC	29484	WESTVACO LUMBER
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