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Symposium on the Shortleaf
Pine Ecosystem

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University of Arkansas
Department of Forest Resources
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FOREWORD

Shortleaf pine has the largest range of any of the southern pines, covering more than 440,000 square miles in 22 states, and has an inventory volume second only to loblolly pine. Despite this importance, shortleaf pine lags behind in terms of research information and management effort. This is generally due to the preference of forest managers for faster-growing species, and problem of littleleaf disease in the Piedmont region. However, shortleaf pine continues to be of primary importance on public lands in regions where it is the only naturally-occurring southern pine. Furthermore, it typically maintains itself as a significant component of natural stands, through mechanisms which are not fully understood. Recently, concern that loblolly pine is being planted to the north of its natural range has prompted a renewed interest in shortleaf pine. We hope that this symposium and its proceedings will provide managers and researchers with an up-to-date reference and that it will spark fresh interest in studying, growing, and managing this most neglected of the major southern pines.

The symposium committee wishes to thank the speakers, who did a superior job in preparing and presenting their topics. All of us who benefit from this information are in their debt. The committee also appreciates the fine efforts of the moderators, whose administration of the individual sessions contributed greatly to the success of the symposium.

To have a memorable symposium, there also must be a dedicated planning committee working hard behind the scenes. Those who organized this conference are:

Garner Barnum, Arkansas Forestry Commission
Edwin H. Barron, Texas Forest Service
Ted S. Chancey, Self-Employed, Weyerhaeuser Company, retired
Roger W. Dennington, USDA Forest Service
Billy G. Gresham, Arkansas Kraft Corporation
Dr. James M. Guldin, University of Arkansas
Dr. Edwin R. Lawson, USDA Forest Service
Dr. Paul A. Murphy, USDA Forest Service
Louis D. Rainey, Deltic Farm & Timber Company, Inc.
O. D. Smith, Jr., USDA Forest Service
William D. Walker, USDA Forest Service
Dr. R. Larry Willett, Arkansas Cooperative Extension Service
Dr. Robert F. Wittwer, Oklahoma State University

Not least, those who attended the symposium made it a success by their actively participation in the discussion. We thank each of you for contributing your knowledge, experience, and questions.

Finally, we acknowledge with gratitude the commitment of those organizations which made it possible for the program committee, speakers, moderators, and other participants to take part in the symposium at a time when operating budgets were unusually tight.

The authors are responsible for the content and accuracy of their papers. Nancy Smith and Pam Booker of the University of Arkansas at Monticello assisted in preparing the manuscript. Their help was invaluable. We appreciate the fine artwork done by Edward Rhodes and Les Harshaw of the Arkansas Cooperative Extension Service. Special thanks go to Carol Reiner and Elizabeth Childs, Arkansas Cooperative Extension Service, who served as technical advisors at every stage, composed the meeting announcement and program, and ultimately did the layout and final work on the proceedings. The Arkansas Cooperative Extension Service Print Shop printed the proceedings.

R. Larry Willett
Symposium Chairman

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HISTORICAL PERSPECTIVE

Kenneth L. Smith [1]

ABSTRACT

The history of shortleaf pine in the South generally parallels that of the area having the largest concentration of shortleaf, the Ouachita Mountains of Arkansas and Oklahoma. There, in the nineteenth century, agricultural settlers cut trees to clear land for crops and supply local needs for wood. Around 1900, cutting greatly expanded as large sawmills began to log by railroad and to ship lumber to out-of-state markets. In the 1920s, with the old growth timber diminishing and second growth widespread, sustained yield forestry was initiated with a program to protect young trees from fire. Through the 1920s and 1930s, the harvest of second growth was encouraged by expansion of the pulp and paper industry, the proliferation of small portable mills, and especially by the introduction of bulldozers and dual-wheeled trucks for logging. After World War II, the increasing value of timberland, and concentration of land with the U.S. Forest Service and large corporate owners, made possible more intensive management to insure a continuing timber supply. About 1970, corporations and the Forest Service began a fundamental shift from uneven- to even-aged stands.

The Ouachita Mountains of Arkansas and Oklahoma originally contained what has been called the largest shortleaf pine forest in the world. While their exact extent was never measured, shortleaf and shortleaf-hardwood stands must have

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[1] Historian and author, Fayetteville, AR

[2] The extent of the shortleaf and shortleaf-hardwood stands is based on the author's estimate. Eighteen large mills, each having one or two band saws, operated in the Ouachitas during the period from 1895 to 1965, cutting about two million acres, or three thousand square miles. Medium-sized and small mills were also active throughout the region, and in total they could have cut two thousand square miles of virgin pine. Hence the total area in virgin pine is given as five thousand square miles--admittedly an educated guess, but one that seems reasonable.

Figure 1. Felling a shortleaf pine on Dierks timberland near Pine Valley, Oklahoma, in March 1930. This unusually large specimen was probably saved until the photographer arrived. Trees, logs, and stumps in the background suggest the average sizes and open spacing of virgin shortleaf in the Ouachitas. --Photo courtesy of Forest Heritage Center, Broken Bow, OK.

covered about five thousand square miles of the eleven-thousand-square-mile area of the Ouachitas.[2] The Ouachitas pine forest was the last extensive virgin forest east of the Rocky Mountains. Old growth was being cut in the Ouachitas even after 1960; thus it has been possible in recent years to gather firsthand recollections of the first cut, as well as more recent changes.[3] In its most important aspects, the history of shortleaf pine in the Quachitas appears to be the same as for shortleaf throughout the South.

Virgin shortleaf pine in the Ouachitas often existed in open stands of widely spaced mature trees. Both hardwood and pine seedlings were killed off by ground fires caused by lightning, or by Indians, or later by white settlers who wanted to encourage the growth of "woods grass" for their free-ranging livestock. Apparently the forest existed in this state of equilibrium maintained by periodic fires, with mature or over-mature pines in open groves having a carpet of grass, when the settlers arrived and for years afterward.[4]

Many old photographs of virgin shortleaf pine logs in the Ouachitas--most often pictures of logs piled alongside logging railroads, or on the logging trains--show that logs ranged from about twelve to twenty-eight inches in diameter. A majority were twenty inches in diameter and smaller, though almost every photograph shows a few ranging up to twenty-eight inches. Logs thirty inches and above are rarely seen. A number of the logs show red heart and fire scars.[5]

Glen R. Durrell, who was a forester in the Ouachitas during the 1920s, recalls that in his experience, even twenty-four-inch-diameter logs were quite rare and that the great majority of logs were smaller; only rarely would a log be

---

[3] Much of the information in this paper, where sources are not identified, comes from oral history interviews and documentary research by the author for his book, Sawmill, about the forest and the timber people of the Ouachitas from 1900 to the 1950s. Interviews were conducted with more than three hundred men and women who were involved with cutting the region's virgin pine. the history of shortleaf pine in the Ouachitas appears to be the same as for shortleaf throughout the South.

[4] While the openness of the pine forest must have usually been the result of fires that killed off seedlings, Ouachitas forester Conley Culpepper of Hot Springs, Arkansas, states his belief that shortleaf cannot tolerate crowding as much as other pine species such as loblolly.

[5] These conclusions are based on the author's examination of nearly thirty photographs of logs taken during a period from shortly after 1900 to 1948.

much larger. Durrell also recalls one timber sale on the Ouachita National Forest in 1926 in which scars and decay caused by fire had ruined twenty-five percent of the total volume logged.[6]

The mountain pine of the Ouachitas, however, had grown slowly and was described as having "a light, soft, lustrous texture and fine grain..." It was a favorite material for sash, doors, and ceilings, and the dense heartwood was ideal for pine flooring (Brooks 1940).

While longleaf pine in southern Mississippi yielded between ten and twelve thousand board feet per acre, log scale (Hickman 1962) and shortleaf on the coastal plain of southern Arkansas provided seven to ten thousand feet per acre (Morbeck 1915), shortleaf in the Ouachitas averaged less. In the hills west of Little Rock, a timber cruiser found that one large tract averaged about five thousand feet per acre--a figure that appears to be typical for virgin shortleaf in many parts of the Ouachitas (American Lumberman 1904). In the western Ouachitas north of Fort Towson, Oklahoma, poorer sites where pine was mixed with hardwood had an average of a little over three thousand feet per acre (Hauenstein 1979). Foresters recall that occasionally the yields were much higher--ten thousand board feet, Doyle scale, in one case from a measured acre north of Hot Springs, Arkansas, that was clearcut about 1960[7].

The earliest cutting of virgin pine was done by settlers who wanted to clear land for crops and get material for homes. In time, there were small water- or steam-powered sawmills making lumber for local communities. Cutting of this sort continued throughout the nineteenth century, but widespread, systematic removal of the forest did not begin until around 1900, after trunk line railroads had penetrated the region. Lumber companies built big mills and logging railroads, first on the fringes of the Ouachitas and later within the region's interior. About 1919--the end of World War I--cutting reached an all-time high, with fourteen single- or double-band sawmills processing nearly one million board feet of Ouachitas pine every working day.

When lumber prices were low, as they were much of the time for 1900 to 1915, sawmillers cut only the trees that they could profitably convert into lumber, leaving many small and defective ones standing in the woods. With prices high, during and after World War I, it as said they cut almost any tree that would produce lumber, so that many areas were practically clear-cut (Hall 1945). At that time, lumbermen did not plan to keep their cutover land; they considered it impossible to hold cutover acreage for the seventy-five years they estimated it

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[6] Interview with Glen R. Durrell, August 2, 1983.

[7] Interview with Conley Culpepper, November 1, 1985.

Figure 2. Second growth up to eight years of age in an abandoned field near the Gladstone Road on the Ouachita National Forest northwest of Hot Springs, Arkansas, about 1924. Old growth shortleaf stands in the background. USFS negative No. 261819.
--Photo courtesy of U.S. Forest Service, Hot Springs, AR.

would take to produce another crop of sawtimber. Lumber companies tried to sell cutover land to farmers, and paid no heed when ground fires burned over both cutover acreage and timberland not yet cut. By one estimate, fully one-third of the timberland of the Dierks lumber company in southeastern Oklahoma was burned each year, as local residents set fire to the woods to improve the forage for their livestock.[8]

In spite of clean cutting and ground fires, by the 1920s it was apparent that second growth was coming up in many areas. William L. Hall, a consulting forester in the Ouachitas, noted that widespread fires in early 1925 were followed by an enormous crop of pine seed later that year, so that in 1926 seedlings were coming up everywhere (Hall 1945). The second growth was not evenly distributed, and was of uneven genetic quality, but it had begun to take hold.

By this time, the mid 1920s, a few Ouachitas mill owners, notably the Dierks family, realized that in the future they would either have to operate on second growth or go out of business. William L. Hall organized sustained yield forestry programs for these owners, which at the beginning were simply plans to cut to a twelve-or fourteen-inch diameter limit and to protect the timberlands from fire. The Clarke-McNary Act of 1924 permitted cooperation between public and private landowners for fire control, and companies such as Dierks began to work hand in hand with the U.S. Forest Service to suppress wildlife on their adjoining lands. Young pines now had a chance to survive.

Forester Glen Durrell later wrote about the inherent risk in the Dierks forestry program:

> This was a decision based largely on faith in the future. The action could not have been justified at that time on an economic basis. When you put the low price of stumpage in the West and on the National Forests, the high interest rates, the relatively slow growth of timber, the costs of taxes and of administration, the lack of fire protection, the prevalence of timber theft, and the price that finished lumber would bring, all into the formula, the answer always came out that the private landowner couldn't afford to be in the tree-growing business (Durrell 1984).

DeVere Dierks, writing in 1928, bore out Durrell, saying that the members of the Dierks family "don't yet know if reforestation will pay for itself" (Dierks 1928).

The 1930s depression resulted in cutbacks in private forestry programs and expansion of public undertakings. The Dierks lumber companies, largest in the region, were in receivership for several years; other firms struggled to survive or went bankrupt. Several companies sold large blocks

[8] Interview with Fred M. Dierks, November 5, 1979.

of cutover land to the U.S. Forest Service as additions to the Ouachita National Forest. One, the Caddo River Lumber Company, sold the government nearly two hundred thousand acres of cutover at prices ranging from $1.25 to $2.60 an acre. During this time the Civilian Conservation Corps (CCC) built roads, lookout towers, phone lines and other fire control facilities on the national forest, and in areas of private landholdings as well.

Through the 1920s and 1930s, technological changes made it increasingly possible to log second growth. The pulp and paper industry had begun to utilize southern pine, and along the southern flank of the Ouachitas, International Paper Company acquired cutover lands from defunct lumber companies. Log trucks, first used in 1913, were gradually improved, and crawler tractors were introduced to pull road graders in the woods. In the 1930s both the bulldozer and the dual-wheeled log truck arrived on the scene, and "cat-truck logging" quickly became established. It required at least four thousand board feet of timber per acre to log profitably by railroad, but only five hundred board feet to log by truck. A mill operator could log tracts of timber as small as ten or twenty acres, as far as twenty miles away from the mill, and now make a profit. Logging by truck also made it possible to selectively cut only the mature trees on a tract managed for sustained yield (Lubell and Pollard 1939).

To log scattered tracts of old growth, and second growth as well, sawmill operators increasingly resorted to portable "tractor" mills, trucking the rough green lumber from these small mills to concentration yards for seasoning and finishing. The 1920s and 1930s became the heyday of the tractor mill; the total output of these small mills in the Ouachitas at times exceeded the production from larger mills in the region.

World War II helped to initiate an uptrend in prices for both lumber and timberland. A seller's market for lumber developed, and timber firms could afford to purchase cutover land and manage it for sustained yield. During the first twenty-five years after the war, large lumber companies and the Forest Service practiced and refined the techniques of selective-cut, uneven-aged management. In the Ouachitas even through the 1950s, Dierks and the Forest Service still had tracts of virgin pine, which they selectively cut. Federal, state, and private interests cooperated to suppress wildfire. Controlled burning had not yet come into use as a management practice.

During the 1960s, however, the large family-owned timber firms in the region were acquired by national forest-products corporations. The remaining lands of the Malvern Lumber Company went to the Georgia-Pacific Corporation; the Ozan

Lumber Company was purchased by the Potlatch Corporation; Dierks Forests, Inc. became a division of Weyerhaeuser Company. Including other lands owned by International Paper Company,much of the region's private commercial timberland was with these national timber firms. Already experienced in clearcutting and replanting in the Pacific Northwest and elsewhere, these companies about 1970 began to convert uneven-aged stands of timber to even-aged plantations of genetically improved pine. With computer-assisted records-keeping, forest management became a much more closely controlled undertaking. In the long perspective, however, even-aged management with the help of computers can be seen as just the latest in a series of changes that have always been leading toward ever-more-intensive use of the forest.

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THE SHORTLEAF RESOURCE

William H. McWilliams, Raymond M. Sheffield,

Mark H. Hansen, and Thomas W. Birch[1]

ABSTRACT

Shortleaf pine (*Pinus echinata Mill.*) is found throughout the South and is the second most important southern pine. The area of shortleaf stands has been declining in recent decades and shortleaf pine growing-stock volume decreases are expected in the near future. Shortleaf's decline is the result of management preferences for other pine species and reductions in the area of cutover land and retired agricultural land, once common sources of shortleaf pine acreage in the South. Shortleaf pine management should continue as an important option in regions where other pine species do poorly and on nonindustrial forests.

INTRODUCTION

Shortleaf pine is the most widely distributed of the southern yellow pines, ranging from Texas to New York (U. S. Department of Agriculture, Forest Service, 1965). It ranks second behind loblolly pine (*Pinus taeda L.*) for its contribution to total softwood volume in the South and is important to timber economies throughout most of its range. Shortleaf flourishes across the southern Coastal Plain and is known for its ability to tolerate drier upland sites, making it important in the Highlands and Piedmont province.

This paper summarizes timber statistics compiled from periodic inventories conducted by USDA Forest Service Forest Inventory and Analysis units (Forest Survey). The information was compiled in a cooperative effort between the Southern, Southeastern, North Central, and Northeastern Forest Experiment Stations of the Forest Service, with the goal of providing complete coverage of the shortleaf resource. Most of the data contained in the tables and figures are taken from the most recent surveys of Alabama (Rudis et al. 1984), Arkansas (van Hees 1980), Florida (Bechtold and Knight 1982), Georgia (Sheffield and Knight 1984), southern Illinois (Raile 1987), southern Indiana (Spencer 1969), Kentucky (Kingsley and Powell 1978), Louisiana (Rosson et al. 1986), Mississippi (Murphy 1978), Missouri (Spencer and Essex 1976), North Carolina (Sheffield and Knight 1986), Oklahoma (Murphy 1977), South Carolina (Knight and McClure 1979), Tennessee (Birdsey 1983), Texas (Murphy 1976), and Virginia (Brown 1986). Other States where shortleaf is found as a minor

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[1] Authors are Research Forester, Southern Forest Experiment Station, Starkville, MS; Research Forester, Southeastern Forest Experiment Station, Asheville, NC; Biometrician, North Central Forest Experiment Station, St. Paul, MN; and Research Forester, Northeastern Forest Experiment Station, Broomall, PA.

forest component are excluded in all but Figures 1 and 3. States where shortleaf is considered rare are Delaware (Ferguson and Mayer 1974a), Maryland (Powell and Kingsley 1980), New Jersey (Ferguson and Mayer 1974b), Ohio (Dennis and Birch 1981), Pennsylvania (Considine and Powell 1980), and West Virginia (Bones 1978). Some supplemental data are limited to the Southern and Southeastern Regions as noted.

Shortleaf's far-reaching range covers several physiographic provinces. The data in this report have been grouped into two broad provinces: the Coastal Plain province and the Highlands and Piedmont province. The Coastal Plain spans the Gulf and Atlantic Coastal Plains and includes the Hilly, Middle, and Flatlands physiographic provinces. Delta provinces along the Mississippi River, where shortleaf is rare, have also been grouped with the Coastal Plain provinces. The Highlands and Piedmont province encompasses the Ouachita Highlands, Ozark Plateaus, Interior Low Plateaus, Appalachian Plateaus, Valley and Ridge, and Blue Ridge provinces along with the Piedmont province, which lies northwest of the Atlantic Coastal Plain extending from Alabama northeastward to New York.

AREA

Forest Survey type classification is based on the relative stocking of pine and hardwood species. The shortleaf pine type is defined as forests in which pine comprises at least 50 percent of the stocking of all live trees, with shortleaf pine the most common pine (U. S. Department of Agriculture, Forest Service 1972). The shortleaf pine type is a sub-type of the loblolly-shortleaf forest type. This major type also includes the loblolly pine type, along with some lesser pine types, and is the predominant forest type of the southern pine region (Barrett 1980). Shortleaf is also an important component in the mixed pine-hardwood or oak-pine forest type. Mixed pine-hardwood stands are defined as those in which pine comprises from 25 to 50 percent of the total stocking. The most common associates of shortleaf pine are loblolly pine, oaks, hickories, and gums.

Shortleaf pine is prevalent across the South, extending into Missouri and eastward into Virginia and Pennsylvania (Figure 1). The distribution map includes all counties having timberland classified as the shortleaf forest type or in which shortleaf pine growing-stock volume[2] is found. As shown, the current distribution of shortleaf pine overextends its natural range as described by Little (1971). Planting efforts during the 1930's through the 1960's have established shortleaf in southwest Indiana and expanded its occurence in Missouri and southern Illinois.

The area of the shortleaf pine type has been declining steadily over the past 30 years. Its extent prior to that time can only be surmised since very few records exist. Early information on the shortleaf pine type is further

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[2] The volume of sound wood in the bole of shortleaf trees 5.0 inches d.b.h. and larger from a 1-foot stump to a minimum 4.0-inch top diameter outside bark, or to a point where the central stem breaks into limbs. Trees that are unmerchantable for saw logs (currently or potentially) because of defect or rot are excluded.

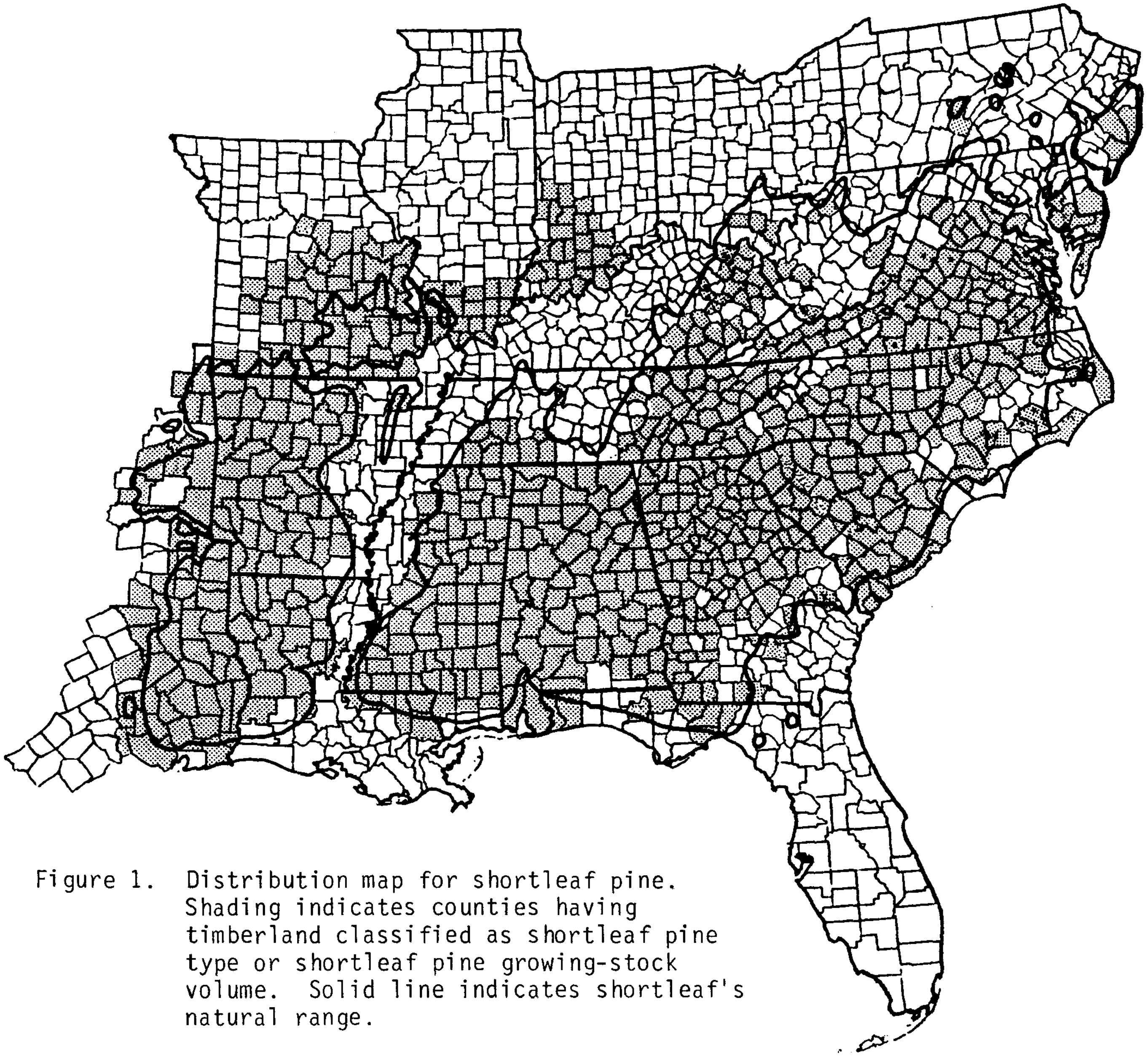

Figure 1. Distribution map for shortleaf pine. Shading indicates counties having timberland classified as shortleaf pine type or shortleaf pine growing-stock volume. Solid line indicates shortleaf's natural range.

limited since some Forest Survey records do not distinguish shortleaf from the loblolly-shortleaf forest type. An estimate based on the current distribution and trends observed over the last 20 years indicates that the shortleaf type may have occupied 16 to 17 million acres in the early 1950's. This most likely represents a peak. In the first half of the century, shortleaf expanded by populating cutover virgin forest comprised of pines mixed with hardwoods and sparsely stocked second-growth acreage that was burned repeatedly by wildfire. During the late 1940's and 1950's, additional acreage became available from retired agricultural lands (Boyce and Knight 1979).

Recent declines have been most rapid in the Southeastern region, where the acreage of shortleaf pine type went from 7 million acres in the early 1950's to 3 million acres in the late 1970's and is currently estimated to be just under 2 million acres. In the South Central region, shortleaf occupied 9 to 10 million acres around 1950 and dropped to 7 million toward the end of the 1970's. It is currently estimated to cover about 6 million acres. Data for the North Central Region indicate sharp declines for shortleaf stands and mixed pine-hardwood stands containing high proportions of shortleaf.

Major reasons for the decrease in the area of shortleaf stands include declines in sources of new stands that were prevalent in the past and the replacement of mature stands with plantations of other southern pines that exhibit more rapid growth over the first 20 years of life. Management recommendations for planting other species also affect shortleaf stands infected with littleleaf disease (*Phytophthora cinnamomi Rands*), which occurs most often on poorly drained sites with heavy soils (Hepting 1971). Other reasons include shifts from the pure pine type to mixed pine-hardwoods or hardwood types, clearing of shortleaf stands for agricultural crops and pastureland, urbanization, and losses to manmade lakes. The area of shortleaf stands will probably continue to shrink until sites capable of supporting pines that exhibit faster initial growth are converted to plantations. Shortleaf will continue to be a common associate of loblolly in stands managed naturally in the Coastal Plain and Piedmont Regions. In the Interior Highlands of West Gulf States, shortleaf will predominate where natural stand management is practiced and where owners decide to perpetuate shortleaf rather than introduce loblolly as a planted species.

Upland hardwood is the most abundant forest type in the region where shortleaf is found, while pine types are second in abundance (Table 1). The shortleaf type ranks fourth behind the loblolly, slash, and longleaf types, occupying 9.4 million acres or 14 percent of the pine type acreage and only 4 percent of the total timberland base. Shortleaf stands are most prevalent in the Highlands and Piedmont province and are especially important there because they contribute over one-fourth of the pine type acreage of that province.

For reasons discussed earlier, the bulk of the shortleaf forest (94 percent) originated from natural seeding. Planting of shortleaf is somewhat rare, but has been done in regions where cold, ice, and drought are common because shortleaf outperforms loblolly under these conditions (Williston and Balmer 1980).

Shortleaf forests are common in 16 States (Table 2). Arkansas contains the highest concentration with 2.0 million acres or 21 percent of the total shortleaf area.

Table 1.--Area of timberland where shortleaf pine is commonly found, by forest type and broad physiographic province.

Forest type	Total	Broad physiographic province: Highlands and Piedmont	Broad physiographic province: Coastal plain
	- - - - - - - - - -Thousand acres- - - - - - - - -		
Shortleaf pine:			
Natural	8,829.8	4,972.2	3,857.6
Plantation	545.2	305.7	239.5
Other pine	55,195.3	14,937.5	40,257.8
Mixed pine-hardwood	29,246.0	11,525.2	17,720.8
Upland hardwood	83,767.3	61,409.3	22,358.0
Bottomland hardwood	33,409.3	6,756.3	26,653.0
All types	210,992.9	99,906.2	111,086.7

Table 2.--Area of timberland classified as shortleaf pine type, by State.

State	Area of shortleaf pine type	State	Area of shortleaf pine type
	-Thousand acres-		-Thousand acres-
Alabama	899.4	Missouri	116.0
Arkansas	1,983.7	North Carolina	502.9
Florida	37.2	Oklahoma	765.0
Georgia	914.7	South Carolina	655.9
Illinois	45.5	Tennessee	271.3
Indiana	53.7	Texas	1,236.8
Kentucky	128.5	Virginia	146.5
Louisiana	304.2		
Mississippi	1,313.7	All States	9,375.0

Table 3.--Area of timberland classified as shortleaf pine type, by ownership class and broad physiographic province.

Ownership class	Total	Broad physiographic province: Highlands and Piedmont	Broad physiographic province: Coastal Plain
	- - - - - - - - - -	-Thousand acres-	- - - - - - - - - -
Public	1,649.9	1,251.4	398.5
Forest Industry[1]	2,147.7	990.1	1,157.6
Other private	5,577.4	3,036.4	2,541.0
Total	9,375.0	5,277.9	4,097.1

1 Includes land under long-term lease.

As with most forest resources in the east, the shortleaf type is largely controlled by nonindustrial private owners who have 59 percent of the acreage (Table 3). Forest industry owns 23 percent of the shortleaf type. Comparison with statistics for the loblolly pine type indicate forest industry lands support 34 percent of the total loblolly forest, reflecting a preference for loblolly (McWilliams and Birdsey 1984; Sheffield and Knight 1982). Public owners have 18 percent of the shortleaf type and only 7 percent of the loblolly type.

Shortleaf forests tend to be found on productive sites (Table 4). Forest Survey assesses site productivity in terms of the potential yield in cubic feet per acre of mean annual growth at the culmination of the increment in fully-stocked natural stands. Eighty percent of the area of shortleaf stands tallied were on sites capable of growing 85 cubic feet or more per acre per year.

The distribution of shortleaf acreage by stand-size class is 17 percent in sapling-seedling, 30 percent in poletimber, and 53 percent in sawtimber stands; however, the size-class distribution varies by ownership and physiographic province (Figure 2). Nonindustrial acreage of the Highlands and Piedmont province contains equal proportions of poletimber and sawtimber stands (both 39 percent), while the distribution of the Coastal Plain province is more like the overall average. Forest industry stands include higher percentages of sawtimber in both provinces. Public acreage also tends to be more mature, especially on the Coastal Plain where 80 percent of the stands are sawtimber size.

Table 4.--Area of timberland classified as shortleaf pine type, by site class[1] and broad physiographic province.

Site class	Total	Broad physiographic province: Highlands and Piedmont	Coastal Plain
	- - - - - - - - - Thousand acres	- - - - - - - - -	
165 ft^3 or more	1,112.4	519.1	593.3
120-164 ft^3	1,829.8	896.8	933.0
85-119 ft^3	4,511.5	2,037.3	2,474.2
50-84 ft^3	1,634.3	1,561.0	73.3
less than 50 ft^3	287.0	263.7	23.3
All classes	9,375.0	5,277.9	4,097.1

1

A classification of forest land based on potential yield in cubic feet per acre of mean annual growth at culmination of the increment in fully stocked natural stands.

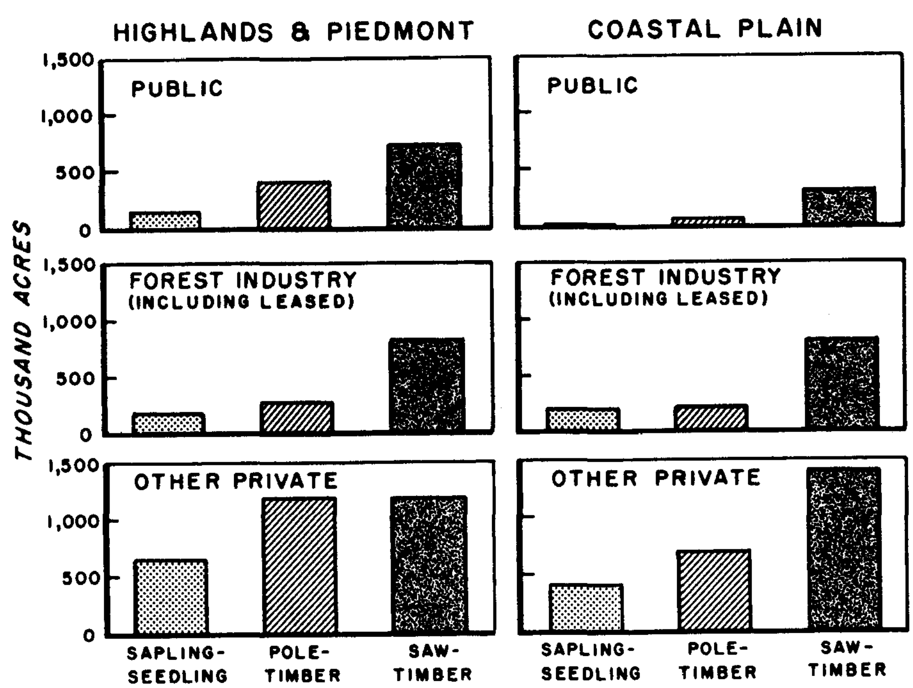

Figure 2. Area of timberland classified as shortleaf pine type, by stand-size class, ownership class, and broad physiographic province.

VOLUME

The distribution of shortleaf pine growing-stock volume highlights major shortleaf timbersheds (Figure 3). The primary shortleaf timbershed is found west of the Mississippi River in the Ouachita Highlands of Arkansas and Oklahoma and extends southward across northwestern Louisiana and well into Texas (Braun 1950). Shortleaf's abundance is also apparent in Mississippi and the Piedmont regions of Alabama, Georgia, South Carolina, North Carolina, and Virginia. When compared to an earlier map of shortleaf volume (U. S. Department of Agriculture, Forest Service 1969), the distribution appears more dense in northern Mississippi and more sparse in the Piedmont. Increases are apparent in southern Illinois, southern Indiana, and Ohio.

Results of the two most recent survey cycles of the South Central and Southeast Regions show an increase in the volume of shortleaf growing stock of only 1 percent. This trend is contrasted by significant increases in the volume of loblolly pine over the same period. The distribution of shortleaf volume by diameter class for the two survey cycles reveals that declines have occurred in the 6-and 8-inch diameter classes along with increases in the larger diameters (Figure 4). This situation characterizes a maturing forest that is not being replenished following harvest.

The current inventory shows the volume of shortleaf growing stock to be 19 billion cubic feet (Table 5). Shortleaf is found in all the major forest types within its range. Half of the shortleaf volume is in the pure type. Mixed pine-hardwoods contribute 22 percent of the shortleaf volume. Softwood volumes in these stands average 60 percent of the total volume per acre. Other pine types contain 19 percent, and hardwood types contain 10 percent of the shortleaf volume.

Two-thirds of the shortleaf growing-stock volume is concentrated in the five top-ranking States of Arkansas, Texas, Mississippi, Alabama, and Georgia respectively (Table 6). These states have a similar share of the 69 billion board feet of shortleaf sawtimber volume[3]. States not shown in Table 6 that contain minor shortleaf volumes include Maryland (3.0 MMCF, 6.8 MMBF), New Jersey (22.8 MMCF, 65.4 MMBF), Ohio (20.6 MMCF, 87.3 MMBF), and West Virginia (14.9 MMCF, 50.7 MMBF).

GROWTH AND REMOVALS

The total periodic annual growth of shortleaf pine growing stock is 1 billion cubic feet based on the most recent surveys of States where shortleaf is commonly found (Table 7). Periodic annual removals from growing stock also total 1 billion cubic feet, indicating a growth-to-removals ratio of 1.0. Removals include the volume of all trees removed from the inventory by

[3] The volume of sound wood in the saw-log portion of shortleaf trees 9.0 inches in d.b.h. and larger, from a 1-foot stump to a minimum 7.0-inch top diameter and containing at least one 12-foot saw log. Sawtimber volume is expressed in board feet International Rule, 1/4 inch kerf.

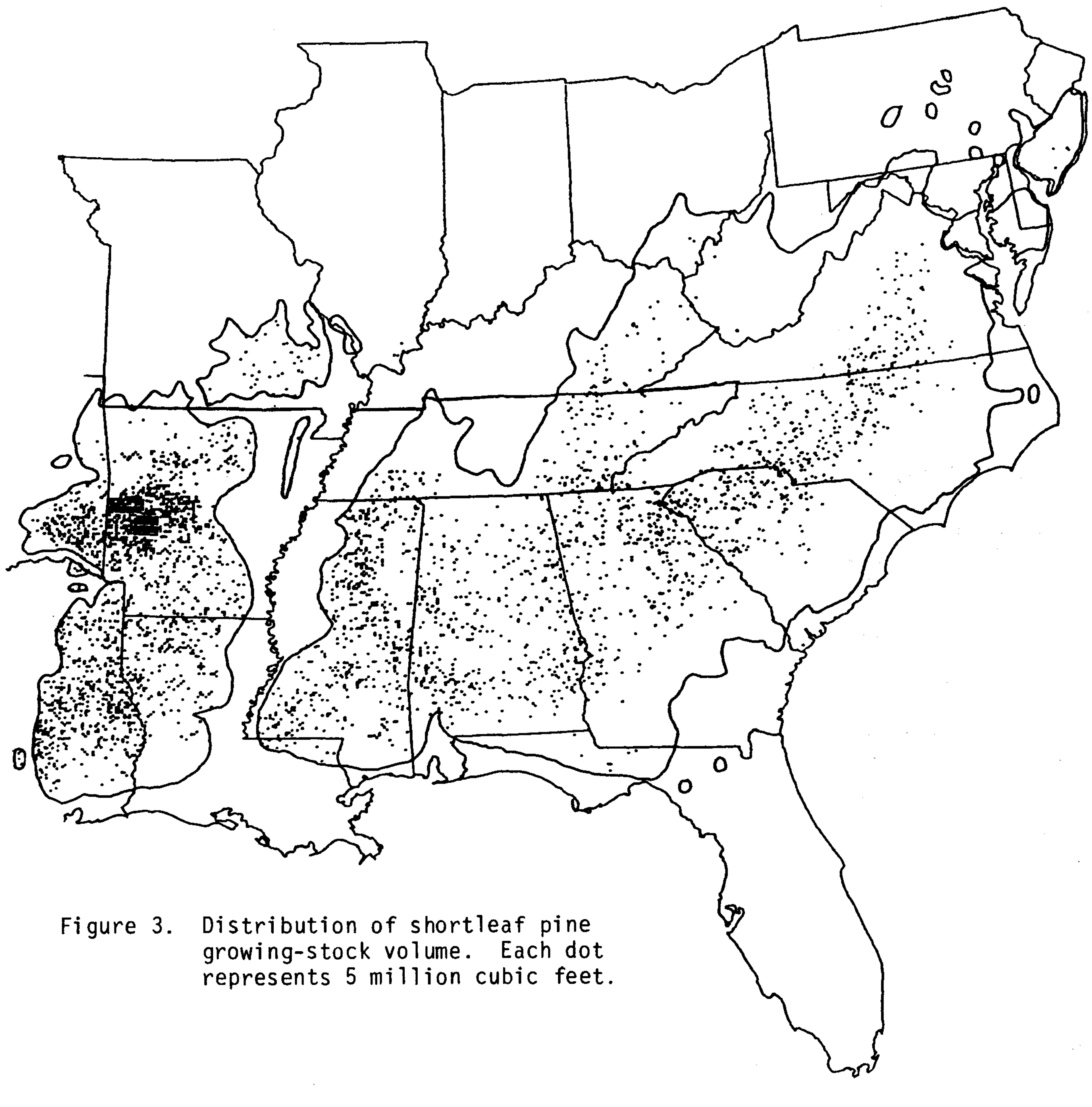

Figure 3. Distribution of shortleaf pine growing-stock volume. Each dot represents 5 million cubic feet.

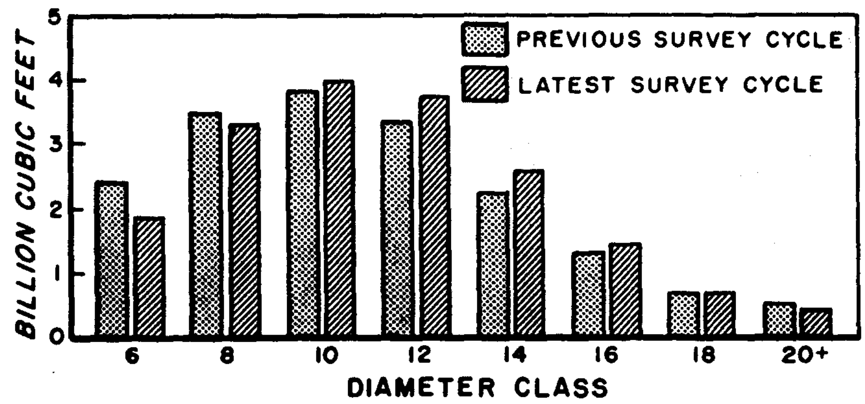

Figure 4.--Volume of shortleaf growing stock on timberland, by period and diameter class, South Central and Southeast Regions.

Table 5.--Volume of shortleaf pine growing stock on timberland, by forest type and broad physiographic province.

Forest type	Total	Broad physiographic province: Highlands and Piedmont	Broad physiographic province: Coastal Plain
	- - - - - - - -Million cubic feet- - - - - - - -		
Shortleaf pine	9,431.1	5,254.5	4,176.6
Other pine	3,592.9	1,327.3	2,265.6
Mixed pine-hardwood	4,177.4	2,147.8	2,029.6
Upland hardwood	1,815.9	1,180.3	635.6
Bottomland hardwood	34.9	14.9	20.0
All types	19,052.2	9,924.8	9,127.4

Table 6.--Volume of shortleaf pine growing stock and sawtimber on timberland, by State.

State	Volume of shortleaf pine growing stock	Volume of shortleaf pine sawtimber
	- -Million cubic feet- -	- -Million board feet- -
Alabama	2,051.2	7,180.2
Arkansas	4,088.5	16,843.4
Florida	52.8	189.1
Georgia	1,690.7	4,961.6
Illinois	63.5	193.7
Indiana	42.4	133.1
Kentucky	226.9	592.6
Louisiana	1,141.4	4,701.2
Mississippi	2,391.3	8,619.4
Missouri	303.5	1,032.4
North Carolina	1,336.7	4,166.9
Oklahoma	939.8	3,275.5
South Carolina	1,016.3	2,596.1
Tennessee	664.3	2,403.2
Texas	2,539.6	10,582.2
Virginia	503.3	1,497.1
All States	19,052.2	68,967.7

harvesting, cultural treatments, landclearing, and changes in land use --whether the tree was utilized or not. A growth-to-removals ratio of unity indicates that the shortleaf ecosystem has reached the limit of its capability for expansion of harvest without reducing growing-stock inventories. A comparable ratio for the loblolly pine ecosystem is 1.3. Some regions with ratios less than the overall average will undergo reductions in shortleaf inventories in the near future.

STAND STRUCTURE

Changes in the shortleaf stand table underlie trends in volume. Recent surveys have shown declines in the number of shortleaf trees throughout most of the South (Table 8). Especially important for shortleaf inventories is the status of saplings (trees from 1.0 to 4.9 inches d.b.h) since they represent future ingrowth. Major declines in the number of shortleaf saplings are evident in all States of the South Central and Southeastern Regions. Substantial decreases are also found well into higher diameter classes in both physiographic provinces. These conditions foretell reductions in shortleaf inventory volumes in the future. The situation seems most severe in States with more recent inventories, making forthcoming survey results especially important for monitoring the shortleaf ecosystem.

Table 7.--Periodic annual growth and removals of shortleaf pine growing stock on timberland, by State[1].

State	Periodic annual growth	Periodic annual removals	Growth-to-removals ratio
	- - - - Million cubic feet - - - -		
Alabama	130.9	129.0	1.0
Arkansas	173.5	219.2	0.8
Florida	4.3	2.0	2.2
Georgia	81.4	111.1	0.7
Illinois	1.8	1.4	1.3
Indiana	1.1	.1	11.0
Kentucky	10.4	3.8	2.7
Louisiana	74.7	56.5	1.3
Mississippi	138.2	142.4	1.0
Missouri	10.7	6.8	1.6
North Carolina	31.4	63.5	0.5
Oklahoma	52.7	44.1	1.2
South Carolina	61.3	42.4	1.4
Tennessee	55.5	22.6	2.5
Texas	133.1	130.7	1.0
Virginia	9.4	30.6	0.3
All States	970.4	1,006.2	1.0

[1] Based on the most recent surveys conducted over the past ten years.

HARVESTING AND REGENERATION

A critical factor affecting the future of shortleaf pine is the current status of regeneration on harvested shortleaf timberland. Forest Survey has collected information on harvesting and regeneration during the most recent surveys of Alabama, Florida, Georgia, Louisiana, North Carolina, South Carolina, and Virginia. Pine regeneration on harvested acreage can be considered successful if harvested pine stands remain in pine forest types. Harvesting as used here refers to stands that were clearcut. Regenerating to the mixed pine-hardwood forest type should also be considered successful since young pine stands often contain considerable hardwood stocking.

Data for pure stands of shortleaf indicate that nearly two-thirds of the harvest area was regenerated to pine and mixed pine-hardwood types; however, only 8 percent remained as shortleaf pine stands (Figure 5). Public owners succeeded in regenerating the highest proportion of harvested shortleaf stands (86 percent). Six percent of their stands remained in the shortleaf type. Nearly three-fourths of forest industry shortleaf forest was regenerated but only 2 percent to the shortleaf type. Nonindustrial owners were least

Table 8.--Percentage change in number of all live shortleaf pine trees, by broad physiographic province, State, and diameter class, South Central and Southeast Regions.

Broad physiographic province and State	Period of change	Diameter class (inches at breast height)							
		2	4	6	8	10	12	14	16+
		Percent							
Highlands and Piedmont:									
Alabama	1972-1982	-70	-46	-54	-24	-20	- 8	+ 4	+ 8
Arkansas	1969-1978	- 8	-13	-16	- 2	0	+15	+ 37	+23
Georgia	1972-1982	-61	-50	-41	-21	-17	- 9	- 1	+ 4
North Carolina	1974-1984	-62	-53	-42	-26	-18	0	+ 3	+ 4
Oklahoma	1966-1976	- 9	0	+11	+22	+46	+43	+ 31	+54
South Carolina	1968-1978	-26	-31	-14	+ 7	+24	+24	+ 13	+25
Virginia	1976-1985	-57	-36	-45	-35	-29	-16	- 19	+16
Tennessee	1970-1980	-59	-40	-39	-16	+ 4	+53	+ 28	+14
Coastal plain:									
Alabama	1972-1982	-59	-40	-39	-29	-24	-17	+ 65	0
Arkansas	1969-1978	-12	-16	-28	-29	-16	- 6	+ 7	+ 3
Florida	1970-1980	-53	-36	+34	+27	+34	+87	+186	+31
Georgia	1972-1982	-68	-52	-25	- 9	-12	-12	0	+31
Louisiana	1974-1984	-52	-44	-37	-27	- 9	- 5	+ 9	- 9
Mississippi	1967-1977	-31	-20	-13	+12	+21	+48	+ 51	+54
North Carolina	1974-1984	-60	-71	-71	-38	-23	+ 3	+ 27	+16
South Carolina	1968-1978	-27	-14	-20	-12	+34	+24	+ 4	+64
Virginia	1976-1985	-51	-29	-50	-56	-27	-56	- 37	-20
Texas	1965-1975	-22	-33	+ 4	+ 9	+34	+37	+ 28	- 6

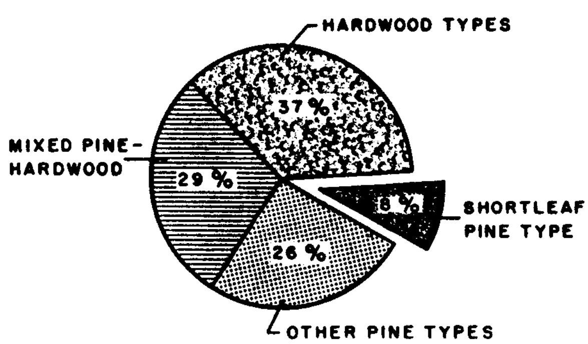

Figure 5.--Status of shortleaf pine type acreage harvested annually based on surveys of Alabama 1972-1982, Florida 1970-1980, Georgia 1972-1982, Louisiana 1974-1984, North Carolina 1974-1984, South Carolina 1968-1978, and Virginia 1976-1985.

successful at establishing pine regeneration on harvested shortleaf acreage but most successful at regenerating to the shortleaf type. Fifty-seven percent of the harvested nonindustrial stands were regenerated with 12 percent remaining as pure shortleaf stands. This relatively high percentage of regeneration to the shortleaf type indicates these owners rely more heavily on natural methods of regeneration than planting or seeding of other pine species. Upcoming survey results for the top three shortleaf States of Arkansas, Texas, and Mississippi should provide valuable information on the regeneration of harvested shortleaf acreage.

CONCLUSIONS

The foregoing analysis confirms what may have been suspected concerning the destiny of shortleaf pine in the near future. Prior to the 1950's, shortleaf proliferated by naturally seeding onto cutover and burned sites and abandoned farmlands. These pure stands of shortleaf and shortleaf mixed with hardwoods have matured and are currently being harvested. Harvested stands are regenerated primarily to loblolly where feasible on intensively managed land (Lambeth et al. 1984; Wells and Rink 1984), and are often left to regenerate naturally on other timberland. This has caused decreases in the area of the shortleaf type and a peak in shortleaf inventory volumes. Information on forest drain, stand structure, and regeneration indicate that shortleaf inventories will fall in coming years. Shortleaf volume is currently 22 percent of the total volume of the four major southern pines compared to a 57 percent share for loblolly. Slash pine and longleaf pine account for 14 percent and 7 percent respectively. Information from the previous survey cycle showed shortleaf with 24 percent and loblolly with 54 percent. While shortleaf's portion has dropped slightly, it should maintain its relative position as second behind loblolly. Shortleaf pine will continue to be an important component in naturally managed pine stands and in mixed pine-hardwood and hardwood stands on unmanaged sites.

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ECOLOGY OF SHORTLEAF PINE

James M. Guldin [1/]

ABSTRACT

Shortleaf pine (Pinus echinata Mill.) occupies the broadest natural range of all the southern pines, and is found across a diverse range of geography, soils, topography, and habitats. Individual shortleaf trees achieve their best development on deep, well-drained soils of the Upper Coastal Plain, but shortleaf pine communities are most prominent in the Ouachita Highlands of the West Gulf Region. Two major ecological issues confront shortleaf pine -- the susceptibility of shortleaf pine stands to depredations of acid deposition, and the ecological tradeoffs underlying the planting of loblolly pine (P. taeda L.) on shortleaf pine sites which are north of loblolly's natural range.

OVERVIEW

Shortleaf pine (Pinus echinata Mill.) is the most widely distributed of all of the major southern pines, growing in 22 states over more than 440,000 square miles (Lawson and Kitchens 1983). Yet, it is also perhaps the most maligned of the southern pines as well. Reasons for this silvicultural disrespect center upon its slow growth rate, the difficulty in obtaining regeneration (both naturally and artificially), and its susceptibility to certain pathogens such as littleleaf disease (Phytophthora cinnamomi Rands). It is no wonder that some foresters look upon the species as little more than a resinous weed occupying sites better utilized for one of the 'real' southern pines.

However, undue concern over these limitations may mask the inherent silvicultural potential of shortleaf pine. Stem and crown form are generally better than in the other southern pines, and the species is a good pruner (Dorman 1976). It is unusually free from serious diseases, and is particularly resistant to fusiform rust (Cronartium fusiforme Hedg. & Hunt) (Hepting 1971). It is generally less susceptible to the adverse effects of ice, snow, and cold temperatures than any of the other major southern pines. Opportunities for genetic improvement in shortleaf pine include breeding for enhanced volume production, drought resistance, or the incorporation of desirable traits such as fusiform resistance in hybridization work with other southern pines (Dorman 1976).

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Taxonomically, shortleaf pine is in the subgenus *Pinus*, section *Pinus*, and subsection *Australes*, which also includes longleaf (*P. palustris* Mill.), loblolly (*P. taeda* L.), spruce (*P. glabra* Walt.), pitch (*P. rigida* Mill.), pond (*P. serotina* Michx.), table-mountain (*P. pungens* Lamb.), slash (*P. elliottii* Engelm.), Caribbean (*P. caribaea* Morelet), West Indian (*P. occidentalis* Sw.), and Cuban (*P. cubensis* Griseb.) pines. The other common southern pines, Virginia pine (*P. virginiana* Mill.) and sand pine (*P. clausa* (Chapm.) Vasey ex. Sarg.), are in the subsection *Contortae* (Little and Critchfield 1969).

A thorough literature review of shortleaf pine has been published by Haney (1962). Silvics of the species have been described by Fowells (1965) and updated by Lawson and Kitchens (1986); the genetics of the species have been reviewed by Dorman (1976). Silvicultural systems common to shortleaf pine have been described by Walker and Wiant (1966), and Lawson and Kitchens (1983).

NATURAL RANGE

Geography

Shortleaf pine occupies the broadest and most geologically varied habitats of any of the pines in the southeastern United States (Critchfield and Little 1966). Comparing its natural range to the physiography of the region (Fenneman 1946, USDI 1970), shortleaf pine is found in all of the states of the Atlantic Coastal Plain from southwest Connecticut and southeast New York to east Texas and southeast Oklahoma. In the Appalachian Highlands, the species is found in the Piedmont, the Blue Ridge, the Valley and Ridge, and the Appalachian Plateaus from isolated populations in Pennsylvania southwestward to northern Mississippi. Its range skirts the southern edge of the Interior Low Plateaus of the Interior Plains Division in Kentucky, Tennessee, and northern Alabama. However, shortleaf pine achieves its best community development generally west of the Mississippi River in the Ouachita and Ozark Highlands, extending from the isolated population in southwest Illinois, through Missouri and Arkansas, and into eastern Oklahoma.

Climate

Climate varies widely across the natural range of shortleaf pine. The southeastern United States is characterized by warm and humid summers, mild winters, and abundant rainfall. However, within the range of shortleaf pine, wide variations exist in temperature and rainfall (Wahlenberg and Ostrom 1956).

Mean annual precipitation varies from 40 inches along the western and northern edges of the natural range to 64 inches along parts of the Gulf Coast. Variation is between 40 and 48 inches through the northeastern half of its range, and from 48 to 56 inches in most of the southwestern half (USDI 1970). Annual snowfall is also quite variable, ranging from virtually none in the southernmost part of the range to as much as 80 or more inches in the Appalachian Highlands.

Temperatures are similarly variable. Over shortleaf's range, average annual temperatures vary from 45°F. to 75°F. The 50°F. average annual temperature isotherm approximately parallels the northern limits of the natural range (Lawson and Kitchens 1983).

The interrelationship between temperature and precipitation is probably ecologically significant with respect to shortleaf pine. In the northeastern part of its range, temperature varies considerably with the seasons, but rainfall is more or less uniformly distributed throughout the year. Conversely, in the southwestern part of its range, temperatures are warmer and less variable, whereas precipitation occurs primarily during the winter and spring months; in summers, when annual temperatures are at their peak, precipitation is sporadic. Patterns such as these not only define shortleaf's physiological environment, but also undoubtedly affect shortleaf's ability to compete with other species.

Soils and topography

As might be expected from its extensive range, shortleaf pine occupies a wide variety of soils (USDI 1970). It occurs most commonly on soils with prominent clay textures in the surface or, especially, subsurface horizons rather than on sandy soils. Across the Coastal Plain, it is found primarily on Paleudults. These soils are generally moist, with low levels of subsurface organic matter and a thick horizon of clay accumulation without appreciable weatherable minerals. In the Piedmont, it is typically found on Hapludults which are characterized by a thin subsurface horizon of clay accumulation and/or a subsurface horizon having appreciable weatherable minerals. In the Appalachian Highlands, soils are generally Dystrochrepts which are moist, low in exchangeable bases, and have no free subsurface carbonates. Other soils in this subdivision which support shortleaf include scattered Fragiudalfs, Hapludalfs, and Paleudalfs characterized by subsurface clay horizons.

Individual shortleaf pine trees attain their best development on deep, well-drained sandy loam soils in the uplands of the Coastal Plain (Lawson and Kitchens 1983). Within narrower geographic subdivisions, shortleaf pine has been reported to attain its optimal development on deep soils in the Ozark Highlands of Arkansas and Missouri (Graney and Ferguson 1972) and southern Illinois (Gilmore 1963), and on deep soils of the Piedmont from North Carolina to Alabama, Georgia, and Virginia (Coile 1952, Coile and Schumacher 1953, Della-Bianca and Olson 1961, Kormanik 1966, Georgia Ike and Huppuch 1968.

Unfortunately for shortleaf enthusiasts, other species also exhibit high growth rates on such sites. Toward the southern part of its range, loblolly pine reaches its best development on similar soils (Baker and Balmer 1983), and tends to predominate in mixed stands by virtue of its superior growth rate. In the upland areas, shortleaf pine occupies deep soils only temporarily, maintaining dominance over the succeeding oak-hickory climax type (White 1980a).

Topographic factors associated with soil depth have also been reported as being significantly related to the development of shortleaf pine. In the Ozark Highlands, site quality increased as slopes went from convex to concave, as aspect was increasingly oriented from the south and southwest to the north and northeast, and as latitude generally decreased (Graney and Ferguson 1971, 1972). Similar trends were noted in the Georgia Piedmont, where site quality for shortleaf pine increased with decreasing elevation, lower slope position, and increasing orientation to the north and northeast aspects (Ike and Huppuch 1968).

Plant community associates

The recent reclassification of forest cover types (Eyre 1980) places shortleaf pine as a major component of three forest types -- the shortleaf pine type (#75), the loblolly pine-shortleaf pine type (#80), and the shortleaf pine-oak type (#76). Shortleaf pine is a varyingly minor component in 15 other cover types (Eyre 1980, Lawson and Kitchens 1986), typically in association with loblolly, longleaf, pitch, Virginia, and occasionally eastern white (P. strobus L.) pines, as well as the many species of more xerophytic oaks throughout the Appalachian region. Shortleaf is undoubtedly occasionally present in association with other species as well. This cosmopolitan occurrence is not surprising in light of its broad range and varied habitat.

Ecological implications

In summary, researchers have implicated site quality for shortleaf pine with soil moisture. Individual shortleaf pine trees attain their physiologically optimal development on deep soils in advantageous topographic positions, most notably in the Upper Coastal Plain. On these sites shortleaf is typically outcompeted by faster-growing associates such as loblolly pine. But through a variety of poorly-understood traits, shortleaf is not completely excluded from such sites; it persists as a minor component of varying importance in natural mixed stands.

As sites become increasingly thin-soiled, oriented to more extreme topographic exposures, and subject to increasingly harsh climatic conditions, site quality for shortleaf pine decreases. Yet, the ecological importance of shortleaf pine in plant communities increases. Reasons for this might include shortleaf's larger root system or its lower demand for soil nutrients (Zak 1961), or its greater tolerance of site disturbances such as fire (Bramlett 1980, White 1980b), than its common associates. In the absence of disturbance, or on better sites, hardwood species (particularly the longer-lived oaks) will eventually outcompete shortleaf. But in the presence of either natural or human disturbance, the succession to hardwoods will be arrested, and shortleaf will be more likely to successfully reestablish itself.

In the Ouachita and Ozark Highlands, ecological conditions are so unfavorable for loblolly pine that it reaches the northerly limits of its natural range in the lower foothills of the southern part of the Ouachita Plateau. Further, particularly on poorer sites, the competitive abilities of hardwood species are limited by unfavorable physiographic and edaphic conditions and by disturbances such as drought and fire. Perhaps not coincidentally, shortleaf pine as a forest type reaches its most extensive development in this region, occurring in pure stands over the largest areas, and having the highest stand volumes, of any region throughout its natural range (Fowells 1965, Sternitzke and Nelson 1970).

A hypothesis regarding the prominence of shortleaf pine in the Ouachitas can be drawn from these considerations. To the south, shortleaf's dominance is limited by superior competitive associates, most notably loblolly pine. To the north, it is limited by climatic, physiographic, and ecological conditions in which species such as the oaks and interior pines are able to gain competitive advantage. Shortleaf is generally the most successful overstory species in those areas where climate and physiography limit the other southern pines, and where instability of moisture and nutrient supply conspire against its oak-hickory associates from the northeast. The region where these factors allow shortleaf to most prominently express its species individuality is in the Ouachita Highlands.

LIFE HISTORY

Reproduction

Shortleaf pine is monoecious, with male and female flowers borne on the same tree. Trees begin to produce seed at about age 20, though earlier fruiting has been reported (Fowells 1965). Some seed is produced every year, and three-year cycles of seed production are commonly reported

(Yocom and Lawson 1977). One can expect good seed crops every 3 to 6 years in the southwestern range of the species, and every three to ten years in the northeastern range (Lawson and Kitchens 1983).

Flowering in shortleaf pine occurs from March to April, cones ripen from October to November, and seedfall occurs fairly quickly upon ripening (USDA 1974). The earlier phenologies occur in the southern part of its natural range. Hybridization with other pines, particularly loblolly pine, is thought to occur rather extensively (Bilan 1966, Hare and Switzer 1969), although many putative hybrids are thought to more closely resemble shortleaf than loblolly pine. Some workers have suggested that if hybridization is occurring, it is via the introgression of loblolly genes into shortleaf populations rather than vice versa (Bhat and Hicks 1976). The most obvious trait promoting reproductive isolation of shortleaf pine from loblolly pine is non-synchronous flowering (Cotton et al. 1975).

Shortleaf has smaller cones and seed, and fewer seed per cone, relative to other southern pines. Data indicate approximately 35 pounds of cones per bushel, and seed ranging from 2 to 3 pounds per 100 pounds of cones; these values are roughly the same as for loblolly (USDA 1974). A bushel of shortleaf cones produces from 0.4-1.1 lb of seed per bushel, compared to from 0.6-1.3 lb for loblolly. In a pound of shortleaf seed, one can expect between 32,100 and 72,900 seeds, whereas loblolly will have 12,300-26,400 seed per lb (USDA 1974). Shortleaf seed have germinative energies of between 81 and 88 percent, germinative capacity of 90 percent, and viability in cold storage of up to 35 years (USDA 1974).

Establishment and early growth

Autumn dissemination results in stratification of the seed during the winter months. Germination then commences in early spring (Fowells 1965) and, like other pines, is most assured when the seed is on exposed mineral soil. Establishment is best if a small amount of overstory shade is present to prevent seedling dessication, particularly on exposed sites (Lawson 1979).

Seedlings develop a characteristic J-shaped crook near the base at an early age, usually within 2 to 3 months of germination. Axillary buds form at this crook, and provide the tree with the rather unique ability to sprout in the event of mortality of the upper stem (Chapman 1942, Fowells 1965). This characteristic might contribute to the ability of shortleaf pine to maintain itself in mixture with loblolly pine on the deep, well-drained sandy loams of the upper Coastal Plain.

Shoots of the seedlings develop slowly, as the plant invests its photosynthetic production in development of its root system. Growth in the species is multinodal; most growth is completed by July, but shortleaf will respond to favorable late-season precipitation by resumption of height growth (Fowells 1965). Average annual growth rates of saplings have been reported as ranging from 1 to 3 feet (Lawson and Kitchens 1986).

Stand development

Shortleaf pine is intolerant of shade. Overstory competition generally inhibits the development of reproduction. However, the species will persist in exceedingly dense stands, and responds to release at older ages (Fowells 1965).

Because of its intolerance to shade and the ecology of disturbance, shortleaf pine most commonly develops in even-aged aggregations. The development of a hardwood stand beneath a shortleaf overstory frequently follows, although depends upon overstory density and absence of disturbances such as fire (White 1980a). While the species is infrequently managed to its biological capabilities, individual stems can attain sizes of 3 feet in diameter, 120 feet in height, and 150 years in age, with larger and older veterans reported (Harlow and Harrar 1969).

IMPLICATIONS FOR CONTEMPORARY RESEARCH

Within the realm of the ecology of shortleaf pine, the last decade has not been a fruitful period for promoting an enhanced understanding of the species. But society's pressure on the use of forests for non-timber resources will undoubtedly increase in the future, and these needs must be satisfied on an ever-decreasing forest land base. In the future, available forest land must be used efficiently, and in harmony with other uses. From this perspective, a new consideration of the ecology of shortleaf pine may be in order.

Areas of contemporary research which would undoubtedly be of value are those relating to both acid deposition and a further understanding of the ecological interrelationships between loblolly and shortleaf pine. These concerns can be effectively illustrated using the shortleaf forests of the Ouachita Mountains.

Acid deposition

Acid deposition encompasses two related phenomena, that of the deposition of wet precipitation (familiarly known as acid rain) and dry deposition, which includes aerosol and particulate deposition. It has been implicated in observations of forest decline both in Europe and the United States. Among the many hypotheses which attempt to explain the relationship between forest decline and acid deposition (Schutt and Cowling 1985), two have become the focus of international scientific inquiry.

The first hypothesis suggests that air pollution directly causes a decrease in net photosynthesis in the tree, which, in association with other secondary effects, results in the tree being afflicted with an overall debilitating syndrome (Schutt and Cowling 1985). The second hypothesis suggests that the problem is in the displacement of exchangeable bases by acids in the soil, resulting in both the loss of those cations by leaching and the increasing availability of aluminum in the soil as soil pH becomes increasingly acid. The aluminum then interferes with normal uptake of nutrients (Matzner and Ulrich 1985). In either case (or both, if concurrently occurring), the result is reduced tree vigor and, ultimately, mortality.

Large areas through the heart of the range of shortleaf pine are thought to be highly susceptible to acid deposition. The problem is expected to be particularly acute in those soils which are low in exchangeable bases and organic matter. Currently, Arkansas is thought to be at the fringe of the region affected by acid precipitation in North America. As such, it represents an opportunity to provide baseline ecological data on normal ecosystem processes in the absence of acid deposition. If acid deposition becomes more widespread and eventually encompasses Arkansas, then such baseline data will serve as an invaluable ecological benchmark for studying the effects of whatever forest decline which might result. In accordance with these ideas, researchers in Arkansas are initiating a long-term project to monitor conditions in this state, so as to better understand and document the potential ecological damage which will result as the West Gulf Region becomes increasingly exposed to acid deposition (Beasley 1986).

Competitive interrelationships of loblolly and shortleaf pine

The ecological interrelationships between loblolly and shortleaf pine are readily apparent in Arkansas. West of the Mississippi River bottomlands, loblolly pine is found in Louisiana, east Texas, and southern Arkansas (Critchfield and Little 1966). Shortleaf pine is also found in Louisiana and east Texas, but extends northward throughout western and northwestern Arkansas into eastern Oklahoma and southern Missouri (Critchfield and Little 1966).

Westward migration of these species is most likely limited by some fundamental climatic factor, as evidenced by the approximately congruent demarcation of the range of the two pines in east Texas. Most prominent is an increasingly xeric environment, which exerts an effect on both growth and reproduction. Factors affecting growth include increased competition from more drought-tolerant species such as post oak (Quercus stellata Wangenh.); factors affecting reproduction include smaller and increasingly rare seed crops, and an increasingly dry and hostile environment for seedling establishment and survival (Bilan and Stransky 1966, Schneider and Stransky 1966, Eneim and Watterston 1970).

The environmental factors limiting northern expansion of the two species are more complex. The northern boundary of the natural range of loblolly is a sharp demarcation across central Arkansas; shortleaf extends into Missouri. The reason for the difference is not clear. Critical factors might include temperature (Hocker 1956, Yates and Cullom 1973), cold-related damage (Meade 1951, Shoulders 1952, Boggess and McMillan 1954, Shepard 1975, Shepard 1978, Burton 1981), soils and surface geology (Yates and Cullom 1973), soil moisture (Phares and Rogers 1968, Graney and Ferguson 1971, Shoulders and Tiarks 1980), and actual transpiration (Manogaran 1975).

These ecological speculations relate directly to a major silvicultural issue in Arkansas -- the practice of planting loblolly pine in areas which are at the limit or to the north of its natural range. In plantation comparisons through age 20, loblolly has been reported to outgrow shortleaf in southwest Arkansas (Meade 1969), the Arkansas Ozarks (Meade 1951), east Texas (Chandler et al. 1943), northern Mississippi (Williston 1958, 1972), western Tennessee (Williston 1959, 1972), and southern Illinois (Gilmore and Gregory 1974). Improved strains of loblolly pine show the potential for gains of 8 feet in site index and as much as 25 percent in volume over local sources of loblolly in southern Arkansas (Grigsby 1973, 1977, Wells and Lambeth 1983). Thus, it is likely that planting improved strains of loblolly pine in areas to the north of its range will continue, though with increasing effort to delineate exactly which sites have a high potential for risk (Lambeth et al. 1984).

Why, then, does the natural range of loblolly stop where it does? Ecologically, some natural barrier may act as an impediment to either growth or reproduction. A growth impediment would be the rare disturbance severe enough to kill loblolly, but not shortleaf, over broad areas. Extensive drought or heavy ice storms might be appropriate examples of this. Such disturbances would, in the long run, require an assessment of risk in corporate management strategies. By way of example, loblolly plantations established north of its range have not all been successful. In newly-established plantations subject to severe drought, widespread seedling mortality can result (Lambeth et al. 1984). Older plantations are also subject to mortality, as has been reported when mild-climate seed sources planted in an area subject to severe climatic conditions undergo a sudden stressful climatic event, such as extended drought (Wells and Lambeth 1983, Wells and Rink 1984, Wells 1985). As a result, the use of local seed sources on sites subject to environmental stress is becoming an increasingly accepted recommendation (Long 1980, Wells 1983).

Alternatively, a reproduction impediment would be a disturbance which causes failures in either seed production or seedling establishment. Drought may affect quality and viability of seed produced, as appears to be the case in east Texas (Bilan and Stransky 1966). Cold damage to newly-emerged female strobili has been noted in shortleaf pine (Campbell 1955, Schoenike 1955); similar damage could occur to loblolly pine strobili, which are known to flower earlier than shortleaf (Dorman and Barber 1956). Heavy rains during pollen release may wash pollen from the air, resulting in smaller crops of seed (Schoenike 1955, Boyer 1966). If impediments such as these are the major limitation for the northerly natural dissemination of loblolly pine, then planting the species to the north of its natural range, and thus circumventing the impediment, might be successfully accomplished.

Conclusion

Work on the ecological characterization of shortleaf pine in the past decade has been minimal, reflecting the gradually declining interest in management of the species. However, opportunities currently exist which might allow the next decade of ecological research to be more fruitful. Baseline ecological studies of shortleaf pine stands will quantify the long-term effects of acid deposition, and will be of international scientific interest. The ecological interrelationships of loblolly and shortleaf pine, especially on shortleaf pine sites directly to the north of loblolly's natural range, have important implications for contemporary forestry. Research such as this may help foresters to better understand shortleaf pine, and will go a long way to enhance the professional respect in which foresters hold the species.

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SITE QUALITY RELATIONSHIPS FOR SHORTLEAF PINE

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ABSTRACT

Existing information about site quality relationships for shortleaf pine (Pinus echinata Mill.) in the Southeastern United States is reviewed in this paper. Estimates of site quality, whether from direct tree measurements or indirect estimates based on soil and site features, are only local observations for many points on the landscape. To be of value to the land manager, a system of site quality evaluation based on identifiable units of the landscape must be devised. Physiographic site classification systems may provide the basis for reliable site quality evaluation in the Southeast.

INTRODUCTION

Shortleaf pine has the widest range of the southern pines. Its botanical range is greater than 400,000 square miles and extends over 22 states. It grows naturally on most upland soils and physiographic divisions of the Southeastern United States.

Shortleaf pine is adapted to a variety of soil and site conditions resulting in considerable variation in productivity throughout its range. Site indexes at age 50 can vary from more than 100 feet on deep, well-drained sandy loams of stream bottoms of the Upper Coastal Plain to nearly 30 feet on shallow, rocky, or clayey soils in the western portions of the Ozark and Ouachita Mountains (Murphy and Beltz 1981, Graney 1974, Graney and Burkhart 1973).

Yield and tree quality of shortleaf pine vary greatly with site quality. To gauge returns from silvicultural treatments and to select a species for management on a given site, forest and managers need reliable site quality estimates for shortleaf pine and major associated species. Information about site quality relationships for shortleaf pine is limited mainly to the eastern and western portions of its range (Carmean 1975). Few, if any, additional results on shortleaf pine site quality have been published since the mid-1970's.

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Site quality is usually expressed as site index (the height of the dominant and codominant trees at an index age of usually 25 or 50 years), which can be measured either directly by site curves or species comparisons or indirectly by soil-site relationships and by soil survey or site classification methods.

DIRECT MEASUREMENT

Site Index Curves

With the site index curve method of direct estimation, height and age measurements from free-growing dominant and codominant trees are compared with published site index curves or tables to estimate how tall the trees were or will be at the index age. The site index curve method is both simple and accurate when suitable trees and stands exist for measurement and reliable site index curves and tables are available.

In addition to the regional natural stand shortleaf pine curves in Miscellaneous Publication 50 (USDA Forest Service, 1929), local site index curves have been developed for natural shortleaf pine stands in the Piedmont (Coile and Schumacher 1953), the Ouachita Mountains of Arkansas and Oklahoma (Graney and Burkhart 1973), and the Ozark Highlands of southern Missouri (Nash 1963, Graney and Popham[2]). Site index curves have also been developed for shortleaf pine plantations in southern Illinois (Gilmore and Metcalf 1961, Gilmore 1979), the Interior Uplands of Tennessee, Alabama, and Georgia (Smalley and Bower 1971), and the Ozark Highlands of southern Missouri.[2] The importance of accurate localized curves has been indicated by several studies showing that height growth patterns for pine and hardwoods may vary considerably by species, locality, soil condition, and site index class (Carmean 1972, Graney and Burkhart 1973, Graney 1976, Zahner 1962).

Significant errors caused by inaccurate curves are most likely in very young or very old stands. If uncertainty exists as to the reliability of regionwide or local harmonized curves, site index measurement trees as near the index age as possible should be selected to minimize errors. Also, using trees appreciably younger or older than the main stand could cause errors in site index estimates, because such trees often have height growth patterns different from those of the main stand.

Graney and Burkhart (1973) found that height growth patterns for natural shortleaf pine stands in the Ouachita

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[2]Graney, D. L. and Popham, T. Site index curves for shortleaf pine in Missouri. Unpublished manuscript.

Mountains differed from those indicated by the curves of Coile and Schumacher (1953) and of Miscellaneous Publication 50 (USDA Forest Service, 1929) and that the pattern of growth varied by site index class. For site index classes 40, 60, and 80, the local curves and the regional curves agreed fairly well for all sites and ages older than 50 years. For younger ages, the Ouachita Mountain and Miscellaneous Publication 50 curves are similar for poor sites, but Miscellaneous Publication 50 curves tend to overestimate site index on medium to good sites. The curves of Coile and Schumacher (1953) underestimated site index for all site index classes at stand ages of 35 years or less.

Site index curves (25-year base) constructed from tree section data representing 200 shortleaf pines in 99 plantations in southern Missouri were compared with curves for plantations in the Interior Uplands (Smalley and Bower 1971) and with 25-year base curves for natural stands in the Ouachita Mountains (Graney and Burkhart 1973). Except for poor sites, both the Interior Uplands and Ouachita Mountains curves produce accurate estimates in Missouri plantations between ages 15 and 30. However, for younger and older plantations, errors of 3 to 5 feet could occur. On medium to good sites, the rate of height growth declined more rapidly in Missouri plantations than for the pines in the other regions. This decline in rate of height growth should be carefully considered when making long-term projections of plantation yields. For example, the mean site index (25-year base) of the 99 plantations sampled in southern Missouri was 5.5 feet greater than the mean of 76 natural stands sampled on similiar sites in the same area. When plantation heights at age 25 were projected to age 50, the average site index for plantations was nearly 10 feet higher than the measured site index for the 50-year-old natural stands, and many plantations were assigned the unlikely site index of 80 to 85 feet.

Species Comparisons

Many even-aged stands are suitable for site index measurement, but they may not contain shortleaf pine in the dominant or codominant crown classes. In some areas, the shortleaf pine site index can be estimated by measuring the site index of existing species and then using comparison graphs or equations to determine the site index of shortleaf pine. Such graphs or equations are available for shortleaf pine and several associated species in the Piedmont of Virginia, North Carolina, and South Carolina (Olson and Della-Bianca 1959) and the Southern Appalachians (Doolittle 1958). Equations comparing shortleaf and loblolly pine in mixed stands have been developed for the Piedmont of North Carolina (Coile 1948) and the Coastal Plain of northern Louisiana and southern Arkansas (Zahner 1957, 1958). All comparisons have shown that, except on poor sites, the site index for shortleaf pine growing in mixed stands tends to be lower than the site index of associated pine and hardwood species. Site index differences between shortleaf and loblolly in mixed stands are usually 10 to 15 feet on better sites in the Carolina Piedmont area and 0 to 10 feet, depending on the soil and site condition, in the western part of the range (Walker and Wiant 1966). In the Arkansas and Missouri Ozarks, where summer droughts and high soil moisture deficits are common, the shortleaf pine site index equals or exceeds values for associated oak species on all but the best sites. On sandy soils common to the broad, gently sloping ridges in the Boston Mountains of Arkansas, the site index of shortleaf pine averages 6 to 10 feet higher than the site index of white, black or northern red oaks (*Quercus alba* L., *Q. velutina* Lam., *Q. rubra* L.) (Graney 1976).

INDIRECT METHODS

Where suitable site index trees are not available, land managers need methods to estimate site quality that can be used regardless of species composition or existing stand conditions. Soil-site techniques, soil survey, and site classfication methods have received the most emphasis as indirect methods of site quality estimation.

Soil-Site Relationships

The most recent comprehensive review of forest site quality evaluation in the United States listed 24 papers on soil-site relationships for shortleaf pine and associated species (Carmean 1975). However, even with the wealth of information contained in this summary, site relationships for the species are not well understood, because shortleaf pine covers a wide geographic range that includes extreme variation in physiography, soils, and climate. The soil-site studies, however, have provided some general trends concerning the soil and topographic site features most often associated with differences in shortleaf pine site quality. Most upland tree species respond similarly to the same general site conditions although the degree of response for any one site factor can vary widely among species and with other interacting soil, topographic, or climatic conditions.

Soil features most often correlated with shortleaf pine site quality are surface soil thickness; depth to a restricting, mottled, or less permeable horizon; surface soil texture; subsoil texture; and subsoil consistency. The surface soil is generally considered to be most favorable for fine root development and absorption of nutrients and moisture. The relationship between surface soil thickness and site quality is usually curvilinear; where surface soils are shallow, small increases in surface soil thickness can cause large increases in site quality. Coile (1948) found that shortleaf pine site index increased rapidly as the thickness of the A horizon of North Carolina Piedmont soils increased from less than 1 inch to 6 or 8 inches. The site index changed little with increases in thicknesses greater than 8 inches. For well-developed Coastal Plain soils in Louisiana and Arkansas, Zahner (1957, 1958) found that shortleaf pine site index increased with increases in surface soil thickness up to 20 inches, then declined for thickness greater than 20 inches.

The best shortleaf pine sites are usually on well-drained, medium-textured soils. Texture and stone content affect the levels of available moisture, nutrients, drainage, and aeration. Thus, coarse-textured soils generally have lower site qualities because soil moisture holding capacity and nutrient levels are limited. Medium-textured soils make good sites because they have adequate available moisture and nutrient levels, good soil structure, internal drainage, and sufficient aeration, all of which favor root development. Fine-textured soils generally have adequate soil moisture and nutrients, but they are often of lower site quality because they commonly have a dense clay subsoil with poor structure, internal drainage, and aeration. In the southern Piedmont, the incidence of littleleaf disease (*Phytophthora cinnamomi* Rands) is associated with fine-textured, plastic subsoils having poor internal drainage (Copeland 1949).

Topographic features affecting shortleaf pine site quality are aspect, slope steepness, slope position, slope shape, and elevation. The best shortleaf pine sites are generally on north- or east-facing, gently sloping, concave, or lower slope positions, whereas poor sites are on narrow ridges and south- or west-facing, steep, convex upper slopes. Topographic features are often closely correlated with soil depth and profile development, amounts of available soil moisture and nutrients, and microclimate (Carmean 1975,; Lee and Sypolt 1974). Generally, on rough hilly and mountainous terrain, topographic features are more closely correlated with site quality; on more level terrain, soil variables are more important in determining site quality.

On mountainous terrain, aspect is strongly correlated with shortleaf pine site quality. In the Ozark-Ouachita Mountains the site index of shortleaf pine on north aspects averaged 4 to 7 feet higher than on south aspects (Graney 1976, Hartung and Lloyd 1969). In the Georgia Blue Ridge Mountains, shortleaf pine site index averaged 10 to 20 feet higher on north than on south aspects (Ike and Huppuch 1968).

Slope position and slope shape are related to many of the soil properties that have been correlated with shortleaf pine quality. Midslopes, lower slopes, and concave slopes generally have deep, colluvial soils with a relatively thick surface horizon. Upper slope soils are usually shallow and have a relatively thin surface horizon. In mountainous areas with "bench and bluff" topography, upper and lower slopes alternate along the entire length of mountain slopes. In such situations, site quality changes significantly within a distance of a few feet, and slope shape and slope position must be integrated to accurately define the relationship between site quality and topographic features (Graney 1976, 1977).

In the mountains of western Arkansas and northern Georgia, shortleaf pine site index was significantly lower at the higher elevations. Site index of shortleaf pine at elevations higher than 2,000 feet in the Boston and Ouachita Mountains of Arkansas and Oklahoma averaged 4 feet lower than site index on lower mountain slopes (Graney and Ferguson 1971, Graney 1976). In the Blue Ridge Mountains of northern Georgia, the shortleaf pine site index at 3,000 feet elevation averaged about 9 feet less than site index of pines growing at 1,800 feet (Ike and Huppuch 1968). In western Arkansas, higher elevation sites have shorter growing seasons, and a greater proportion of shallower, residual soils than are observed for the lower elevation sites.

Throughout the Ozark-Ouachita Highlands, site index for shortleaf pine in mixed pine-oak or oak-pine stands is significantly lower than it is for relatively pure shortleaf stands on either old-field or non-old-field sites (Graney and Ferguson 1971, 1972; Graney 1974, 1976). On equivalent sites, stands with only shortleaf pine in the overstory averaged 5 to 10 feet higher in site index than in mixed pine-hardwood stands. In southern Missouri, site index for pure shortleaf pine plantations averaged more than 5 feet greater than for plantations where hardwoods had not been effectively controlled.

One major source of error for indirect estimation of site index comes from using soil-site prediction equations and tables from outside the specific geographic area; the soil and topographic conditions used for equations and tables should be similar to those of the soil-site study. Errors can also occur if site prediction equations do not accurately represent the true correlations between site conditions and site index in the study area. Few soil-site prediction equations have been tested with independent sets of soil-site data to determine whether equations produce reasonable estimates of site quality within the study area.

The coefficient of determination (R^2) and standard error of the estimate have generally been the measure of success for a derived equation. However, these statistics simply show how well the equation fits that particular data set without indicating how well the equation will predict for other data sets.

Soil-site equations have shown mixed success in predicting site index for stands not used to derive the equations. Equations for bottomland hardwoods in the lower Mississippi Valley (Broadfoot 1969) and black oak in the Missouri Ozarks (McQuilkin 1976) were inaccurate when tested with additional plot data from within the study areas. But shortleaf pine soil-site equations for the Ozark Plateaus of southern Missouri and northern Arkansas, the Boston Mountains of Arkansas, and the Ouachita Mountains of Arkansas and Oklahoma produced accurate predictions on check plots (Graney and Ferguson 1971, 1972; Graney 1974, 1976). Such conflicting results indicate that all soil-site equations, both new and existing, should be adequately tested for reliability before general use as site quality predictors.

Soil Survey

Although soil surveys for agricultural lands have been made for more than 75 years, not much attention has been given to forest lands until recently. In most States, modern soil maps are now prepared for both agricultural and forested lands.

Most modern soil survey reports include an average site index or a range in site index values for each soil series. When these average site index values are based on many measurements over the range of site conditions common to a given soil, comparisons of average values can provide general productivity levels for a given tree species on different soils or for a number of species on the same soil series. Often, however, average site index values for various species and soils are based on few actual site index measurements, and estimates of productivity can be misleading.

A greater problem in using soil taxonomic unit site index averages arises from the often excessive variation in site index within a given soil series (Carmean 1961, 1975; Graney 1976, 1977). Much of the site index variation is caused by wide variations in the soil or topographic factors within the soil series. Features such as depth of surface soil, subsoil texture, aspect, slope position, and slope shape, which are often strongly correlated with site quality, could be incorporated in determining phases of established soil series. Based on soil-site studies in southeastern Ohio, Carmean (1967) suggested topographic phases that could aid in defining differences in oak site quality. Hartung and Lloyd (1969) found that a correlation for aspect explained much of the shortleaf pine and oak site index variation within the Clarksville soil in southern Missouri. Although the range in soil and site characteristics for individual soil series has been narrowed substantially in recently published soil surveys, even the best soil survey maps are unreliable for strict office or computer site quality estimates (Harding and Baker 1983).

A National Forest soil survey in southeastern Missouri (Gott 1975) is a good example of an attempt to incorporate soil-site information into a soil survey. Mapping intensity was medium, and mapping units were slope phases of each soil type. Species productivity estimates were presented by landsite groups, which were determined by soils, topographic position, aspect, and microclimate. Site quality estimates for each species and landsite group could be refined as additional site index and soil-site information becomes available.

Physiographic Site Classification

Although foresters and soil scientists have studied soil-site relationships of shortleaf pine and associated species for nearly 50 years, no reliable techniques have been developed for evaluating potential site quality for an individual site or management unit. Much information has been accumulated on soil and site factors influencing shortleaf pine site quality; however, site evaluations based on soil-site equations or soil taxonomic units have rarely been successful.

A site classification system should be relatively simple, practical, and applicable to all sizes and classes of ownership. The scale and intensity of delineations should be appropriate for a wide variety of management objectives (Smalley 1984b). The recent physiographic site classifications for the Interior Uplands (Smalley 1978, 1979, 1980, 1982, 1983, 1984a, 1984b), Alabama-Mississippi (Hodgkins et al. 1979), and Louisiana (Evans et al. 1983) represent significant advances toward effective classification of shortleaf pine site quality.

The classification system described by Smalley (1984b) involves stratification of the landscape according to the hierarchal significance of physiography, geology, soils, topography, and vegetation. The basic management units, landtypes, are visually identifiable areas that have similar soil and productivity and have resulted from similar climatic and geologic processes. Each landtype is described in terms of nine elements that relate geographic setting, soils, moisture, fertility, and most common wood vegetation. Each landtype is evaluated in terms of productivity for selected species and species desirability for timber production. Also, each landtype is rated for soil-related problems that may affect forest management operations. The site classification system was designed to allow foresters and other resource professionals to make onsite determinations of site productivity and should provide a site-dependent framework for forest management planning.

CONCLUSIONS

Estimates of site quality, whether from direct tree measurements or indirect estimates based on soil and topographic features, are simply local observations for many points on the landscape. To be of value to the land manager, a system of site quality evaluation based on some identifiable unit of the landscape must be devised. The system should include all available knowledge of soils, site index, and soil-site relationships for each species that can be reasonably managed in a given area. Some precision in site quality estimation might be sacrificed, but such a system would have the advantage of identifying a manageable portion of the landscape. The physiographic site classfication efforts in Louisiana, Alabama-Mississippi, and the Interior Uplands provide an excellent foundation on which to build.

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NATIONAL REGENERATION OF SHORTLEAF PINE

Edwin R. Lawson[1]

ABSTRACT

Natural regeneration with clearcutting, shelterwood, seed tree, and selection systems is a viable method for establishing and managing shortleaf pine stands. An adequate seed source, a suitable seedbed, control of competing vegetation, follow-up cultural treatments, and protection of reproduction are the primary prerequisites for establishing and maintaining natural stands.

INTRODUCTION

Shortleaf pine (*Pinus echinata* Mill) is an important commercial species on millions of acres of forest lands and occupies a wide variety of sites from southeastern New York and New Jersey into eastern Texas and eastern Oklahoma. In the West Gulf region (Arkansas, Oklahoma, Texas and Louisiana) shortleaf pine ranks second only to loblolly pine (*P. taeda* L.) in commercial importance (Murphy 1982). Where shortleaf is found as a primary species or mixed with loblolly pine, it is estimated that about one-third to one-half of the existing stands will be regenerated naturally. Langdon (1981) indicates that 75 percent or more of the loblolly pine stands will be established by natural regeneration.

The major need for pine regeneration is on private nonindustrial ownerships, which include 75 million acres, or 72 percent, of commercial forest land in the midsouth (Birdsey et al. 1981). Natural regeneration may be the best alternative for maintaining pines on the vast acreages of private forest land, since it has the lowest establishment and capitalized costs of any regeneration method available (Baker 1982; Vesikallio 1981). For example, stands in the Southern Coastal Plains can be naturally regenerated for about $50 per acre--$5 per acre for a preharvest prescribed burn and $45 per acre for postharvest herbicide treatment. In comparison, artificial regeneration costs on the same sites would range

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from $100 to $200, depending on the specific treatments selected.[1]

SILVICULTURAL SYSTEMS FOR NATURAL REGENERATION

Forest managers using natural regeneration can choose to manage either even-aged or uneven-aged stands (Baker 1982; Lawson and Kitchens 1983; Williston and Balmer 1974). Single-tree or group selection, or a combination of the two methods, may be used in uneven-aged management. However, single-tree selection is more difficult to implement and maintain (Farrar 1981) in mixed pine-hardwood stands, which are common throughout the natural range of shortleaf pine. Where regeneration is badly needed, a combination of single-tree and group selection may be required. Uneven-aged management may work well on small private nonindustrial ownerships or other holdings where it fulfills special management objectives (Baker 1982; Baker and Murphy 1982; Gibbs 1975; Williston 1978; Williston and Balmer 1974).

In even-aged management, clearcutting, shelterwood, and seed-tree systems are alternatives for natural regeneration. The clearcutting method is used to regenerate small patches, blocks, strips, or ribbons if there is a seed source available from adjacent stands. These areas should not be over 300 to 400 feet wide with the long axis oriented perpendicular to the direction of prevailing winds (Baker 1982). The clearcutting method can also be used to regenerate larger areas where seedlings are in place or where a good seed crop is expected. When seeds are in place, clearcutting is done after seed-fall, but prior to germination, whereas when seedlings are in place, cutting is done in late summer after the seedlings are established (Baker 1982; Haymond 1983).

In the shelterwood system, the mature stand is removed in two or more cuts. Regeneration takes place under a partial forest canopy, which is completely removed when the stand contains about 1,000 seedlings per acre and 60 percent of the milacres are stocked. The overwood is usually removed 3 to 5 years after the regeneration cut. Growth rates of residual stems also increase because of thinning and may show a greater increase if additional understory control is provided (Bower and Ferguson 1968; Yocom 1971). Thinning and hardwood control will also enhance crown development for increased cone production.

With the shelterwood system, reducing the pine stocking to as low as 20 to 30 square feet of basal area per acre may be desirable (Baker 1982). Phares and Rogers (1962) found

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[1]Personal communication with Dr. James B. Baker, March 1986.

that more seeds were produced at 50 square feet of basal area than at higher levels and suggested that maximum seed production per acre might occur at even lower levels of stocking. Besides resulting in greater seed production, the lower stocking levels greatly reduce competition for seedlings. In south Arkansas, however, Grano (1970) found that densities of 60 to 70 square feet of basal area per acre produced the most seeds in loblolly-shortleaf pine stands.

The seed-tree system, probably the most widely used in natural regeneration of shortleaf pine, involves removal of all the overstory except 6 to 20 well-spaced, vigorous trees per acre. In mixed loblolly-shortleaf pine stands, 12 to 20 trees per acre should be left where shortleaf comprises a majority of the stand (Baker 1982; Williston and Balmer 1974). As with the shelterwood system, seed trees should be removed when there are about 1,000 well-distributed seedlings per acre (Walker and Wiant 1966).

Some managers prefer to leave a minimum of 12 seed trees for added protection against loss of seed trees and to make the final harvest more profitable. Widely scattered seed trees are not as resistant to windthrow as the more dense residual stands of the shelterwood system. In shallow, rocky soils where taproots do not develop, windthrow hazard is increased. Seed trees may be attacked by engraver (*Ips* spp) and other beetles if slash is not removed from around the tree bases before burning. Lightning also kills some trees, and losses to lightning may be critical where few seed trees are left.

Loss of seeds after they reach the forest floor is high but variable. On the average, only about 1 percent of the sound seed dispersed in the Ouachita Mountains produce seedlings (Yocom and Lawson 1977). In selection stands, where tree density is normally higher, 200 to 400 viable seeds may be required to produce each seedling (Grano 1970). Birds, animals, and insects may eat the seeds. Some seeds fall where they do not get enough moisture to germinate, and seedlings from seeds that do germinate may die before their roots reach mineral soil. High mortality may also result from droughty periods after seedling establishment.

SEED PRODUCTION

Annual seed production by shortleaf pine trees varies greatly, ranging from near zero to more than a million seeds per acre in moderately stocked stands. In one study (Yocom and Lawson 1977), an average of 10 seed trees per acre produced 3-year totals of from 308,000 to 916,000 sound seeds per acre. In mixed loblolly-shortleaf pine stands with basal areas of 12 to 92 square feet per acre, Grano (1970) found that 4-year viable seed yields ranged from 400,000 to 800,000 per acre.

Many factors contribute to the success or failure of seed crops during the 2 years required for maturity. In early stages of seed development, temperature and evaporation may limit successful fertilization of female strobili (Lamb et al. 1973). From the beginning of strobili development through cone maturity, losses due to insect predation are high. Other organisms and weather conditions cause losses, and many seeds abort from unknown factors.

Predicting seed crops very far in advance is difficult. Probably the best predictor is the presence of maturing cones during the growing season before cone maturity. This indicator is not infallible, however, since seed quality can vary greatly. For example, limited data from seed collected in traps in the Ouachita Mountains in the fall of 1975 indicated that 22 percent of the seeds were defective. Half of one shortleaf pine bumper seed crop in the Piedmont was defective (Haney 1957). Another study in south Arkansas showed that the proportion of seeds germinating was 24, 38, 65, and 29 percent during 4 consecutive years (Grano 1970).

Several silvicultural practices can enhance good seed crops. First, trees left as seed trees should be selected on the basis of vigor, size (particularly crown size), and past cone production. Generally, pine seed trees should be at least 12 inches in d.b.h. This minimum diameter provides trees that are old enough to produce large cone crops and large enough to provide good distribution of the seed. Shortleaf pines usually do not produce an abundance of seeds before they are 20 years old, although there are examples of seed production on trees much younger than 20 years (USDA 1965). A seed-tree cut will usually harvest young trees that are unsuitable for seed trees. Leaving very old (100 years or older), slow-growing trees should also be avoided, but if trees are vigorous, there is probably no upper-size limitation. Also, trees that have only a few old cones should not be selected for seed trees.

Second, because reduction of competition increases both the number of cones and the number of sound seed per cone, most harvest cuts and subsequent understory vegetation control will increase seed production. One study showed that releasing seed trees from surrounding competition doubled the cone production from a prerelease average of 498 cones to 1,069 cones following release. Release also increased the average number of seeds per cone from 35 to 38. Percentages of sound seed were 81 and 85 for unreleased and released trees, respectively. Partial girdling also increases cone production (Bower and Smith 1961). Phares and Rogers (1962) found that thinning and hardwood removal also significantly increased shortleaf pine seed production.

SITE PREPARATION

Adequate site preparation for natural regeneration of shortleaf pine must provide two basic requirements: (1) a seedbed without heavy litter accumulation so that radicles of germinating seeds can reach mineral soil, and (2) control of competing vegetation.

Seedbed Preparation

Often the disturbance caused by harvesting the overstory will remove enough litter to adequately prepare the seedbed. Litter usually decomposes rapidly when stands are opened during timber removal and hardwood control operations (Smith 1960). Most litter will be gone after being exposed for one summer, particularly on south and southwest aspects. On some sites, however, litter accumulation is a problem. When litter is redistributed during harvesting and mechanical site preparation, mineral soil is also exposed. In the Ouachita Mountains, Yocom and Lawson (1977) found that an average of 35 percent of the surface area was disturbed by logging. Whole-tree logging soon after seedfall has also been found effective in preparing the seedbed for regenerating pine stands (McMinn 1985).

Prescribed burning also removes litter and logging debris effectively. Yocom and Lawson (1977) found that burning and logging enhanced seedbed conditions and increased tree percents (ratio of established seedlings to sound seed produced x 100) as follows:

Burning treatment	Logging Disturbance: Undisturbed	Logging Disturbance: Disturbed
	Tree Percents	
Unburned	0.42	0.98
Burned	0.98	1.29
	Percent Milacre Stocking	
Unburned	53.5	74.5
Burned	82.7	87.8

Both burning and logging disturbance resulted in similar tree percents and percent of milacres stocked. Thus, either burning or disturbance may satisfy seedbed requirements. Burning, however, generally provides seedbed conditions that are more uniform than those provided by logging disturbance alone. Multiple prescribed burns in seed-tree or shelterwood stands several years before final harvest have resulted in effective seedbed preparation (Crow and Shilling 1980).

Timing of seedfall in relation to seedbed preparation is also important. If spring or summer cone counts indicate low seed production, seedbed preparation should be delayed until the next year. Otherwise, establishment and growth of herbaceous vegetation before the next seedfall may negate the benefits of seedbed preparation.

Competition Control

On most sites, competition for water and light becomes critical to newly established seedings. Competition control should be implemented before seedfall or before growth starts the next spring. Burning, if it is part of the final site preparation, must be done before the seedfall that is expected to provide regeneration. In uneven-aged stands, hardwood control must be provided on a periodic basis to coincide with 5- to 7-year cutting cycles (Cain and Yaussy 1984).

On typical pine sites, many hardwoods are present and must be controlled to allow adequate natural regeneration. Single-stem injection, foliar spray, or soil application of herbicides will effectively reduce hardwood competition (Loyd et al. 1978), especially when many very small hardwoods are present. Mechanical methods, such as hand cutting and shearing, also temporarily reduce hardwood competition but may cause problems with sprouting. Maple (1965), however, found that a brush cutter provided higher tree percents and stocking levels than chemical treatment or burning. A good prescribed burning program begun several years before the harvest/regeneration cut has been found to be effective in reducing hardwood competition for newly established seedlings (Crow and Shilling 1980).

On south-facing slopes, achieving total hardwood control may not be necessary. In the Ouachita Mountains, Yocom and Lawson (1977) found that single and repeated hardwood control treatments on north aspects resulted in tree percents of 0.91 and 1.03, respectively. On south-facing slopes, however, these two values were 0.97 and 0.76. Southern slopes are drier than northern slopes, and some residual hardwood stems may help pine regeneration for the first few years by shading and protecting the seedlings from drying winds.

If adequate regeneration is not achieved within 3 years, additional site preparation may be needed. Our experience in the Ouachitas indicates that we can achieve adequate regeneration in 3 years when hardwoods are controlled with chemicals followed by burning on some sites. On better sites, hardwood regrowth will likely be so rapid that seedlings will have little opportunity to survive and grow, even if they are established soon after site preparation. Because most herbicide sprays may harm pine seedlings, sprays generally should not be used during the first year or two after establishment (Lawson 1960). Some of the newer herbicides, such as hexazinone, do not harm 1- to 2-year-old seedlings when applied at the recommended rates.

STOCKING CONTROL

Getting the correct number of seeds and seedlings distributed over the area being regenerated for even-aged management is often difficult. The number of seed trees left for regeneration gives some control over stocking. Results of one study (Yocom 1968) in the Ouachita Mountains showed that most of the shortleaf seeds fell within 2.5 chains from the seed source. Half the seeds fell within 1 chain of a forest wall (stand of mature trees adjacent to a clearcut or seed tree area), and 85 percent fell within 2.5 chains of it. In one year, 16,600 to 31,500 seeds per acre fell in traps 2.5 chains from the wall. At 1.5 chains from the wall, the number of seeds approached 42,700, or about a pound per acre. Neither prevailing nor shifting winds made a significant difference in seed catch, although they have in other studies (Little 1940; Siggins 1933). The maximum distance over which a tree will distribute seed is about 2-1/2 times the tree height. Thus, about 6 to 10 well-spaced seed trees per acre should distribute enough seeds to cover the area, with a little extra for insurance. However, some managers prefer more seed trees per acre or a shelterwood overstory to provide a greater seed source and a protective canopy (Haymond 1983). An overstory is always present in uneven-aged stands.

One of the big problems with natural regeneration is getting too many seedlings. This usually happens when there is a combination of a good seed crop, an adequate amount and distribution of rainfall, and a suitable seedbed. But overstocking may also occur because mature seed trees are left too long. In uneven-aged management, overstocking is generally not considered a problem (Farrar 1981).

Seedling counts should be made after each growing season to avoid leaving seed trees too long. Ideally, the seedling count should be made in late summer or early fall in time to remove the seed trees if adequate numbers of seedlings are present. Where herbaceous and other vegetation is dense, however, making an accurate inventory may be nearly impossible in late summer, so the inventory should be postponed until just before vegetative growth begins in later winter or early spring. The disadvantage of a spring count is that the number of seedlings that will be established at the end of the next growing season is unknown. If a good seed crop was present the previous fall and the regeneration area is approaching full stocking, you may want to go ahead and remove the seed trees.

If there is overstocking, reduce the number of seedlings to a suitable level as soon as feasible. If post markets are available, however, delaying thinning until most trees are merchantable may be desirable. The best thinning methods for upland sites have not been determined. Hand thinning or strip cutting with brush cutters (Cain 1983) and drum choppers have been used. Up to about post size, shortleaf pines severed above ground will sprout and are likely to remain as competitors for water and nutrients. As the seedlings develop into saplings, prescribed burning may be used to precommercially thin shortleaf pine stands, although there are risks of the fire becoming too hot (Crow and Shilling 1980; Nickles et al. 1981). Herbicides can also be used to thin young pine stands (Nickles et al. 1981), but may not always be successful (Cain 1983).

Natural regeneration may create overstocking problems next to forest walls on areas that have been (or will be) planted or direct seeded. Invading natural seedlings can cause a serious problem in plantations where genetically improved seedlings have been planted. Distinguishing natural from planted seedlings may be difficult at early ages. Natural seedlings may be present before harvesting and site preparation and will readily sprout back with vigorous growth if damaged by fire or equipment. I have observed newly germinated seedlings in the middle of large areas that were harvested, sheared, windrowed, and burned the previous summer. The presence of these seedlings suggests that shortleaf pine seeds may germinate later than the first year after seedfall, but this phenomenon has not been documented in the literature.

On many sites throughout the shortleaf pine range, natural regeneration is a viable management alternative and may be the only practical alternative on steep, rocky sites. On much of the vast acreage of private nonindustrial forest lands, natural regeneration may be the most desirable method of establishing pine stands because of economic and other considerations (Baker 1982; Haymond 1983; Williston 1978).

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ARTIFICIAL REGENERATION OF SHORTLEAF PINE

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ABSTRACT

The artificial means for establishing stands of shortleaf pine seedlings are reviewed. In addition to the relative merits of direct seeding and planting of bare-root and container seedlings, techniques that should help ensure successful stand establishment are discussed.

INTRODUCTION

Artificial regeneration of shortleaf pine holds great promise for increasing the productivity of major forest sites in the interior South. Most current shortleaf stands are of natural origin, although millions of acres have been planted and large acreages seeded. Natural regeneration will continue as an important shortleaf management technique in the future. However, the need for artificial regeneration is great and will continue to increase due to (1) deterioration of natural stands and increasing encroachment of low quality hardwoods, (2) the opportunity to increase stand growth by the use of genetically improved seedlings, and (3) the improvement in productivity by strict control of spacial distribution of seedlings.

ARTIFICIAL REGENERATION OPTIONS

Artificial regeneration options available to the forest manager normally include planting of bare-root and container stock, and direct seeding. What are the bases of selecting one technique over another? Planting provides a higher assurance of success than direct seeding, but seeding may be the best or only option for some situations. Direct seeding provides a rapid method of regenerating large acreages of open cutover land. However, such large areas are not common in the interior South where the typical reforestation site is 250 acres or less. Seeding is still an ideal technique to quickly regenerate large areas following wildfires or where terrain is difficult to plant. Seeding also provides cost conscious

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small nonindustrial forest landowners with a relatively inexpensive option for regenerating their lands. Comparisons of shortleaf pine growth after seeding and planting indicate that no significant differences occurred after 11 years (Phares and Liming 1960).

Compared to seeding, planting offers better control of stocking, makes more efficient use of expensive, genetically improved seeds; makes thinning and harvesting operations easier to accomplish, and prevents the need for precommercial thinning. Planting of container seedlings is an artificial regeneration option that has become available only in the past few years. The use of container-grown shortleaf pine seedlings has not gained widespread popularity because bare-root stock is usually relatively easy to procure, generally reliable, and because high quality container seedlings have been difficult to obtain. However, bare-root seedlings may not provide the desired results in some situations, and the use of container seedlings should be considered. Container seedlings can be used to: (1) improve survival and growth, particularly on sites difficult to regenerate; (2) extend the planting season by allowing regeneration of dry sites in the fall and wetlands that are subject to winter flooding in the spring, and (3) obtain greater flexibility in seedling production to meet unexpected demands.

If container seedlings are grown in sufficient quantities to take advantage of the economics of scale, they will be cost competitive with bare-root stock (Guldin 1983).

SITE SELECTION AND PREPARATION

No "typical site" exists for shortleaf pine. This species does grow best on moist, well-drained sites. However, shortleaf is adapted to and usually planted on the drier, poorer quality, and more mountainous sites of the interior South that are north of the range of loblolly pine. It is the preferred species on south- and west-facing slopes where soil moisture usually is critical. Soils in much of this mountainous region developed from metamorphosed sandstone, shales, and stony colluvium; and abundant rock is common in most soil profiles (Wittwer et al. 1986). Sites are droughty and difficult to plant. On better quality sites, hardwoods enter succession early and became more competitive as stand age increases. Upon harvest, then, hardwoods are a significant component of the stand unless site preparation is used to encourage successful establishment of pine on the reforested site.

Both survival and growth of shortleaf pine are often improved by site preparation. Such action addresses residual hardwood sprouting and grasses and herbaceous weeds that present serious competition problems. Several site preparation techniques are commonly used or have potential for use preceding the planting or seeding of shortleaf pine: (1) prescribed burning, (2) mechanical techniques, (3) chemical treatments, and (4) combination treatments.

Prescribed burning

Burning is a tool valued for its economy in preparing sites for reforestation if a prescribed burning program is established several years prior to harvesting. The routine use of burning beginning early in stand development results in smaller and fewer competing hardwoods when reforestation occurs. A prescribed burn in late November or early December, after leaf fall, is an effective and inexpensive way to reduce a heavy litter layer in preparation for direct seeding. The fire should consume only the loose, dead leaves, leaving a thin layer of duff. The hardwood overstory could then be removed by injection with chemicals. Usually, burning must be used with some other site preparation technique such as mechanical or chemical treatments.

The advantages of prescribed burning for site preparation are: (1) economy, when compared to mechanical or chemical means; (2) its use with caution on steep terrain; (3) its not being a cause of soil compaction, and (4) it's resulting in easily planted sites. Disadvantages include: (1) fire control that can be difficult and expensive; (2) air pollution that may be a problem; (3) intense burns that result in erodible conditions on some sites; and (4) resprouting if fires do not kill roots and root crowns.

Mechanical techniques

Mechanical site preparation includes a wide range of techniques and is probably the most reliable means of obtaining a stand of adequately stocked, free-to-grow shortleaf pine seedlings. There are basically four kinds of mechanical techniques: (1) crush or knock down the residual stems, but leave the debris in place (roller drum chopping), (2) knock down residual stems and pile the debris (shear and windrow), (3) whole tree harvest of standing trees (which combines site preparation with final harvesting), and (4) loosening of the soil to allow free drainage and aeration and provide channels to collect surface run-off (ripping). Of the first two techniques, foresters usually prefer roller drum chopping because of less soil disturbance, compaction, and nutrient depletion (Haywood 1982). Shear and windrowing is used when there are too many large residual stems for tree crushing to be effective or if the residual debris will hamper other operations. Yet on many upland sites, such intensive culture is unwarranted because the other mechanical treatments will produce similar results (Haywood et al. 1981). Poorly applied mechanical site preparation can also displace topsoil and organic matter and increase the potential for soil erosion. Thus, soil stability, slope, and timing of establishment of plant cover should be considered when selecting a technique.

Ripping of eroded, compacted, or rocky sites has improved performance of shortleaf and loblolly pine seedlings (Berry 1979). Recent research conducted in the Ouachita Mountains of Arkansas and Oklahoma has shown that height growth of loblolly pine after two growing seasons was increased 10 percent by ripping alone (Wittwer et al. 1986).

Chemical treatments

Herbicide treatments are a viable alternative to mechanical site preparation and are highly versatile tools for the landowner. They expose no mineral soil but are effective in retarding competing vegetation. Chemical site preparation can be accomplished by single stem treatments or broadcast applications. Since there are a number of chemicals available, selecting the most appropriate may be a problem because many factors influence herbicidal behavior. These include weather conditions before, during and after treatment; soil moisture levels; texture and structure of the soil; kind and vigor of the treated vegetation; the herbicide used and its formulation, and the quality of the application job. Not all of these factors are controllable. However, the landowner should have reasonable success by following the instructions on the herbicide's label. Guidelines are usually available from the Cooperative Extension Service in each state.

Under many conditions, herbicides are used most effectively in conjunction with either mechanical treatment or prescribed burning.

Combination treatments

A combination of mechanical, burning, or chemical treatments is usually most effective for site preparation. A combination of mechanical techniques and prescribed burning is commonly used. For example, mechanical roller-drum chopping followed by burning after the downed vegetation has browned is an effective technique for many shortleaf pine sites.

Herbicides and prescribed burning have also proved to be an excellent site preparation technique under appropriate conditions. The method has two variations, one termed "brown and burn" and the other "spray and burn" (Stewart 1978). The brown and burn method uses contact herbicides to desiccate leaves and twigs before burning. Because contact herbicides are not translocated into roots, they will not prevent resprouting after burning. The spray and burn technique is more effective because the herbicides used are translocated to defoliate and control residual vegetation before burning. Burning is delayed several months after spraying to achieve maximum root kill and stem desiccation.

DIRECT SEEDING

Direct seeding is an effective, rapid, and inexpensive regeneration alternative for shortleaf pine. But like other regeneration methods, it is not fail-safe. However, most recorded failures have been due to improper application techniques such as seeding on unsuitable sites, seeding out of season, inadequate site preparation, poor quality seed, and sowing too few or untreated seeds. Poor stand appraisal techniques also have classified some successful seedings as failures. Many failures can be avoided by following some simple guidelines. Since seeding and planting techniques differ so greatly, most aspects of direct seeding will be discussed in this section.

Condition of seedbed

Every site is different and must be judged on its individual merits before a prescription can be prepared. Generally, sites that can be planted can be seeded, but some conditions should be avoided:

1. Sites subject to heavy grazing unless grazing can be controlled the first 2 or 3 years.

2. Highly erodible soil and steep slopes where insufficient rough exists to hold the seed in place.

3. Thin, rocky soils or deep, upland sands that dry out rapidly after a rain, particularly those on south- and west-facing slopes.

There is one inviolate ground rule for direct seeding--seeds must be in contact with mineral soil. Seeds landing on surface litter, grass sod, or any other material besides mineral soil will not establish a seedling (Campbell 1982a, Russell and Mignery 1968).

Seed handling and protection

A prerequisite for direct seeding success is the use of good quality seeds that have been properly collected, stored, stratified, and treated with bird and rodent repellents. Minimum specifications for seedlots should be 95 percent purity and 80 percent germinative capacity. But even high quality seeds that have been properly stratified must be treated with bird and rodent repellents if the seeding is to be successful (Derr and Mann 1971). Heavy concentration of these seed predators can consume up to 5 pounds per acre of untreated seeds during the germinating period.

Few forest managers are equipped to collect cones and then extract, store, stratify, and treat seeds with repellents. The simplest procedure, especially for the small landowner, is to purchase seeds ready for sowing from a reputable seed dealer. Seeds should be purchased and a sowing contractor (if needed) engaged well in advance of the seeding operation. Seed delivery should be delayed until the time for sowing, however. Stratified and repellent-treated seeds should be held only about 2 weeks under cool conditions; air-conditioned facilities are advisable. If seeds are to be held longer than 2 weeks, they should be cold-stored between -3.8 and 4.5°C (Barnett and McLemore 1966). Storage below -3.8 degrees will damage the water-saturated megagametophytes; if kept too long above 4.5 degrees, germination or spoilage is likely to occur.

Repellent-treated seeds are coated with thiram and endrin. Rates of chemical use and application techniques are clearly provided by Derr and Mann (1971). Both of the recommended chemicals are labelled for this use and are environmentally safe if guidelines are followed (Barnett et al. 1980). Endrin is toxic to humans and handlers should always wear rubber gloves and an approved toxic-dust mask. After handling treated seeds, even with rubber gloves, the hands and face should be washed thoroughly before eating, drinking, or smoking. Treated seeds are safe to handle when proper precautions are followed; otherwise they can be very dangerous.

Seeding methods

Broadcast seeding.--Small acreages are usually most economically seeded by hand. One person using a cyclone seeder on easy-walking terrain can cover up to 12 acres per day. Walking straight, carefully flagged lines will result in fairly uniform distribution of seeds. The seeder should be carefully calibrated for the sowing rate in use. On farm woodlands, seeds may be scattered by hand in a relatively uniform pattern.

Larger acreage is best seeded by aircraft, but equipment must be well calibrated for the sowing rate in use. On a calm day when everything goes well, a helicopter can seed up to 3,000 acres per day.

The major advantages of broadcast seeding are its speed and low cost. Major disadvantages are the lack of spacing and stand density control.

Row seeding. -- Row seeding may be preferred over broadcast sowing when the landowner wants better control over spacing and density, or wants his trees in rows for mechanical harvesting. On a well-prepared site the seeds can be dropped by hand as one walks a furrow, row, or line. Seeds should be spaced one or two feet apart within the row. A common recommendation for spacing between rows is 10 feet.

Spot seeding.--Spot seeding is just what the name implies: dropping a predetermined number of seeds on a small spot. It offers the same spacing control as that of planted nursery seedlings, but is the slowest and most labor-intensive of the three sowing methods. However, spot seeding is the most highly recommended method for the small landowner who can do the work in his spare time with a minimum of tools and equipment, and who must minimize out-of-pocket expenses.

When the site has been properly prepared and mineral soil is exposed, three to five seeds should be dropped in a cluster (Phares and Liming 1961a). If surface litter or grass sod still occupies the site a spot should be cleared with the foot, a hoe, firerake, or other means to bare mineral soil. The seeds are dropped and pressed into the soil surface with a foot. On drier sites or sloping terrain it may be beneficial to cover the seeds with a layer of soil not to exceed 1 cm deep.

Sowing 3 to 5 seeds per spot is recommended to ensure stocking on most all spots. However, 2 or more seeds will germinate on many spots and result in a cluster of seedlings. Such multiple-stocked spots should be thinned back to a single seedling at age 2 or 3 years. Clustered seedlings on a spot cause a significant reduction in height and diameter growth by age 15 years (Campbell 1983).

Time and rate of sowing

Shortleaf pine seeds can be successfully sown from December 1 to April 1. Some of the best results have been obtained by sowing in December, January, or February, using unstratified repellent-treated seed (Seidel and Wilson 1965, Phares and Liming 1961b). Weathering will reduce the effectiveness of the repellent coating. Any seeds that are sown in the spring (after about March) must be stratified to obtain prompt and uniform germination. The change from dry to stratified seeds should be made 2 to 4 weeks before the average date of the last killing frost (Russell 1979). The length of stratification most appropriate for direct seeding of shortleaf pine seeds is about 60 days (Seidel 1963, Barnett and McGilvray 1971). Freshly collected lots are generally less dormant than stored ones.

The key to a proper sowing rate is an adequate number of sound, germinable seeds per acre. We recommend 18,000 broadcast, 10,800 row seeded, and 7,200 spot seeded. However, broadcast sowing rates are usually developed on a weight basis, so the number of seeds per pound must be determined for each separate lot. Seeds per pound vary greatly from year-to-year and from lot-to-lot; shortleaf seeds may range from 32,000 to 73,000 per pound, so an accurate seed count is needed for each operation.

Once the number of seeds per pound has been determined, seed germinability must be considered. If a seed lot averages 45,000 per pound, and germination tests average 88 percent, then that lot has only 39,600 germinable seeds per pound. Stratification and repellents add about 15 percent to the weight.

Recommended uses of direct seeding

Although direct seeding is not widely used to regenerate shortleaf pine, it does meet several reforestation objectives. Seeding is an excellent technique for landowners to inexpensively regenerate small acreages. Seeding has also been used to quickly reforest large acreages ruined by wildfires in the Ouachita Mountains. Clearly, direct seeding will continue to be used to meet these special needs. However, general interest in direct seeding has decreased due to the lack of control of tree spacing and due to failures under unfavorable climatic conditions. Furthermore, direct seeding does not efficiently utilize genetically improved seeds because the process uses many seeds to establish one seedling.

PLANTING CONTAINER SEEDLINGS

Many aspects of planting container seedlings are the same as those for bare-root stock. However, there are some important differences. Despite their bulk and weight, container seedlings are attractive because of planting ease. The uniformly shaped root systems of container seedlings are easily planted by hand or machine.

Hand planting

Container seedlings can be hand planted using conventional bare-root planting tools or tools designed for specific container types. Such special tools have been used to plant container stock at twice the rate of hand planting bare-root stock (Appelroth 1971). These planters work by displacing or dibbling the soil to make room for the seedling root ball. Their effectiveness depends greatly on the soil type and soil moisture, and they work well on mid-range soil types such as sandy loam, loam, and silt loam. For clay soils, tools must be designed to avoid soil compression or case hardening of the side walls when the hole is opened. For very sandy soils the tool must prevent the side walls from caving in before the seedling can be properly planted. Hand-held power augers can be used for planting stock grown in very large containers.

Removing a soil core having the same configuration as the container seedling plug before planting results in better seedling performance in heavy soils or compacted soils. In Louisiana, loblolly pine seedlings planted in a heavy silt loam soil survived better after 18 months when a core was removed rather than when a dibbled hole was made (Barnett and Brissette 1986).

Mechanical Planting

Most mechanical planters designed for bare-root seedlings can be adapted for planting container stock with only minor modifications. Conventional planting machines are either of the continuous furrow type or the intermittent furrow type and are usually fed manually. Modifications for container seedlings may only require changes in operator technique on continuous furrow machines, while intermittent planters may need some changes to the seedling holding mechanisms.

Depth of Planting

As with bare-root stock, planting container-grown seedlings to the proper depth is important to ensure good survival and growth. Container seedlings should be planted deep enough to allow covering the top of the root plug with about 1.25 cm of soil. Covering the container reduces drying in the root zone caused by the wicking effect of the media or planted container. Planting below the groundline also reduces the chance of frost heaving of fall- or winter-planted container stock.

PLANTING BARE-ROOT SEEDLINGS

Shortleaf pine planting procedures are basically the same as those for any southern pine species. Detailed instruction is available in Planting the Southern Pines (Wakeley 1954), which remains the most complete guide available. Limstrom (1963) offers additional information applicable to planting shortleaf pine in the central and northern portions of its range. Key requirements for planting shortleaf are selection of a suitable site, use of the best seedling quality and planting technology, and adequate control of competing vegetation.

Drought is probably the most widespread cause of the low initial survival (Wakeley 1954). Probably the greatest loss of planted pine seedlings occurs when they have not re-established good soil-root contact within 5 days after planting. Failure to make contact may result from poor planting, low initial soil moisture, prolonged rainfall deficiency following planting, and seedling quality. We can improve on poor planting, but the other variables require an understanding of seedling and environmental characteristics.

There is a period of time, termed a "planting window", in which the probability of seedling establishment is quite high. The size of the window varies from year to year, depending on environmental factors; within any one year it varies with nursery management and seedling care. Seedling dormancy and moisture level at the planting site are particularly important in defining duration of the window opening.

The safest time to plant seedlings is late winter and early spring, after most of the severe winter weather has passed. From mid-February through March is usually the ideal time to plant. This is based on many studies we have done comparing survival of seedlings planted from early December through May. Two reasons explain why survival is usually best from late winter and early spring plantings. First, weather conditions are generally more favorable. With early planting, in December and January, the danger is cold weather. When the ground is frozen, roots cannot take up moisture. If at the same time seedling tops are exposed to strong winds, they dry out. The problem is desiccation rather than outright freeze damage. On heavy textured soils that have been mechanically prepared, frost heaving may also be a problem. Winters vary considerably, and survival from early planting during mild winters can be as good as survival from March planting. An advantage of early planting, when it is followed by a winter mild enough to permit good survival, is that the seedlings start growing earlier in the spring and, therefore, make better growth.

With late planting, in April and May, the danger is that a drought may occur before the seedlings can become established. Also, when planting is done in April or May, some of the growing season has already passed, and grass, weeds, and hardwood brush have gained an advantage on the seedlings. Consequently, late planted seedlings do not grow as well as seedlings planted in February or March.

Second, pine seedlings reach a physiological peak in March just prior to breaking dormancy. A low level of photosynthesis takes place in the seedbeds during the winter whenever the weather is favorable, and the food produced is transported to and stored in the roots. The more stored food in the roots, the better chance a seedling has to quickly initiate new root growth after it is planted.

A rather common reason for poor survival is root desiccation between the time the seedlings are removed from the package and actually planted. A healthy seedling placed into a dry planting machine box quickly loses its ability to survive. Exposure of fine rootlets to desiccating conditions predisposes the seedling to severe shock, slow recovery, or death. Ideally the moisture film covering the roots should never be allowed to evaporate, but drying for 10 or 15 minutes may be acceptable on overcast days. Many nurseries coat the seedling roots with a clay slurry to retard moisture loss. Alternatively, the seedlings may be dipped in highly absorbent organic gelatinous materials, but these materials' ability to increase shortleaf pine survival has not been rigorously tested.

Planting instructions often caution that J-rooting and other root malformation is to be avoided, but there is little conclusive evidence that malformed root systems are detrimental to survival. A planting slit that is too shallow results in root deformation, but the real cause of mortality is probably shallow planting.

RELATING NURSERY PROCEDURES TO FIELD PERFORMANCE

Seedling Quality

In recent years planting stock quality has received considerable attention. A IUFRO workshop entitled "Techniques for Evaluating Planting Stock Quality" was held in New Zealand in 1979 and subsequently an issue of the New Zealand Journal of Forestry Science (Vol 10, number 1) served as a proceedings of that meeting. In 1984 another workshop, entitled "Evaluating Seedling Quality: Principles, Procedures, and Predictive Abilities of Major Tests," was held at Oregon State University. A proceedings of that meeting was also published (Duryea 1985). The level of interest in this topic reflects the biological, economical, and managerial importances of getting plantations off to a good start.

To foresters, the ultimate measure of seedling quality is field performance. When defined in terms of field performance, stock quality is a function of the seedlings' potential to survive and grow after outplanting. Seedling quality represents a complex integration of physiological and morphological characteristics and, therefore, cannot be measured easily. Also, stock quality must be defined for a specific point in time, because subsequent handling, storage, or planting can have a tremendous impact on potential field performance.

Attributes of seedling quality can be grouped into 2 categories, material attributes and performance attributes (Ritchie 1984). Material attributes are directly measurable morphological or physiological characteristics such as root collar diameter, dry weight, foliar nutrient content, and plant moisture stress. Wakeley's (1954) morphological grading standards for southern pines fall into this category. When several material attributes are considered together they can be useful for describing potential field performance. Individually, however, these attributes have little predictive value unless they are well outside the normal range, such as pine seedlings with very small (< 3 mm) root collar diameters.

Performance attributes are whole-seedling measures of response to particular test conditions. Examples include testing for root growth potential and cold hardiness. Such tests are good predictors of field performance. However, they often require 3-4 weeks to complete, and therefore the results are usually not timely enough to aid in making management decisions. Performance attribute testing is extremely valuable, however, when used to evaluate nursery culture and then apply the results toward improving future crops.

High quality shortleaf pine seedlings can be grown as either bare-root or container stock. For either type of stock, morphological characteristics have been used to define seedling quality. The most widely accepted standards for describing southern pine bare-root stock are Wakeley's (1954) morphological grades. These grades emphasize root collar diameter and classify as cull any shortleaf pine seedling with a ground line diameter of less than 3 mm (Table 1). Recognizing the effect that the basal crook can have on root collar diameter, Chapman (1948) recommended a diameter of 2.5 mm at 2.5 cm above the ground line as the lower limit of plantable shortleaf pine seedlings. Similar standards have not been developed for containerized shortleaf pine.

Wakeley's morphological grades were developed after years of observing the survival and growth of seedlings that had various morphological characteristics when they were planted. In general, the distinction between plantable and cull seedlings is substantiated by outplanting success. However, there are enough exceptions that Wakeley (1949) recommended the development and adoption of physiological grades which better reflect survival and growth potential. He suggested measuring such physiological attributes as nutrient content, stored food reserves, and seedling water status. Since Wakeley's time, much progress has been made in the physiological evaluation of planting stock, with root growth potential receiving most of the attention (Stone 1955, Stone and Jenkinson 1971, Burdett 1979, Ritchie 1985). None of this important work has been done with shortleaf pine. The authors of this paper are currently evaluating several material and performance attributes of shortleaf pine as a means of relating nursery cultural techniques to field performance.

Although morphological grades have limitations, they have provided valuable insights into the importance of seedling quality. For his grading study, Chapman (1948) established shortleaf pine plantations on relatively poor quality, old field sites in southern Indiana and southern Missouri. Clark and Phares (1961) measured these plantations at age 19-21 and found, depending on the site, that the large seedlings (20-30 cm tall and 5 mm diameter at 2.5 cm) produced from 31 to 92 percent more volume per hectare than the small seedlings (10-20 cm tall and 2.5 mm diameter). Much of the increased

Table 1.--Specifications of morphological grades[1/] of uninjured[2/] 1-year-old shortleaf pine seedlings (Wakeley 1954)

Grade	heights	Root collar diameter	Nature of stem	Bark on stem	Needles	Winter buds
	(cm)	(mm)				
1	10-25	About 4.8	Stiff, woody. Usually a crook at ground level; often branching	Usually on entire stem	Almost entirely in 3's and 2's	Usually present
2	7.5-15 sometimes 20	About 3.2	Moderately stiff; often with crook and branches	On lower part at least; often all over	Part at least 3's and 2's	Occasionally present
3	Usually less than 10	Distinctly less than 3.2	Weak; often juicy; often straight	Often lacking	Practically all single, bluish	Practically never present

1/ Grades 1 and 2 usually considered plantable, and grade 3 culled.

2/ Any seedlings with roots less than 12.5 cm long should be considered as grade 3 (culls), regardless of the quality of the tops.

volume was due to better survival of the larger seedlings. Although the large seedlings grew tallest during the first 3-5 years, by age 19-21 no longer did significant height differences existed. The large seedlings had significantly greater d.b.h. at age 21 at the Indiana site but in Missouri there was no relationship between seedling size and d.b.h. at age 19-21. Based on their results Clark and Phares agreed with Chapman's minimum plantable shortleaf pine seedling of 10 cm tall and 2.5 mm at 2.5 cm. However, for best results they recommended planting seedlings at least 15 cm tall and 3.8 mm in diameter at 2.5 cm above the root collar.

In another study, shortleaf pine seedlings selected from 3 nurseries over a 4-year period on the basis of height only were compared at age 9-12 for survival, height, d.b.h., and volume per tree (Grigsby 1975). The study included 289 trials of small (9 cm tall), average (18 cm), and large (30 cm) seedlings planted at 5 locations in southern Arkansas and northern Louisiana. With data combined across ages and sites no differences were found in survival; but the large seedlings were significantly better than the small seedlings in height, d.b.h., and volume, and also had significantly greater volume than the average seedlings.

Similar results from planting large shortleaf pine seedlings have been shown for container-grown stock. In a mycorrhizae study planted on 2 sites on the Ouachita National Forest, large container stock (18 cm tall and 2.5 mm root collar diameter) performed better than small containerized seedlings (10 cm tall and 1.8 mm diameter) on one of the sites (Ruehle and others 1981). On the site with differences, non-innoculated large seedlings had significantly larger root collar diameters and individual volumes than small non-innoculated seedlings 2 years after planting. There were no differences in survival or height. There was dense, overtopping competition to the planted pines on the site where no significant differences were measured.

Large container seedlings were significantly taller than small container stock 28 months after planting in central Louisiana (Barnett 1982). Significant correlation coefficients were obtained between field height at 28 months and seedling height, top and root fresh weights prior to outplanting. Both studies indicate that seedling size has more effect on growth than on survival with container stock. Apparently the intact root systems of containerized seedlings result in good survival over a wider range of seedling size than with bare-root stock.

Developing a Target Shortleaf Pine Seedling

Based on past research and years of observing planting results by field foresters, a shortleaf pine seedling ideotype-or target seedling-can be described. The concept of a target seedling should include the acceptable range for each attribute and be flexible so that it reflects the current state of knowledge. As more evidence is accumulated the target specifications should change. It must also be recognized that different target seedlings may be appropriate for different geographic locations or site characteristics.

The value of a target seedling is that it provides a goal for the nursery manager to work towards and a standard of comparison for the forester.

In December 1984, a group of 19 USDA Forest Service, industry, state, and university foresters and silvicultural researchers met to discuss ways to improve artificial regeneration success with shortleaf pine in the Ouachita and Ozark Mountains. As a result of discussions at that meeting an initial target seedling was defined based on morphological charateristics (Table 2). Material physiological attributes and performance attributes were not included because they have not been investigated in shortleaf pine. The meeting did set a research agenda that addresses other attributes and as results become available the target seedling specifications will be refined and expanded.

PRODUCING SEEDLINGS OF DESIRED QUALITY

Seed Quality

The goal of the seedling producer is to grow as large a percentage of the crop as possible to target seedling specifications. The more uniform the crop, the easier it is to bring the greatest number to the desired quality. Crop uniformity requires sowing high viability seed lots. Seed viability can be markedly reduced by poor extraction, processing, or storage practices. In early studies which included shortleaf pine, Huberman (1940a) determined that the sum of all losses following germination was not nearly as great as the number of seeds that failed to germinate. Because laboratory germination was similar, he concluded that the problem was due to faulty extraction or storage. Modern methods and equipment make it possible to process and store pine seeds while maintaining high viability (Krugman and Jenkinson 1974).

The seeds that Huberman (1940a) used were not stratified. Shortleaf pine seeds exhibit dormancy and need stratification for rapid, uniform germination. Stratification for 56-70 days proved best when both speed and completeness of germination

Table 2.--Initial target seedling specifications for bare-root shortleaf pine seedlings to be planted on Ouachita and Ozark Mountain sites

Attribute	Specifications
Height	15-25 cm
Root collar diameter	2.5-5.0 mm
Root/Shoot ratio (ODWT)	0.40
Foliage	Mostly secondary needles
Stem	Woody
Terminal bud	Well developed by November 1
Root system	$\geq$ 7 laterals, fibrous, mycorrhizal
Tap root	10-20 cm long

were considered over a range of stratification durations (Barnett and McGilvray 1971). Clearly then, uniform establishment in the nursery or in containers requires careful seed extraction and cleaning, followed by proper storage and then stratification for about 60 days before sowing.

Sowing regimes and seedbed density

To grow a crop of seedlings to target specifications requires a thorough knowledge of how those seedlings grow and respond to cultural manipulation. In a bare-root nursery, the first considerations are sowing date and seedbed density. After comparing several sowing dates from March to early May in central Louisiana over a 2-year period, Huberman (1940b) recommended sowing shortleaf pine before mid-April. Based on operational observations, TVA sowed shortleaf pine in March and early April at its nurseries in east Tennessee and northwest Alabama (TVA 1954).

Seedbed density has a tremendous impact on seedling morphology, especially stem diameter and root mass. With loblolly and slash pines, average root collar diameter decreases with increasing density (Shoulders 1961). In loblolly pine, as density increases root weight is reduced proportionately more than shoot weight, resulting in a corresponding decrease in root to shoot ratio (Harms and Langdon 1977). Wakeley (1954) stated the maximum density for shortleaf pine was 540-590 seedlings per square meter. However, he also wrote that under favorable nursery conditions such densities would result in about 20 percent cull seedlings. Based on the results of his grading study, Chapman (1948) recommended a maximum of only 270 seedlings per square meter. Considering the value of seed orchard seed and the current cost of labor for culling nursery stock, a density near Chapman's recommendation is more appropriate.

Seedling Growth and Development

Once seedlings become established in the nursery, they enter a rapid growth phase. In this phase the nursery manager encourages growth by maintaining adequate levels of soil moisture, by addition of nitrogen fertilizers, and by pest management procedures such as weed and disease control.

As seedlings approach the target height, cultural treatments are usually applied to limit shoot growth. Water and topdressing with nitrogen are withheld to induce sufficient stress to stop shoot elongation. Often stress alone will not halt height growth. Single or repeated undercutting of the seedlings has significantly reduced shoot growth, markedly increased lateral root development, and improved field survival of loblolly pine (Tanaka and others 1976). While stress can effectively control seedling height, too much stress will also limit diameter growth. Therefore careful monitoring of the crop is necessary to ensure that the level of stress applied will stop elongation without severely limiting diameter development.

Cultural treatments that work for loblolly pine are usually applied to shortleaf pine as well. However, the two species grow differently in the nursery. Shortleaf pine tends to develop more slowly early in the growing season, but also tends to grow longer into the fall and early winter than loblolly pine (Huberman 1940b). Nursery growth and the effects of nursery culture on field performance of shortleaf pine are currently under investigation by the authors.

Lifting

After high quality stock is produced, careful lifting and handling are essential to ensure good survival and growth after outplanting. Because shortleaf pine may not have as good storage potential as loblolly pine (Venator 1985), lifting schedules need to be closely coordinated with planting needs so that storage time can be minimized. Throughout lifting, handling, and storage operations, seedling roots must be protected from drying exposure, heat, extreme cold (freezing), and mechanical damage.

CARE OF PLANTING STOCK

Storage

Specific guidelines for the timing of lifting and length of time in storage for shortleaf pine genotypes will not be available until further research has been completed. Parallels can be drawn from research of loblolly pine. However, this must be done carefully since the timing of the dormancy cycle appears to be later in shortleaf than in loblolly. That is, shortleaf is later in forming a winter bud and survival potential is maximal from late December to early March (Wakeley 1954). In loblolly pine, root growth potential (RGP) increases as the seedlings are chilled by winter temperatures (0-8°C). However, storage of trees lifted too early causes a rapid decline in RGP (Carlson 1985). Until research specific to shortleaf pine can be completed, it is advisable to delay lifting shortleaf seedlings until late December and to complete that operation by March 1.

In general, storage time should be a maximum of 3 weeks after lifting. However, in one specific study, survival of shortleaf pine seedlings lifted in January and February dropped 36 percentage points following storage for 30 days while seedlings lifted in December stored well (Venator 1985). If seedlings are still in the nursery bed when bud break occurs, then storage time should be reduced to 1 week. These guidelines are very generalized but must remain speculative until research specific to shortleaf genotypes is completed. Storage of planting stock should be at 1-3°C in high humidity conditions. Planting stock must not be allowed to freeze since this reduces survival potential substantially (Bean 1963).

Freshly lifted seedlings should be kept in shaded, cool and moist conditions throughout the grading and packing operation. Seedling root systems should be coated with clay slurry to reduce desiccation in storage and handling. Packaging can be done in open ended U. S. Forest Serivce (USFS) bundles or in closed containers such as Kraft-Polyethylene (KP) bags or boxes. Packaging in bundles creates a need for watering each bundle in storage about every 3 days. Care must be taken to allow watered bundles to drain excess water since souring can occur when seedlings are under flooded conditions in storage. Bundles may be preferred over enclosed containers if cold storage is not available after seedlings leave the nursery. If cold storage is available, then enclosed containers provide high quality and less labor-intensive storage.

Transporting and Handling

Transportation should be via refrigerated van (1-3°C) from the nursery cold storage facility to a regional cold storage facility. Planting contractors should obtain seedlings from this facility on a daily basis. If regional cold storage facilities are not available, and distance from nursery to planting site is relatively short, then planting contractors should pick up seedlings daily from the nursery. If this is not feasible, then USFS bundles should be used and regional storage should be set up in a cool, shaded building protected from freezing, and with a water supply available. Delivery of stock to the planting site should be in a covered vehicle, preferably insulated against solar warming. If seedlings are stored on site outside this vehicle, then they should be protected from direct sunlight and from freezing.

Seedling handling on the planting site should be minimized. Seedlings should not be root pruned or counted under field conditions, since this will result in abnormally long exposure to desiccation. If such activities appear to be necessary then the nursery should be asked to do such work prior to shipment of the seedlings.

Container seedlings should be treated as described for bareroot stock if they are removed from the containers and shipped as plugs. If seedlings are shipped in the containers, then when they arrive at regional storage they should be removed from cartons, rewatered, and kept under shaded conditons. If cold storage is available then container seedlings can be placed in storage in the packing boxes.

PLANTING SPACING

The relationship between seedling planting spacing and stocking levels in the established stand is heavily dependent on seedling quality. If seedling survival can be predicted to be high, the number of seedlings planted per acre can be reduced to the point where precommercial thinning is not necessary. It is therefore apparent that high quality planting stock can play a major role in reducing not only regeneration costs but also the cost of later silvicultural activities. It follows that one can pay a premium price for such stock and reap considerable returns throughout the rotation (Venator 1981). Current planting spacing varies from 8 X 8 ft. to 10 X 10 ft. (681 and 436 seedlings per acre, respectively), depending largely on the confidence the forester has in attaining high survival.

EVALUATION OF PLANTING SUCCESS

An important aspect of regeneration is evaluation of whether the planting or direct seeding was a success. A walk through the area is not an adequate evaluation technique. The most reliable means of evaluation is to randomly select areas to be sampled sometime after the planting is completed. Terry (1983) suggests establishing twenty 1/100-acre plots on a grid on each tract in March or April following planting. Mark the center of each plot with a stake, locate the plot on a map and flag each planted seedling. In the fall after grass has died, return to the plot and count the surviving seedlings.

If at least 350 well-distributed seedlings per acre survive, it probably will not pay to replant. When first-year stocking is unsatisfactory it is often best to burn the area and replant. Most interplanting efforts result in suppressed seedlings. If compelled to interplant, do not plant within 20 feet of established seedlings.

Campbell (1982b) provides a detailed description of how to make inventories of direct seeded stands. A critical evaluation is necessary. Many direct seedings have been misjudged as failures simply because the evaluators did not locate small seedlings in a grass rough. Also, anytime direct seeding is used, some thought should be given to the potential need for precommercial thinning (Lohrey 1972).

When checking survival, evaluation should be made for other problems that may exist--i.e., disease or insect infestations, or need for release from competing hardwoods. Plantations that survive the first year may be lost if needed corrective action is not taken.

SUMMARY

The goal of reforestation should be to plant seedlings of the best genetic and physiological quality available for the site. This requires teamwork between the nursery manager and silviculturist. Nursery practices which have major impacts on seedling quality include soil management, seedbed density, control and protection of seedling development, and timing and methods of lifting. Between lifting and planting, a cool moist environment is essential to maintain stock quality. Seedlings must be protected from heat, desiccation, and freezing during handling, storage, and transportation, and at the planting site.

The ultimate measure of seedling quality is field performance. Silviculturists and nursery managers need to be able to predict seedling performance based on characteristics that can be measured. Conventional morphological traits used to grade seedlings have provided some quality control, but an ability to assess physiological condition would provide a key to accurate prediction of nursery stock performance. Although several techniques have potential, an easy, reliable method for determining physiological quality of shortleaf pine seedlings is needed.

Direct seeding offers optional techniques highly suited to small landowners and for special situations such as reforestation following wildfires.

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TRENDS IN SHORTLEAF PINE TREE IMPROVEMENT

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ABSTRACT

Tree improvement programs of shortleaf pine (*Pinus echinata* Mill.) have developed over the past 25 years to the point that virtually all demand for planting stock is met with genetically improved trees. About 22,600 acres of improved stock are planted each year. Although shortleaf has the largest geographic range of any southern pine, it is not being promoted in reforestation programs as much as alternate species, presumably because of slower growth. The largest shortleaf reforestation and tree improvement programs are on the National Forests with the bulk of the program in Arkansas on the Ouachita and Ozark National Forests. Within a few years National Forests will have second generation orchards established.

Growth gains of 10%-15% are predicted from first generation unrogued orchards. Roguing will add another 5% and second generation gains will more than double those of the first generation.

With the advent of progressively faster growing trees from advanced generation breeding, and/or biotechnology, it is predicted that shortleaf will gain greater favor among landowners since it already has other traits equal to or better than alternative species.

INTRODUCTION

In order to present accurate, up-to-date information on shortleaf tree improvement, a questionnaire was sent to all organizations listed in the 1981 Directory of Seed Orchards (USDA 1982) with shortleaf pine seed orchards. The questionnaire was mailed during January 1986, and all replies were received by March 1, 1986. Follow-up phone calls were made when additional information or clarification was needed. The information in this paper is based on the results of the questionnaire, follow-up contacts, and the author's 15 years experience with the U. S. Forest Service in the National Forest Tree Improvement program.

Genetic tree improvement of shortleaf pine for reforestation programs began during the years 1959-1967 for thirteen organizations: 9 state, 2 federal, and 2 private industry (USDA-1981).

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Three of the states, Ohio, Alabama, and Virginia have dropped the program for lack of demand for shortleaf planting stock. Of the remaining programs, only 4 (Arkansas, North Carolina, Oklahoma, and the U.S. Forest Service) are collecting seed and growing seedlings for operational planting. Kentucky is growing improved seedlings from purchased seed. Tennessee Divison of Forestry plans to begin producing improved stock in 1987. Missouri has begun a cooperative program with the U. S. Forest Service which will provide the State's landowners with improved seedlings in a few years. The remaining programs have no firm plans for growing improved shortleaf planting stock. About 22,600 acres are planted with shortleaf improved stock each year, about 18,500 acres of which is on National Forests.

Figure 1 - Organizations with shortleaf pine seed orchards as of March 1, 1986.

ORGANIZATION	ACRES OF ORCHARD	DATE ESTABLISHED	PRODUCING SEED	M TREES YEARLY SEEDLING PRODUCTION	YEARLY ACREAGE PLANTED
American Can. Co.	7	1963	Yes	0	0
Arkansas, State of	10	1967	Yes	300	430
Georgia, State of	2	1962	Yes	0	0
International Paper	18	1959	Yes	0	0
Kentucky, State of	6	1965	No	2,000	3,000
N. C., State of	7	1963	Yes	200	285
Oklahoma, State of	27	1967	Yes	250	357
Tenn., State of	4	1967	Yes	0	0
Tenn. Valley Auth.	6	1967	Yes	0	0
U.S. Forest Service	580	1963	Yes	13,875	18,500
	667			16,625	22,572

INDUSTRY PROGRAMS

International Paper Company (IPC) made selections in South Arkansas and grafted a 30-clone, 18-acre orchard at Springhill, Louisiana in 1959 (Figure 1). The orchard has been producing seed for many years. IPC has not used much of the seed in the past but now have plans for producing about three million seedlings each year for sale to Arkansas landowners starting in 1987. They are progeny testing the clones with open-pollinated seed. Several of the tests are 5 years old or older. They have no plans for second generation breeding.

American Can Company established a 7-acre orchard at Myrtlewood, Alabama in 1963. The orchard has been producing seed since the mid-1970's but only small amounts have been collected since they have no plans for using it. They have four open-pollinated tests and one controlled-cross test. They also do not have plans for second generation breeding.

STATE PROGRAMS

Presently five state forestry organizations have orchards producing commercial quantities of improved seed. One is producing improved seedlings from purchased seed. Two more will be producing improved seedlings within the next few years.

The Arkansas Forestry Commission has a 10-acre shortleaf orchard and is currently producing about 300,000 seedlings per year for outplanting in Arkansas. They plan to increase production to about 2 million seedlings per year. Progeny testing is being done by controlled crosses and plans are to develop a second generation orchard.

The Georgia Forestry Commission has a 2-acre shortleaf orchard composed of 61 clones obtained from the TVA program. Commercial seed production began in 1973. Open-pollinated progenies from 20 families were planted in 1982. Georgia has no plans for either producing improved shortleaf seedlings or second generation breeding.

The Kentucky Division of Forestry has a 6-acre orchard which was established in 1965 at Gilbertsville. It is not producing commercial quantities of seed; however, about 2 million improved shortleaf seedlings per year are produced from seed purchased from the U. S. Forest Service. They are not progeny testing the orchard and have no plans for second generation breeding.

In 1983, the Missouri Department of Conservation started a cooperative program with the U. S. Forest Service which will provide Missouri with first and second generation improved seed. The Department has already located some additional woods selections both on National Forest and State lands for testing and eventual use in seed orchards.

The North Carolina Division of Forest Resources has a 7-acre shortleaf seed orchard with 20 clones in Morganton. It was established in 1963 and has been producing commercial quantities of seed since 1977. The Division has produced about 200,000 superior shortleaf seedlings per year. Open-pollinated progeny tests were established in 1982 at two sites, one in the Piedmont and one in the Mountain province. Progeny test measurements are scheduled at ages 4, 8, and 12 years.

The Department of Forestry, Oklahoma State University, established 17 acres of shortleaf orchard at Idabel in 1967. The seed is used by the Division of Forestry to grow about 250,000 seedlings per year for Oklahoma landowners. Progeny testing is being done with open-pollinated seed. No plans have been made for second generation orchards.

The Tennessee Division of Forestry has a 4-acre shortleaf seed orchard at Pickett State Forest and has recently assumed management of TVA's 6-acre orchard at Norris. The first production of improved shortleaf seedlings is planned for 1987. There are no firm plans for progeny testing and second generation breeding of shortleaf because other species work has a higher priority.

FEDERAL PROGRAMS

Tennessee Valley Authority

The Tennessee Valley Authority (TVA) established a 6-acre shortleaf orchard in 1967 near Norris. TVA has decided not to continue tree improvement and has turned over management of the orchard to the Tennessee Division of Forestry. The Tennessee Division of Forestry plans production of improved seedlings from this orchard's seeds beginning in 1987.

National Forest Program

The largest shortleaf tree improvement program by far is for the National Forests. This is because the U. S. Forest Service opted to reforest with shortleaf instead of loblolly in many parts of the natural range of shortleaf. National Forest land, where shortleaf pine is the preferred management type, includes 2.8 million acres in 14 states extending from Virginia west to Texas and Oklahoma and north to Missouri and Illinois. Shortleaf management type on National Forests is exceeded only by the white oak red-oak-hickory type which has about 3.5 million acres. By contrast, the loblolly management type has about 2 million acres on the National Forests.

That shortleaf pine is the preferred management type over such a diverse geographic area is not surprising when one considers that it has the most widespread distribution of any southern pine and occurs naturally in 22 states and on a wide variety of soil and site conditions (Fowells 1965) (Lawson and Kitchens 1983).

However, to get a better picture of where National Forest managers intend to grow shortleaf pine, one must consider other factors besides geographic range. The bulk of the shortleaf pine acreage is located in mountainous areas of Arkansas, Missouri, and the Appalachians. In the Piedmont and Coastal Plain, loblolly is generally chosen over shortleaf. One exception to this general rule is demonstrated on the National Forests in Texas where more loblolly is planted than shortleaf but due to excellent shortleaf development about 1,000 acres are regenerated to shortleaf each year.

An area where the decision to reforest with shortleaf is most questioned is in the Ouachita and Ozark mountains of Arkansas. Since many private landowners and timber industries in this area choose loblolly, the question is often asked, "Why reforest with shortleaf when loblolly is a faster-growing species?" There are basically four reasons:

1) The National Forest timber objective is to grow quality sawtimber. Because of this and other multiple-use objectives, the National Forests are on long rotations (60 to 80 years). No doubt, loblolly will outproduce shortleaf on most sites on short rotations, but existing yield data suggests that shortleaf yields on long rotations will match that of loblolly.

Since shortleaf has other excellent lumber qualities (straightness, small limbs and branch angles), it suits the National Forest timber objective for quality sawtimber quite well.

2) On many sites, especially in Arkansas, loblolly has been planted a considerable distance north of its native range by landowners. While experience shows this to increase volume production, the possibility exists for catastrophic events (especially snow and ice damage) to cause losses. This may prove to be best for short rotations, it may not be best for long ones. In other words, the decisions in favor of loblolly for short rotations and shortleaf for long rotations may both be correct.

3) The third reason is diversity. National Forest managers are charged by law to maintain diversity. By growing shortleaf within much of its range, this requirement is being fulfilled. A conscious decision has been made to put loblolly on some former shortleaf sites west and north of the present loblolly range. In Arkansas, this is generally on more mesic pine sites and lower elevation sites. However, the proportion of acres planned for this is relatively small.

4) A fourth reason is that we can breed shortleaf to grow faster and produce more quality volume. Shortleaf already has excellent wood qualities. First generation breeding is producing a high degree of straightness. Therefore, given high-wood quality and straightness at the end of the first generation, subsequent breeding can concentrate on growth and thus make larger gains in growth than could be made if several traits had to be factored into the selection index.

A breeding program for improving shortleaf for National Forests began in 1959 when Tom Swofford, the first Regional Geneticist for the Southern Region, Region 8 (R8), finalized plans for selection and grading. The Eastern Region, Region 9 (R9) started a program in the late 1960's for reforestation in Missouri and Illinois. Since R8 already had an orchard established in Arkansas, R9 established their orchard adjacent to it and used the same personnel for management. The R9 program was developed along the same lines as R8's with some exceptions, such as orchard design. The R8 and R9 programs had 12 geographic sources with 50 mother-tree selections per source. The geographic sources were divided along state boundaries except for Arkansas and Oklahoma which had three geographic sources (two for Ouachita National Forest and one for Ozark National Forest), and R9 which planned one geographic source to be used for Missouri and Illinois.

The very best trees were sought among 2.8 million acres of shortleaf pine as candidate parent trees for first generation orchards. After a candidate was found, it had to pass several screenings before it was finally accepted. Faster growth, pruning ability, straightness, disease resistance, and specific gravity were the traits sought in the superior tree selections. Then the selections were grafted onto potted rootstock and outplanted into clonal seed orchards at 15' X 30' spacing. Five orchard locations were established during the years 1963-1970.

Figure 2 - Shortleaf Pine National Forest Seed Orchards

ORCH. NAME AND LOCATION	REGION	ACRES	YEAR ESTABLISHED	CLONES	GEOGRAPHIC SOURCES
Ouachita Mt. Ida, AR	8	313	1963	147	Arkansas & Oklahoma
	9	85	1968	50	Missouri
Erambert Brooklyn, MS	8	11	1963	59	Mississippi
Stuart Pollock, LA	8	47	1964	100	Louisiana & Texas
Beech Creek Murphy, NC	8	99	1966	117	Tennessee, N. Carolina, Kentucky, & Virginia
Francis Marion Moncks Corner, SC	8	25	1970	50	Georgia

Early graft incompatibility was so great for about 10% of selected trees that they had to be discarded and new selections made. Some apparent graft incompatibilty showed up in later years but the number of clones affected was insignificant.

Once grafts were outplanted, orchard managers worked hard establishing ground cover and growing trees to seed production status. Orchards were fertilized early after establishment to promote grass and tree growth based on the recommendation of Dr. Jack May (for results see May 1977). Later, the fertilization regime was done to promote flower and cone development (Schmidtling 1975). Schmidtling also showed that irrigation would greatly increase seed production. However, due to the large size of orchards and the costs estimated for irrigation systems, irrigation has not been used.

Seed production in collectible quantities began at about age 10 in the shortleaf orchards. The largest crop collected was in 1983 when 8,653 pounds of seed were collected from four orchards. Even this is small in comparison to the 12,000 pounds predicted to be available for the 1986 collection on the Ouachita orchard alone.

The orchards have been thinned two or three times as the trees have grown larger. Thinnings were done based on spacing, appearance of the ramet, ortet characteristics, and seed and cone production. Since progeny test results were not available, no clone was completely removed. Now that some limited progeny test results are available, future thinning will be actual roguings where the poor performer will be removed. This will increase the overall average gain of the orchard seed collected subsequent to roguing.

The two greatest problems in orchard management thus far have been controlling cone and seed losses due to insects and collecting cones and/or seeds.

Because a seed orchard has many trees of the same age, it is an alluring home for insects--especially those which feed on cones and seeds. Safe and effective ways had to be developed to control these seed-destroying insects. Entomologists worked closely with orchard managers on pesticide formulation, application, and timing for effective control. With the help of several organizations, technology for the aerial application of insecticides was developed. Now an orchard can be treated in hours instead of the weeks required for ground-application methods. In addition, aerial applications place the insecticide in the top portion of the crown, where the cones are. This means less insecticide is necessary to do an effective job.

When trees started producing sufficient quantities of cones, picking them presented no real problem. However, when the crop increased to thousands of bushels, the job became formidable. Since this procedure must be done within 4 to 5 weeks (or the cones will open and seeds will fall out), many people are required to pick the cones. Also as the trees grow taller, the conventional ways of using ladders, truck beds, and tractor platforms become less effective. Since bucket trucks and other hydraulic lifts are so expensive, not enough of them can be purchased or rented to do the job.

With the cooperation of the Georgia Forestry Commission, a new system has been developed, called the Net Retrieval System. Netting is placed on the ground. The cones are allowed to ripen then the seeds fall on the net. Then a combine-type machine is used to roll the net and separate the seeds. The Net Retrieval System is now in operation on all or parts of five Forest Service orchards (Edwards and McConnell 1983, McConnell and Edwards 1985), and other organizations are considering using this system.

Results have been excellent on level topography on three of the orchards. The use of the Net Retrieval System has not worked well at the Ouachita Orchard due to hilly, rocky terrain and birds feasting on the seeds. Several noise devices have been used to deter the birds, but with only limited success. In order to shorten the time the seeds were on the nets, a helicopter was used to create a turbulence to remove the seeds from the opened cones. The helicopter worked well--in fact too well--it created so much turbulence that the seams in the netting came loose. Next year, additional tie-downs will be used to keep the netting in place.

Progeny Testing

Progeny testing is being done to measure gains, test worth of parents, and most importantly, as a source of selections for second generation orchards. In 1974, controlled crosses among orchard trees were started according to a plan that employed disconnected half-diallels. Individual matings were made to match desirable characteristics as indicated by the original mother-tree scoring sheets (McConnell 1983).

When the progeny testing plan was developed in 1974, it was decided that the 12 geographic sources for R8 could be combined into five. Due to low demand for shortleaf planting stock in Mississippi, it was decided not to carry that population past first generation breeding, so progeny testing in it has been suspended. Including Missouri, a total of about 1,315 individual crosses will have been made when the progeny-test plan is completed. Through the 1985 breeding season, about 75% of the crosses have been made.

When sufficient controlled-pollinated seed from 15 or more families is available, progeny tests are planted. To date, 123 tests have been established. Eighteen are five or more years old and have had 5-year measurements made.

Figure 3 - 2-year old shortleaf pine progeny test, Caddo Ranger District, Ouachita National Forest. Range pole is in one-foot graduations.

Early results have been quite surprising. Of course, early results must be used with a great degree of caution. Nevertheless, they indicate that large genetic gains are being realized.

Gains

Based on results of progeny tests and observations and measurements of operational plantings, conclusions of benefits and gains can be made. Since loblolly breeding has been going on longer than shortleaf, experienced gain figures for loblolly have been used to estimate those obtainable in shortleaf. Based on early results with shortleaf tests to date, using loblolly results seems reasonable.

Volume gains of 10%-15% from first generation seed in unrouged orchard has been predicted. Thus far on shortleaf progeny tests at 5 years, heights of all control-crossed families has averaged 7%-25% higher than commercial checks on seven tests thus far analyzed. At 5 years, no diameter measurements were taken and no volume measurements made. Measurements at 10 years will give more definitive results. However, for actual gain figures to be fully known, tests will have to be much older. Nevertheless, 10% to 15% volume gain seems to be a reasonable assumption.

One point often overlooked is that volume gains (faster growth) translates into much higher economic gains mainly due to shorter rotations. Trees that will grow 15% faster than woods-run trees will give economic gains of up to 25% or more. In fact, by shortening rotations, some acres that otherwise would lose money growing timber, can be made profitable. Combining faster growth with improvement in quality traits really multiplies gains.

Gain in straightness is apparent early. Straightness has a high heritability and phenotypic selection works well. Almost all families from the first round of selection are producing a high proportion of straight trees.

A very surprising result of the tree improvement program is the great improvement in survival of orchard stock. This was first noted in progeny tests where survival was typically 90% or better and in some tests approached 100%. This was mostly attributed to the fact that progeny test seedlings are handled and planted with greater care than operational plantations.

However, when plantation records for 5 years (1980-1984) were examined, more surprising results appeared. During the 5-year period, the Ouachita and Ozark National Forests planted 57,655 acres with shortleaf orchard seedlings and 11,695 acres with general forest area shortleaf. The orchard seedlings had a survival rate 22% greater than general forest area seedlings. How much of the increase is due to genetics and how much to that intangible "when-you-got-something-good-you-take-better-care-of-it" principle, no one knows. It certainly is plausible that orchard seedlings have better adaptability for a wider range of sites since the mother trees were selected over a wide range of habitats and gene combinations are produced that never could happen in the woods.

FUTURE

Due to rapid advances in genetics and biotechnology, it is hard to predict the exact path of the future of shortleaf tree improvement. One certainty is that additional gains will be made in breeding this marvelous species. I predict that when present and future gains are demonstrated with older tests, shortleaf pine will gain greater favor among landowners and be replanted on formerly occupied sites.

There are at least three possible routes of additional improvement. Combinations of these three are possible also.

Biotechnology/Genetic Engineering

Ledig and Sedaroff summarized the state-of-the-art of genetic engineering new improved trees as follows.

> Gene transfer, using recombinant DNA technology, can be used to engineer new, improved trees in a fraction of the time required by traditional breeding methods. Genetic engineering requires isolation of genes, their multiplication in bacteria, their transfer to tree cells, and regeneration of the transformed cells into new trees. Success has already been achieved in cloning conifer genes and in developing a transfer system, and several genes of potential value to forestry have been isolated from bacteria. The inability to regenerate to forestry conifers from transformed cells is the major remaining barrier to application of genetic engineering in tree improvement (Ledig and Sedaroff 1985).

The major remaining barrier is a huge one indeed and no one predicts it will be overcome soon. However, when it is overcome, tree breeders will make gains in an incredibly short time frame.

Interspecific Hybridization

The greater growth rates of loblolly and slash pines suggest potential for improving shortleaf growth by hybridizing. Shortleaf X loblolly and shortleaf X slash were made as early as 1933 and outplanted at several locations throughout the Southern United States. Generally, both hybrids grew faster at many locations than did shortleaf. Considerable recent work with loblolly and shortleaf has been reported by Kraus and LaFarge (Kraus and LaFarge 1977, LaFarge and Kraus 1980). Their goal is to develop rust-resistant strains of loblolly through hybridization, but it is not known how well these strains will perform in the northern parts of shortleaf's range. The possibility exists that through testing, some excellent strains could be developed for planting in places where shortleaf is the preferred species.

Conventional Breeding Techniques

Given current technology, the greatest additional gains in shortleaf tree improvement will probably be made through another cycle of selection and grafting clonal orchards. Several organizations have indicated plans to go into second generation programs. The U. S. Forest Service is closest in time to establishing second generation orchards.

The 12 first generation shortleaf pine geographical sources have been streamlined into six (five for R8, one for R9) second generation breeding populations (Wells and McConnell, 1983). The decision has been made not to carry the North Mississippi population to a second generation; therefore, there are five populations where second generation orchards are planned. The breeding populations have been prioritized for second generation orchard establishment based on timing of progeny tests and on how important a particular breeding population is to the total tree improvement program (Kitchens 1985).

Selections for second generation orchard parents will be made from first generation progeny tests. The best individual trees from the best families will be grafted into second generation orchards.

The shortleaf breeding population for Arkansas and Oklahoma has the highest priority. Orchard clearing is scheduled for 1988 with establishment shortly thereafter. Other populations will be 2 to 6 years behind. Of course, all plans are contingent on budgets which could delay plans for some time.

In order to keep the genetic base broad, new woods selections of superior phenotypes will be made. These selections will be cloned into breeding orchards for testing and use in advanced generation breeding (past second generation).

CLOSING

Shortleaf tree improvement has developed in the last quarter-century such that almost all demand for planting stock is met with genetically improved seed. Due to size of present orchards and their increasing production, future demand can be met even if there is a significant increase in demand. Second generation orchards should be producing even better stock before the beginning of the 21st century.

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BASAL AREA OR STOCKING PERCENT: WHICH WORKS BEST IN CONTROLLING DENSITY IN NATURAL SHORTLEAF PINE STANDS

Ivan L. Sander[1]

ABSTRACT

Results from a shortleaf pine thinning study in Missouri show that continually thinning a stand to the same basal area will eventually create an understocked stand and reduce yields. Using stocking percent to control thinning intensity allows basal area to increase as stands get older. The best yield should occur when shortleaf pine is repeatedly thinned to 60 percent stocking, the minimum that will fully utilize a site.

INTRODUCTION

There are many trees per acre in fully stocked natural shortleaf pine stands. Each tree has a minimum amount of growing space available to it, individual trees grow slowly, some trees are crowded out and die. When we reduce density, each remaining tree has more room to grow, trees grow faster, and fewer die. If we reduce density further, we reach the point of full-site utilization--where each tree has all the growing space it can use but no more. If we reduce density below this point, diameter growth will be at its maximum, but growing space will be wasted, the yield of products reduced, and a vigorous understory will begin to develop in response to the excess growing space. The question then is, at what density should we maintain a stand to realize optimum growth and product yield?

BASAL AREA VS. STOCKING PERCENT

Controlling density really means controlling growing space so that each tree left in the stand has enough room to grow well. How can we accomplish this most efficiently? Traditionally we have used basal area to control thinning intensity, but basal area alone is not a good measure of stocking or relative density. We also need to know something about the age or average tree size to estimate what the residual basal area should be at that particular point in the life of the stand. The general development of even-aged stands shows that basal area increases rapidly when the stand is young. It then decreases and finally levels off or declines as mortality increases because of overcrowding. If we continually thin a stand to the same basal area level, we do not allow this natural pattern to occur and we soon have an understocked stand.

How can we avoid creating an understocked stand? One way is to let the residual basal area level increase each time the stand is thinned. This will work but requires several site- and age-specific basal areas.

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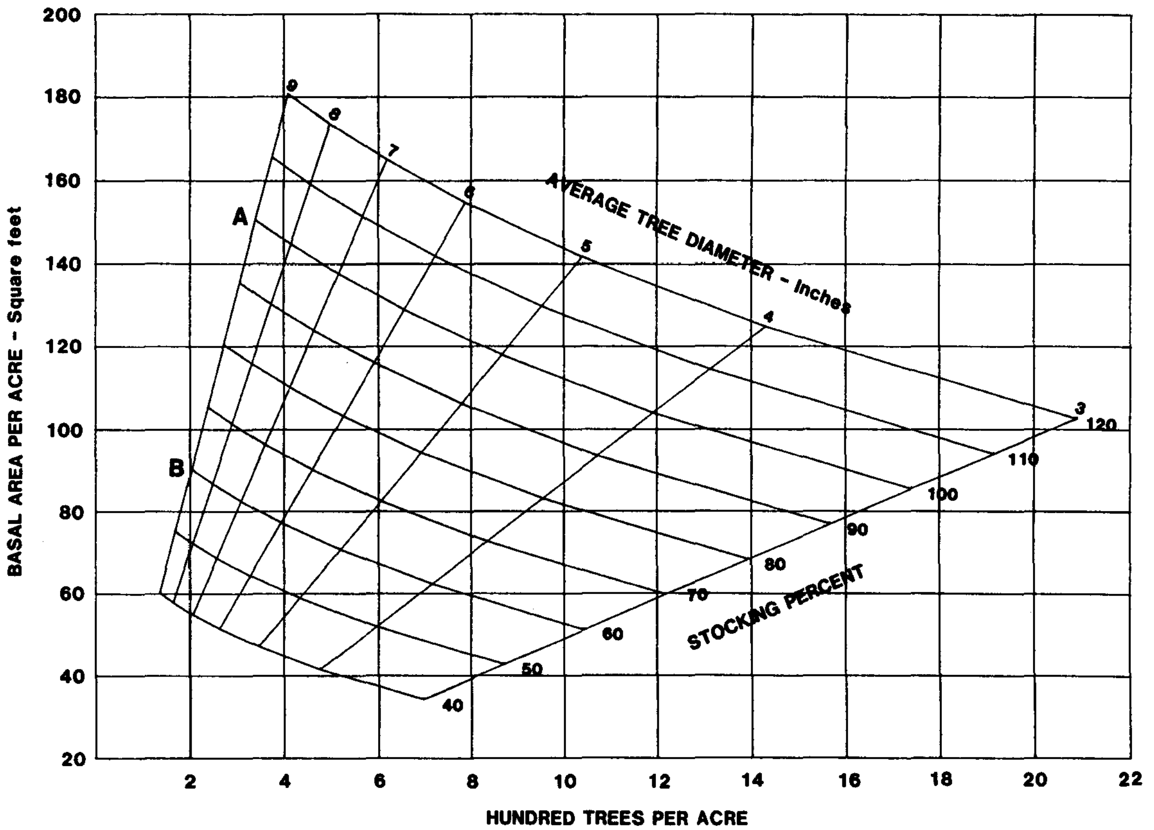
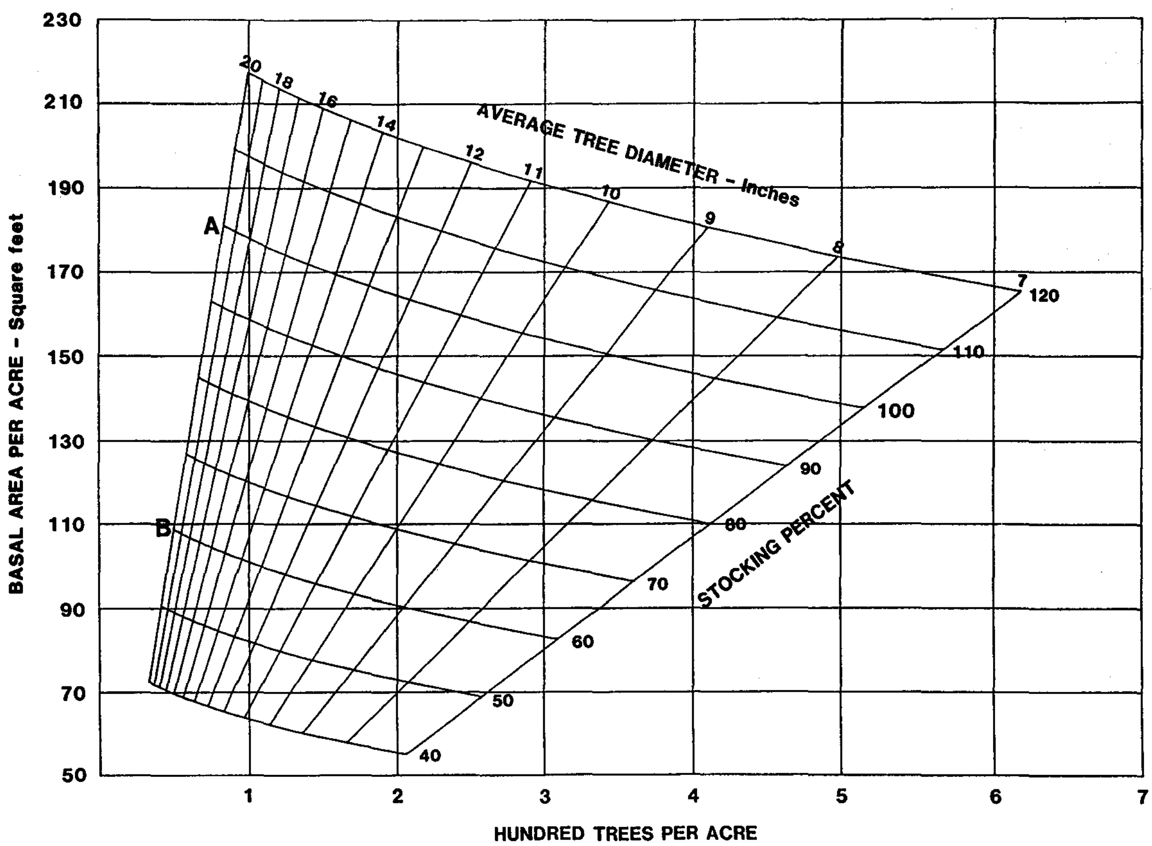


Figure 1. Relation of basal area, number of trees, and average tree uniformity. The area between Curves A and B indicates the range of diameter is the diameter of the tree of average basal area.

A better way to control thinning intensity is to use stocking percent and a stocking chart (Figure 1) developed by Rogers (1983). Stocking percent is an expression of the amount of growing space required by trees of various sizes. The line labeled B on the chart is the stocking at which each tree has the maximum amount of growing space it can use, and is the minimum stocking required for full-site utilization. The A line is the stocking at which each tree has just enough growing space to stay alive. Between the A and B levels, a stand is considered to be fully stocked because it can fully utilize the growing space.

If we maintain a stand at a constant stocking percent, basal area will increase as the stand gets older and average tree size increases. Stocking percent is also independent of site quality and stand age. This means that a tree of a given size needs the same amount of growing space regardless of how old it is or where it is growing. Trees on good sites will grow faster because the same amount of growing space on a good site contains more of the factors necessary for growth than on a poor site. Thus we need only specify one residual stocking percent, and we can continually thin a stand to that level and still maintain a fully stocked stand.



diameter to stocking percent for shortleaf pine stands of average
stocking where trees can fully utilize the growing space. Average tree

The results from a shortleaf pine thinning study in Missouri illustrate how this species responds when thinning intensity is controlled by basal area alone.

THE STUDY

The stand in which the study was installed originated after the harvest of an oak-pine stand. The area burned periodically until the USDA Forest Service acquired it in 1933 and has not burned since.

Information about initial stand establishment and composition is not available. However, we do know that when the stand was 15 years old, the remaining overstory trees were cut or killed, small competing hardwoods were cut, and the pine was reduced from about 1,100 to about 600 trees per acre. When the study was begun, the stand was 30 years old, averaged 570 shortleaf pine trees, and 130 square feet of basal area per acre. Average diameter was 6.6 inches d.b.h. The stand also contained about 3,700 hardwoods per acre, mostly in the understory, that comprised 14 square feet of basal area.

Four density levels were created by thinning--50, 70, 90, and 110 square feet of basal area per acre. An unthinned treatment was left as a check. The thinning method used can best be described as a "free" thinning, in which trees from all crown classes are free to be removed. Generally the smaller, less vigorous trees were removed first, but better trees were also removed to attain uniform spacing. Since the study began, the plots have been thinned three times at 10-year intervals, always to the same basal area level. Any hardwoods in the overstory were cut and the understory hardwoods were controlled with herbicides.

RESULTS

The data have not been subjected to rigorous statistical analysis. Rather, I have used unadjusted plot averages to show a general pattern of stand development when shortleaf pine is thinned to constant basal area levels.

Stocking percent ranged from 88 to 111 percent before any of the plots were thinned the first time (Table 1). After the first thinning, stocking percent of the 50 and 70 level plots was less than needed for full-site utilization, and this understocked condition became worse with each subsequent thinning. The 90 level plots were close to the minimum for full-site utilization after each thinning; the 110 level plots were overstocked. However, stocking percent at all levels was lower after the second and third thinnings than it was after each previous thinning.

Table 1. Stocking percent before and after thinning shortleaf pine to constant residual basal area levels.

		Residual Basal Area Level [1]				
Age		50	70	90	110	Un-thinned
		----- Stocking Percent ------				
30	Before	88	111	104	95	116
	After	37	49	64	79	116
40	Before	56	71	84	97	131
	After	31	45	60	74	131
50	Before	42	62	77	94	134
	After	31	43	58	70	134
60		35	48	67	78	118

[1] Square feet per acre.

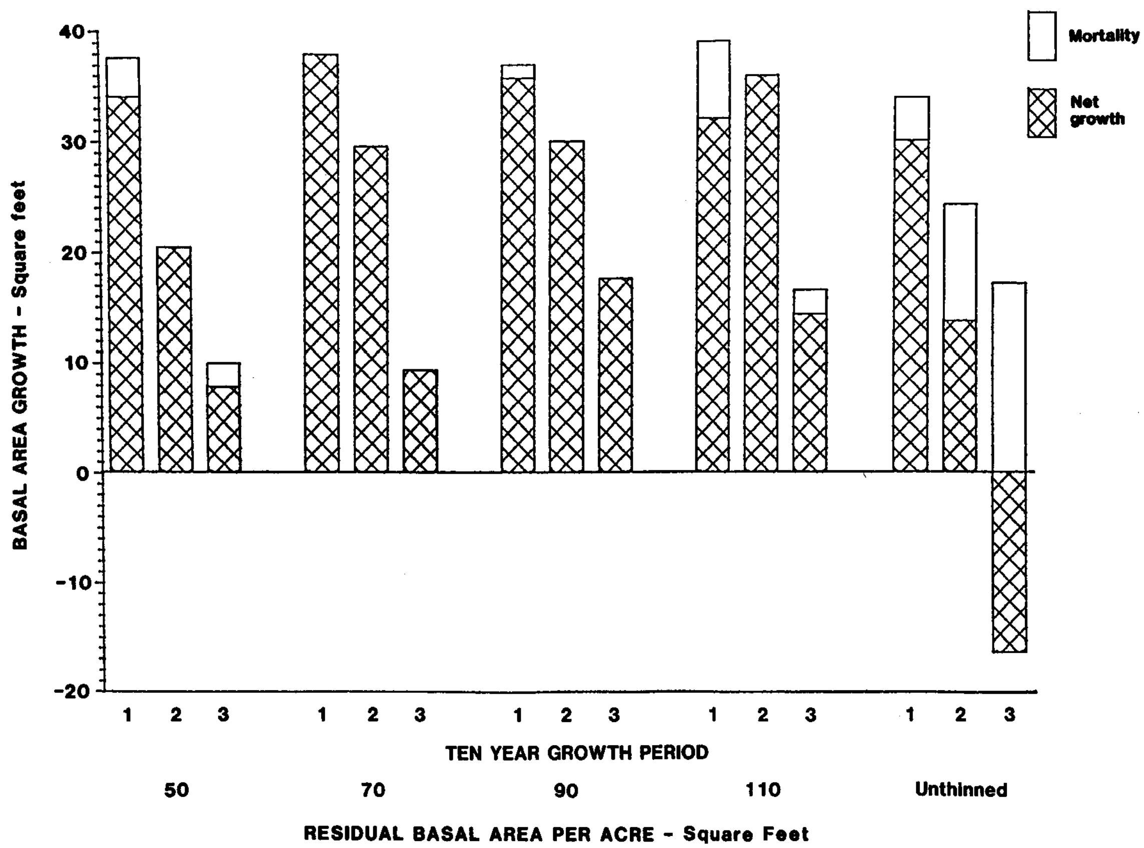


Figure 2. Basal area growth per acre of shortleaf pine thinned to constant basal area levels.

After the first thinning, net basal area growth was greatest at the 70 level (Figure 2). Growth at the other levels fell in the order 90>50>110>unthinned. However, the differences in basal area growth among residual density levels were small and of no practical significance. The amount of growth at the 50 and 70 levels demonstrates the ability of young shortleaf pine stands to recover from an understocked condition if enough trees are present to provide at least 60 pecent stocking at some future age. This ability to recover has also been demonstrated for upland central hardwoods (Gingrich 1967).

Net basal area growth after the second thinning was much lower at the 50 and unthinned levels because of understocking at the 50 level and increased mortality on the unthinned plots. Growth was greatest at the 110 level and about equal at the 70 and 90 levels. Although the residual stocking percent at the 70 level was only 45, enough trees were left to regain full stocking in 10 years, and the stand was still growing fast. Why growth was higher at the 110 level than at the 90 level is not clear. However, the residual stocking percent at both levels was within the range of full stocking (Table 1). Thus, even though net growth at the 90 level could be expected to be higher than at the 110 level, the stocking at the 110 level was low enough to prevent mortality that would result from overcrowding.

During the 10 years after the third thinning, net basal area growth was much reduced from what it was after the first and second thinnings. This reduction occurred because the stands had reached the age--50 years--when in the absence of thinning, basal area per acre was leveling off and net basal area growth was starting to decline. Greatest net basal area growth during this period was at the 90 level, but only slightly more than at the 110 level. At all other levels growth was significantly lower.

The best total net basal area growth from age 30 to 60 was 84 square feet per acre at the 90 level. This was only 1.5 square feet better than at the 110 level, but much better than the 77, 62.5, and 27.5 square feet per acre at the 70, 50, and unthinned levels, respectively. Residual stocking percents after each thinning were closer to the 60 percent minimum for full-site utilization at the 90 level than at any other level. Thus we would expect growth to be greatest at this level.

Net merchantable cubic foot and board foot volume growth followed patterns very similar to basal area growth (Figure 3). The growth after thinning was not consistently greatest at any residual density level for all growth periods. Growth was better at the 90 and 110 levels than at the other levels. The lower growth at the 50 and 70 levels is the result of understocking; the lower growth at the unthinned level stems from overstocking. The difference in total growth between the 90 and 110 levels occurred during the period from age 41 to 50. The reasons for this are not apparent, but as with basal area growth, the lack of any mortality at the 110 level probably contributed to better growth than we expected.

Although not identified separately, ingrowth contributed to total net growth of both cubic and board feet at all density levels after the first thinning. After the second thinning at age 40, no trees were smaller than the 5-inch minimum diameter for cubic foot volume except on the unthinned plots (Figure 4). Board foot volume ingrowth was significant only at the 110 and unthinned levels. After the third thinning at age 50, no trees below the 7-inch minimum for board foot volume were left except on the unthinned plots. Both cubic and board foot volume growth were much lower after the third thinning than after either the first or second thinning.

The volume yields at age 30 are the result of natural stand development except for the thinning at age 15 (Figure 5). The effect of this early thinning cannot be determined because no records were kept. Thus we do not know if the trees removed contained any merchantable volume or what the residual basal area was. Standing merchantable volume at age 30 differed significantly. The 50 level had the lowest cubic and board foot volumes, the 90 level had the highest board foot volume, and the unthinned level had the highest cubic foot volume.

The highest net cubic or board foot yield, like volume growth, did not occur consistently at any one residual basal area level in all growth periods (Figure 5). It was apparent by age 50 that the 50 level plots were falling behind because they were understocked. By age 60, yield on the 70 level plots was significantly less than that on the 90, 110, and unthinned plots. The third thinning to 70 square feet at age 50 had reduced the stocking too much for these plots to reach 60 percent stocking by age 60

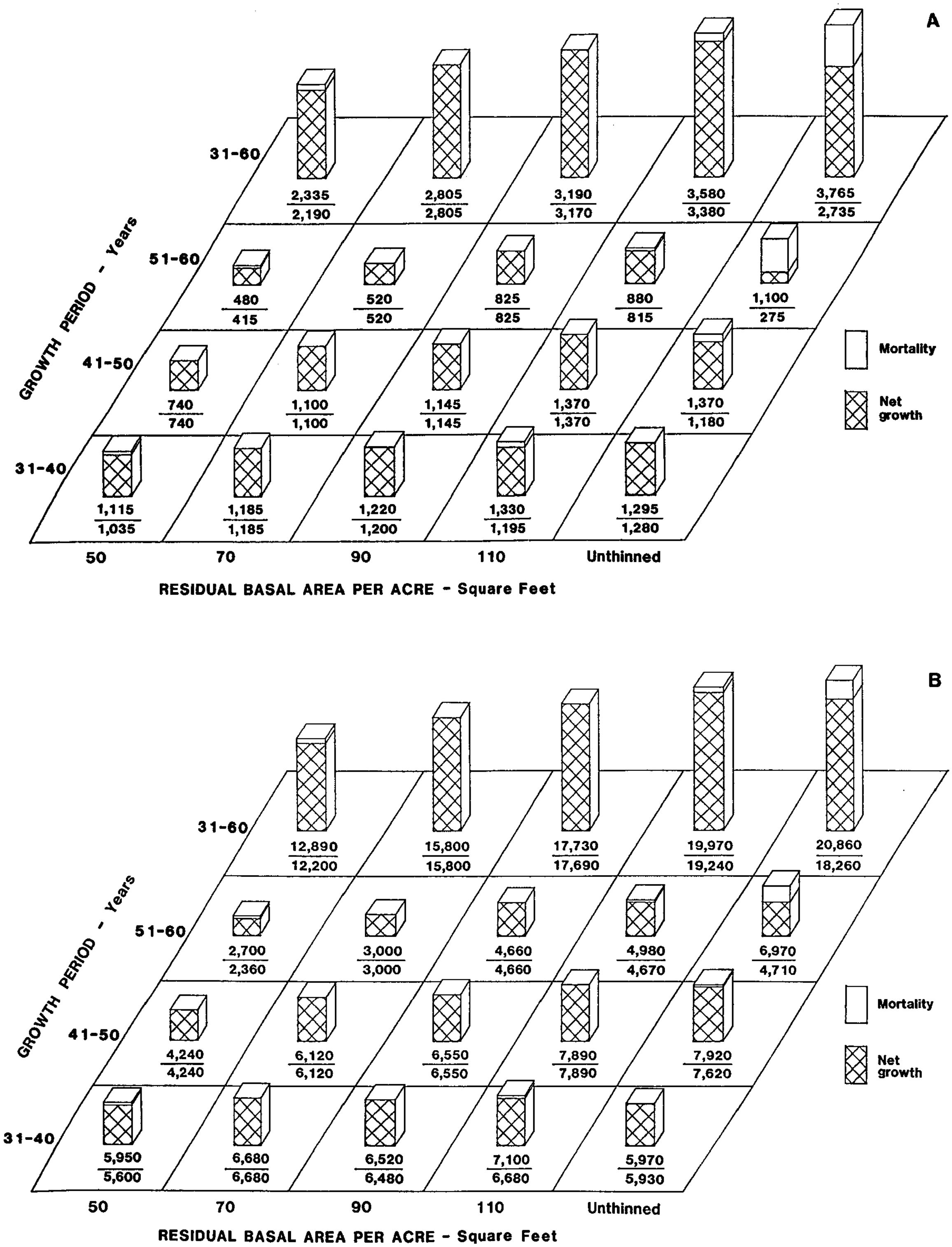


Figure 3. Volume growth per acre of shortleaf pine thinned to constant basal area levels. (A) Cubic feet less bark in trees 5 inches d.b.h. and larger to a 3-inch top I.B. (B) Board feet Int. 1/4-inch rule in trees 7 inches d.b.h. and larger to a 5-inch top I.B.

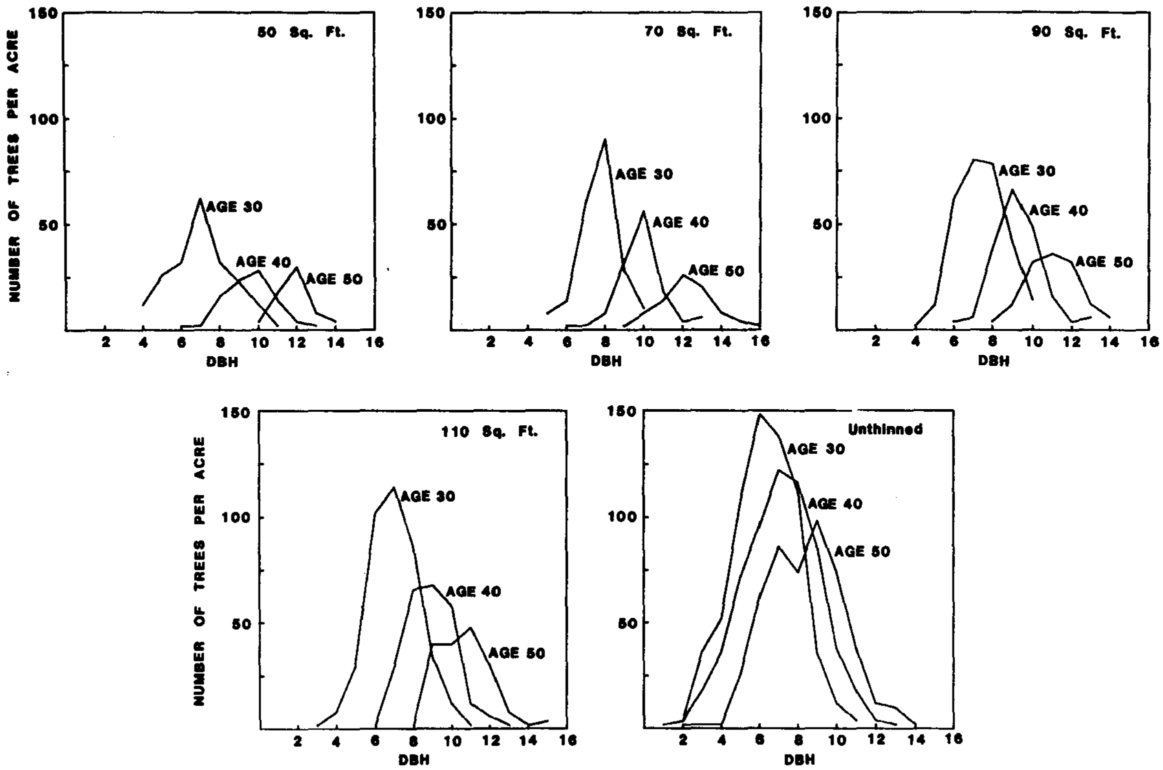


Figure 4. Diameter distribution of shortleaf pine after thinning to constant basal area levels at ages 30, 40, and 50.

and they like the 50 level plots are understocked. Yields at the 90 and 110 levels were about equal at age 60. Both of these levels are within the range of full stocking on the chart, and we would expect their yields to be similar. However, another thinning to 90 square feet would likely put these plots in an understocked condition also. Although net yield on the unthinned plots was about the same as it was at the 90 and 110 levels, mortality is increasing and further declines in net yield can be expected.

The harvested yield is important because most of the trees removed at age 30 were sold, and at ages 40 and 50 all trees removed were sold. The products cut were posts, poles, and saw logs. More volume has been harvested from the 70 level plots than from any other level (Figure 6). However, during the third thinning the most volume was harvested from the 110 level plots.

At age 60 the average tree diameter--diameter of the tree of average basal area--was largest on the 50 level plots and smallest on the unthinned plots (Table 2). This trend was expected because the growing space available to each tree decreased with increasing residual basal area. And, even though the trees are larger on the 50 level plots, yield is reduced because not enough trees are left to fully utilize the site.

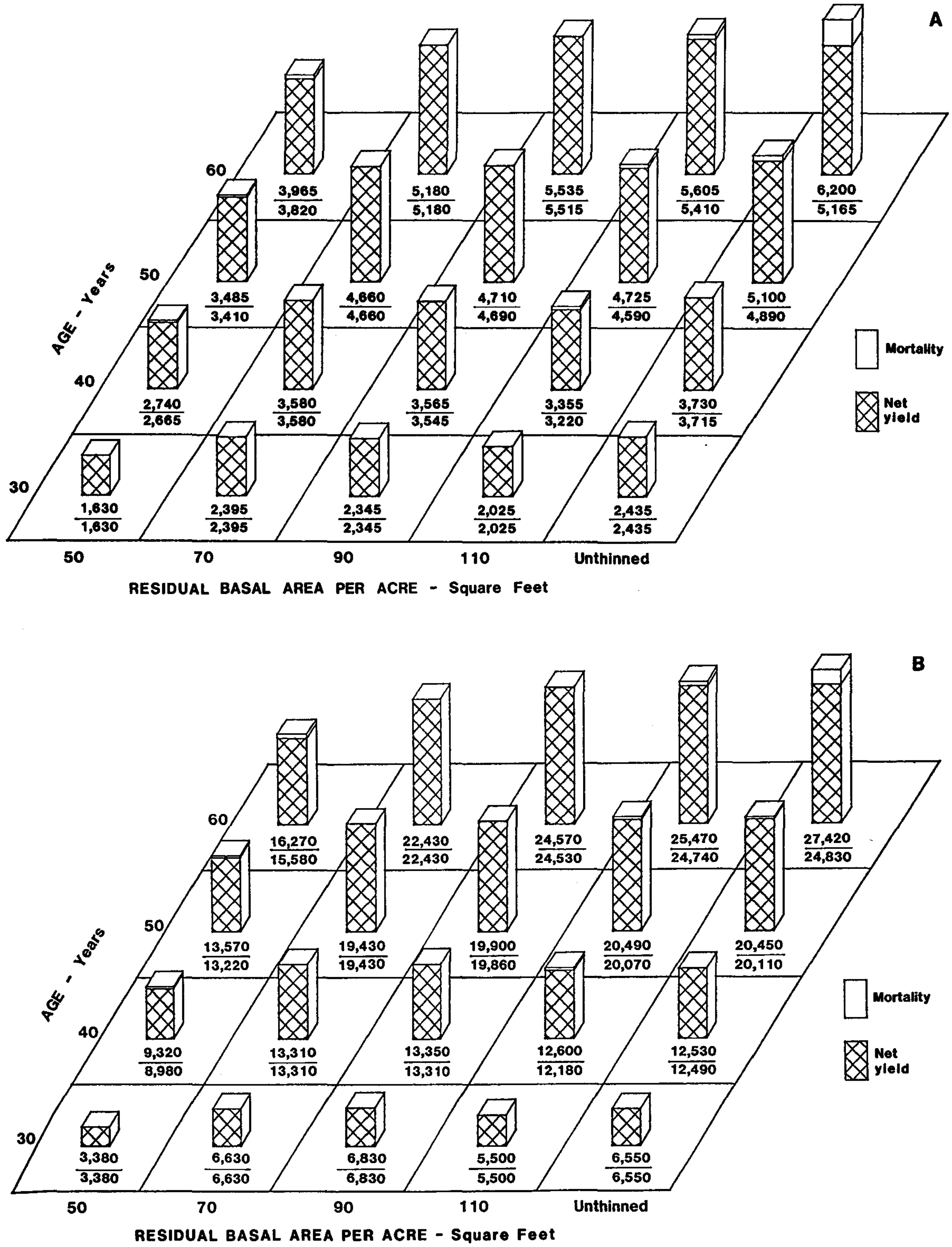


Figure 5. Yield per acre of shortleaf pine stands thinned to constant basal area levels. (A) Cubic feet. (B) Board feet.

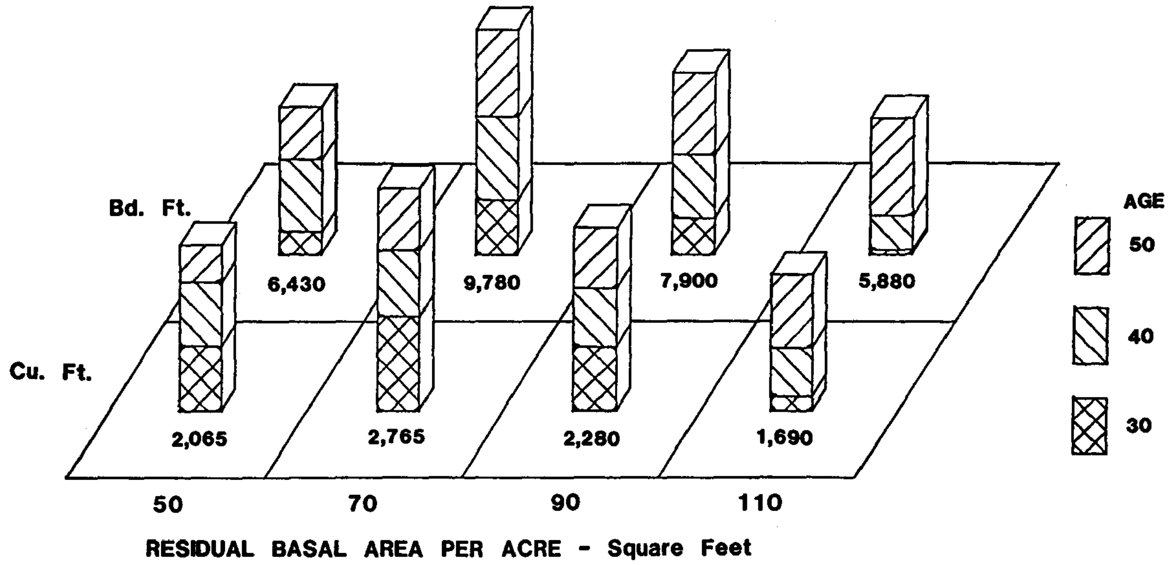


Figure 6. Volume harvested from shortleaf pine stands thinned to constant basal area levels.

Table 2. Average stand diameter [1] of shortleaf pine before thinning to constant residual basal area levels.

	Residual Basal Area				
Age	50	70	90	110	Un-thinned
	- - - - - - - - - - - Inches - - - - - - - - - - -				
30	6.5	6.4	6.7	6.5	6.5
40	9.8	9.4	9.1	8.2	7.5
50	12.5	11.8	11.2	10.0	8.5
60	14.5	13.5	12.2	11.6	9.7

[1] Diameter of the tree of average basal area.

IN CONCLUSION

At what density then should shortleaf pine stands be maintained to produce maximum yield? We cannot answer this question from the results of this study. The optimum density appears to be between 70 and 110 square feet of residual basal area, but we can't tell where or how much we should let residual basal area increase at each thinning. Burton (1980) found the highest yields of shortleaf pine-loblolly pine stands on plots first thinned to 70 square feet of basal area per acre at age 20, and the residual basal area allowed to increase 5 square feet at each subsequent thinning at 5-year intervals. Because no other increasing level was included, Burton's results do not necessarily provide a definitive answer to the best possible thinning regime either.

We can use stocking percent to control density and avoid this dilemma. If we thin to a constant stocking percent each time, basal area will increase and the stand will develop naturally but at a different rate than unthinned stands. Because 60 percent stocking is the lowest stocking that will fully utilize the site, maintaining stands at this level should result in maximum yield. The one exception is the first thinning in stands 10 to 15 years old. Because these young stands grow rapidly, they can probably be thinned to 50 percent stocking the first time. Thereafter they should be thinned to 60 percent stocking. I know of no research studies that have used stocking percent to control shortleaf pine density, so it is uncertain whether or not 60 percent stocking is the best level. However, density studies in oaks have shown that net volume yields are greatest in plots maintained at 50 to 60 percent stocking (Dale 1968).

Stocking percent is easy to use. The data needed are basal area and number of trees per acre. Basal area is easily determined from a number of angle gauge or wedge prism sample points. Number of trees is best determined by counting the trees on a fixed radius plot using the angle gauge point as the plot center. Stocking percent is then determined from the chart (Figure 1).

To illustrate how stocking percent is used, assume that a cruise of a shortleaf pine stand shows it to have 150 square feet of basal area and 400 trees per acre. Then:

1. Find the point on the chart (Figure 7) where number of trees per acre intersects the basal area per acre line.

2. This point shows the stocking percent (103) and average tree diameter (8.3) for the stand.

3. From this point follow down to the 60 percent stocking line, keeping parallel to the next lowest average diameter line.

4. Then, find the basal area per acre (89) that corresponds to 60 percent stocking.

5. Thin the stand to 89 square feet of basal area.

Even-aged shortleaf pine stands should generally be thinned from below because the larger trees being the same age as the smaller trees, have larger crowns, higher vigor, and greater growth potential. Some larger trees will have to be removed to maintain uniform spacing.

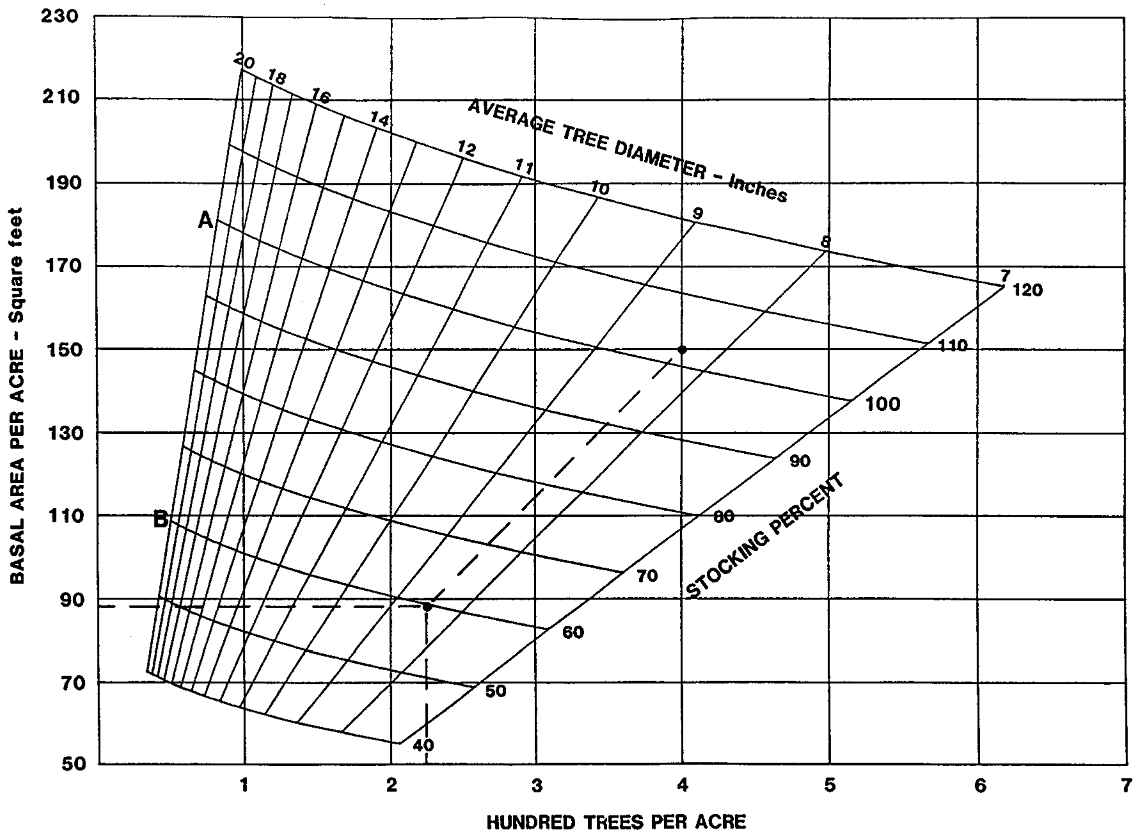


Figure 7. An example of how to determine stocking percent and residual basal area for a specific shortleaf pine stand.

Thinning shortleaf pine stands at regular intervals will help keep them healthy and vigorous, thus enabling them to better withstand insect and disease attacks. Thinning is probably the single most important factor in minimizing losses to the southern pine beetle (Nebeker et al. 1985). Infestations most often occur in dense stands where trees are most apt to be under stress and less vigorous than trees in more lightly stocked stands. However, a carelessly executed thinning operation may increase attacks by the black turpentine beetle because of its attraction to fresh wounds as well as freshly cut stumps.

Density control in natural shortleaf pine stands can help landowners and managers meet their objectives. If those objectives are to produce maximum yields of sawtimber, density control will help attain those yields in the shortest possible time. A market for cordwood or posts makes thinnings to attain sawtimber objectives even more economically attractive. If cordwood is the major objective, controlling density may not be beneficial particularly if the anticipated rotation is about 40 years or less.

Density control in natural shortleaf pine stands is an excellent practice. Stocking percent is biologically sound, easy to use, and I recommend that it be adopted as the standard for controlling thinning intensity.

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STAND DYNAMICS OF UNTHINNED AND THINNED SHORTLEAF PINE PLANTATIONS

Glendon W. Smalley[1/]

ABSTRACT

Growth and yield information about unthinned and thinned shortleaf pine (*Pinus echinata* Mill.) plantations established mostly on old-fields in the Coastal Plain, Piedmont, Ridge and Valley, Cumberland Plateau, and Highland Rim physiographic provinces is covered in this paper. The growth and yield pattern of shortleaf pine is more suited to the production of sawlogs at long rotations than to the production of pulpwood at short rotations. Thinning is needed to capture mortality and to concentrate growth potential on fewer trees. The efficacy of thinning shortleaf plantations depends on planting density, site, quality, rotation age, and availability of markets for small-diameter trees. A management scenario proposed by Williston (1983) should be applicable to most plantations. The paper concludes with some thoughts on the adequacy of existing growth and yield information for shortleaf plantations.

INTRODUCTION

I was asked by the program committee to discuss density management in shortleaf pine plantations. Density management is the manipulation and control of growing stock to achieve specific management objectives. Although the actual control of growing stock is relatively easy to achieve through initial spacing and intermediate cuttings, the determination of appropriate levels of growing stock at the stand level is a complex process involving biological, technological, and economic factors specific to a particular management situation.

There is limited published information about density control of shortleaf pine plantations; there are no economic analyses. Consequently, I found it impossible to pattern this paper after similar ones in the East and West symposia on loblolly pine (*P. taeda* L.) (Hughes and Kellison 1982, Hughes and Herschelman 1984).

In consulation with Dr. Willett and other speakers, particularly Dr. Murphy, I changed my topic to "Stand Dynamics of Thinned and Unthinned Shortleaf Pine Plantations." Published information about the growth and yield of shortleaf plantations is limited in quantity and in coverage of the range of the species (Williston 1975, Smalley 1978), and nearly all is concerned with plantations established on old-fields.

1/ Dr. Smalley is principal soil scientist at the Silviculture Laboratory, maintained at Sewanee, TN, by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the University of the South.

Information in this paper about unthinned plantations was gleaned from accounts of localized silvicultural tests, such as species trials and spacing trials, and from regional growth and yield studies located in the Ridge and Valley, Piedmont, Coastal Plain, Shawnee Hills, Cumberland Plateau, and Highland Rim physiographic provinces (Fenneman 1938). Information about thinned plantations comes from three well-documented studies located in (a) the Highland Rim in southern Indiana, (b) the Shawnee Hills section of the Interior Low Plateau in southern Illinois, and (c) the East Gulf Coastal Plain of northern Mississippi (Fenneman 1938). All ages in this report are plantation ages unless otherwise noted.

UNTHINNED PLANTATIONS

Localized Silvicultural Tests

Ridge and Valley

In upper east Tennessee, shortleaf pine was one of 14 species planted on abandoned fields in a series of experiments begun in 1938 and 1939 by Leon S. Minckler. At plantation age 20, Burton (1964) reported that total height and diameter of experiment-2 plantations were remarkedly uniform within and between aspects (north and south) and soil parent material (shale, dolomite, and limestone) (table 1). However, survival, and hence merchantable volume, was half again as great on south slopes as on north slopes. Poor survival on north slopes was attributed to dense competition from grasses, forbs, shrubs, and trees.

At plantation age 30, shortleaf pines on soils derived from carbonate materials were significantly taller than those on soils derived from shale (table 1). Other stand attributes were not affected by aspect or soil parent material.

Piedmont

Near Union, SC, 13-year-old shortleaf pines established at a spacing of 8 by 8 feet grew reasonably well (table 1) but were exceeded in height and diameter growth by loblolly pine and slash pine (*P. elliottii* Engelm.) (Branan and Porterfield 1971). Virginia pine (*P. virginiana* Mill.), longleaf pine (*P. palustris* Mill.), and eastern white pine (*P. strobus* L.) did so poorly that they were not recommended for timber production.

In Buckingham County, VA, 16-year-old shortleaf pines established at a spacing of 6 by 6 feet did not grow as well as expected (table 1) (Kormanik and Hoekstra 1963). The poor growth might be due to seed source. Although shortleaf pine is native to the area, planting stock came from northern Alabama. Adjacent loblolly and eastern white pine plantations grew much better. Virginia pine growth was similar to shortleaf pine.

In Clarke County, GA, shortleaf pine plantations were established at spacings of 4 by 4, 5 by 5, 6 by 6, 7 by 7, and 8 by 8 feet (Jackson 1958). The seed source was unknown and no details of the site were reported. Spacing appreciably affected survival and growth after 14 years (table 2). Only at the 8 by 8 foot spacing were 50 percent or more of the surviving trees in the 5-inch or larger diameter classes (345 out of 648 trees).

Table 1.--Stand characteristics of shortleaf pines planted on old-fields in the Ridge and Valley of east Tennessee and in the Piedmont of South Carolina and Virginia

Location	Original spacing	Planatation age	Survival	D.B.H.	Basal area	Height	Merchantable volume
	ft	yrs	percent	in	ft^2ac^{-1}	ft	ft^3ac^{-1}
East Tennessee	6 by 6	20[1/]	57	5.3	127	39	860
		30[2/]	61	6.3	166	55	3,996
South Carolina[3/]	8 by 8	13	92	5.3	96	51	-----
Virginia[4/]	6 by 6	16	80	4.6	124	35	-----

1/ From Experiment 2 (Burton 1964). Basal area based on all trees ≥ 0.6 inch d.b.h.; merchantable volume is inside bark to a 3.0-inch top i.b., all trees ≥ 4.6 inches d.b.h.

2/ From Experiments 2 and 3 (unpublished data on file at Silviculture Laboratory, USDA Forest Service, Sewanee, TN). Basal area based on all trees ≥ 0.6 inch d.b.h.; merchantable volume is outside bark to a 4.0-inch top o.b. for all trees ≥ 5.0 inches d.b.h.

3/ From Branan and Porterfield (1971).

4/ From Kormanik and Hoekstra (1963).

Table 2.--Stand characteristics of planted shortleaf pines in the Piedmont of Georgia at plantation age 14 as affected by initial spacing (from Jackson 1958)

Spacing	Survival	D.B.H.	Basal area	Merchantable volume
ft	percent	in	ft^2ac^{-1}	ft^3ac^{-1}
4 by 4	86	3.2	131	772
5 by 5	87	3.8	122	1,236
6 by 6	92	3.9	94	913
7 by 7[2/]	94	4.1	77	779
8 by 8	95	4.7	79	1,042

1/ Cubic volume outside bark to a 3.0-inch top outside bark, all trees $\geq$ 4.6 inches d.b.h.

2/ Data not highly reliable because of excessive soil erosion on two of four plots.

Jackson did not recommend spacings of 4 by 4 and 5 by 5 feet because of the small average diameter and the large number of trees in the 2- and 3-inch diameter classes. Despite the increased percentage of larger trees, the 8 by 8 foot spacing was not recommended because of poor wood quality resulting from large branches associated with retarded natural pruning. Also, the relatively low number of trees would reduce the yield of the first thinning. The 6 by 6 or possibly a 6 by 8 foot, spacing was recommended as the best compromise considering survival, growth, wood quality, and expected yield of pulpwood from the first thinning. However, these recommendations, based on 14-year results, seem to be premature.

Coastal Plain

In Benton County, MS, Williston (1958) reported that dominant and codominant shortleaf pines averaged 48 feet in height at age 22 (table 3). The deep, brown loam soils on the study site were considered fair for shortleaf pine. Original spacing was 5 by 5 feet. Early height growth was retarded by tip moths (*Rhyacionia frustrana* Comst.).

In Madison County, TN (Williston 1959), reported that dominant and codominant shortleaf pines averaged 45 feet in height at age 29 (table 3). These plantations were established at a 6 by 6 foot spacing on an eroded ridge. Early height growth was retarded by tip moths. At age 29, many of the crowns had an unhealthy color and unusually short needles. Stagnation appeared imminent unless the plantation was thinned.

In Lafayette County, MS, annual spraying of insecticides for 6 years to prevent tip moth attack had only a minor impact on stand development (Williston 1985). These shortleaf pines were planted at a 7 by 9 foot spacing in a creek bottom. The somewhat poorly drained, nearly level soils had formed in silty alluvium; the site appeared to be too wet for shortleaf pine to make its best growth. Even at the wider spacing, basal area growth slowed after age 15. Mean annual volume increment at age 25 was 158 cubic feet per acre (table 3). These plantations were overstocked and should have

Table 3.--Stand characteristics of shortleaf pines planted on old-fields in the East Gulf Coastal Plain region of west Tennessee and north Mississippi

Location	Original spacing	Plantation age	Survival	D.B.H.	Basal area	Height of dominants and co-dominants	Site index (50 years)	Merchantable volume
	ft	yrs	percent	in	ft^2ac^{-1}	ft	ft	ft^3ac^{-1}
Benton County MS[1]	5 by 5	12	63	4.7	132	23	--	623
		22	61	6.3	231	48	73	3,369
Madison County TN[2]	6 by 6	19	89	4.4	116	29	50	701
		29	74	5.7	158	45	60	2,080
Lafayette County MS[3]	7 by 9	10	100	5.1	99	32	--	765
		15	99	6.3	147	44	--	1,995
		25	72	7.7	162	67	108	4,120

1/ From Williston 1958.

2/ 19-year data from Huckenpahler 1950; 29-year data from Williston. 1959.

3/ From Williston 1985.

4/ For Benton County, MS and Madison County, TN plantations, merchantable volume is inside bark to a 3.0-inch top i.b., all trees ≥ 4.6 inches d.b.h.; for the Lafayette County, MS plantation, merchantable volume is inside bark to a 3-inch top i.b., all trees ≥ 4 inches d.b.h.

been thinned at about age 15. It may be difficult for the crowns of residual trees to recover if thinned.

According to Williston, yields such as these on formerly cultivated creek bottoms indicate the attractiveness of converting similar sites encumbered with cut-over, low-value hardwoods to shortleaf pine, particularly north of the range of loblolly pine. These creek bottoms are also excellent hardwood sites as attested by a rating of site index 100 to 110 (base age 50 from seed) for bottom land hardwoods.

In 1957, a survey of pulpwood-size, CCC-established pine plantations in north Mississippi showed that the average survival of shortleaf plantations was 48 percent, mean stocking was 633 trees per acre, and mean annual increment was 0.58 cords per acre (Williston and Dell 1974). Form class for the shortleaf pines was 2 to 3 percentage points lower than for loblolly pines. Most of these plantations were established on eroded old-fields at a spacing of 6 by 6 feet. Common soils were Loring, Providence, Grenada, and Ruston. Only 19 percent of the plantations needed any release from hardwood competition at the time of the survey. Most of those needing release were along intermittent streams, in minor stream bottoms, or in dense growths of kudzu (*Pueraria lobata* (Willd.) Ohwi.), muscadine (*Vitis rotundifolia* Michx.), or cow-itch vines (*Campis radicans* (L.) Seem.). Twenty-nine percent of the study plots had been thinned prior to 1959, but the work had been done haphazardly. Loblolly pine plantations were thinned 4 or 5 years sooner than shortleaf pine plantations.

Volume growth rates between ages 20 and 35 were increased by retaining high densities. Thinning could reduce growth as well as increase the risk of loss to *Fomes annosus* (Fr.) Cke. Across the range of ages sampled (17-29), cordwood growth rates increased with age and site index (fig. 1A and B). Across the range of ages sampled (23-29), sawtimber growth rates culminated at all site indexes (fig. 1C and D), because merchantability limits are more stringent for sawtimber than for pulpwood. At a given age, sawtimber growth rates culminated at a higher basal area as site index increased.

Shawnee Hills

In Pope County, IL, shortleaf pine seedlings from an unknown seed source were planted at spacings of 4 by 4, 6 by 6, 8 by 8, and 10 by 10 feet on fields abandoned from cultivation about 10 years earlier (Gilmore and Gregory 1974; Arnold 1978, 1981). The soil, classified as Grantsburg silt loam, developed under forest cover in 50 to 100 inches of loess over sandstone or shale residuum. A moderately well-developed fragipan occurs at a depth of 24 to 30 inches or at a shallower depth if the soil is eroded. Both root penetration and moisture movement are impeded by the fragipan.

Here at the northern limit of its range, shortleaf pine grew satisfactorily for 31 years (table 4). The 6 by 6 and 8 by 8 spacings produced about equal cubic volumes. The 10 by 10 spacing produced about 700 cubic feet per acre less, and the 4 by 4 spacing lost volume in the last 6 years because of excessive mortality. Statistically, there are no significant differences in merchantable cubic volume among the three widest spacings. Arnold (1981) concluded that the 10 by 10 spacing was too wide to

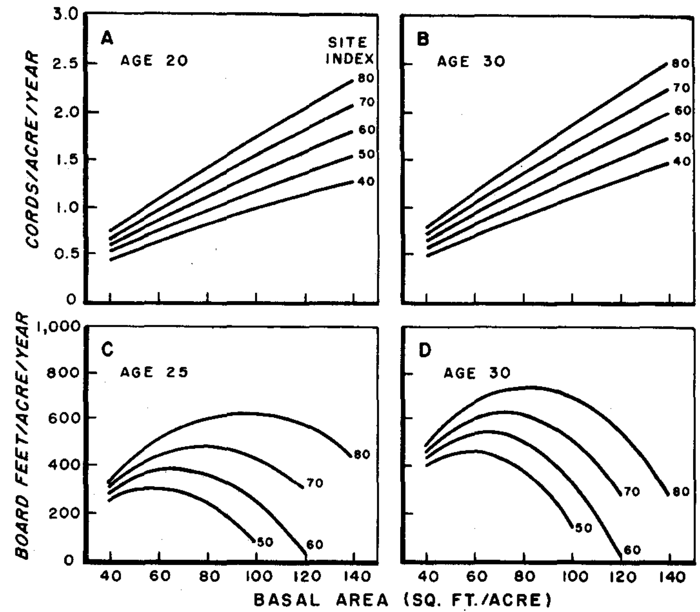

Figure 1.--Effect of plantation age, basal area, and site index (base age 50 from seed) on periodic annual volume increment of CCC-established shortleaf pine plantations in north Mississippi. Basal area is calculated on trees of all sizes (from Williston and Dell 1974).

produce optimal quantities of pulpwood at age 20, but he was encouraged by the production of over 4,600 fbm per acre of sawtimber at age 31.

However, it seems to me that the 10 by 10 foot spacing data supports the idea of managing shortleaf pine plantations for sawlogs. A commerical thinning (mostly from below) for pulpwood seems possible by age 30 when the mean diameter is approaching 9 inches. Probably another thinning of pulpwood and small sawlogs could be made about age 40 when the mean diameter should be close to 10 inches.

Arnold (1981) did not recommend planting any more shortleaf pine in southern Illinois because it was outproduced by loblolly pine. He did feel though that the slower growth and higher survival rates of shortleaf pine should enable owners of plantations to keep posts and poles "on the stump" longer, a definite advantage in the uncertain post and pole market. Because the post and pole market is very limited, early thinning of plantations for these products is not an option for most owners of shortleaf pine plantations.

Regional Growth and Yield Studies

Piedmont

Ralston and Korstian (1962) developed a system of equations for predicting pulpwood yields in the lower Piedmont of North Carolina based on variations in stocking, average stand diameter, and volume-basal area ratios developed from multiple regressions. This analytical system was intended to solve such growth and yield problems as (a) preparation of yield tables for well-stocked stands, (b) growth predictions for nonmerchantable stands, (c) yield estimates for merchantable stands of variable density, and (d) growth

Table 4.--Continued

Plantation age (yrs)	Spacing (ft)			
	4 by 4	6 by 6	8 by 8	10 by 10
	Merchantable volume (fbm $acre^{-1}$)2/			
25	0	0	884	1,862
31	94	483	3,090	4,638

1/ Volume outside bark, total stem, all sizes of trees.

2/ International 1/4" kerf.

projections for thinned stands. However, the system received only limited application.

Interior Uplands

Smalley and Bailey (1974) developed variable-density yield tables for the Ridge and Valley, Cumberland Plateau, and Highland Rim physiographic provinces in Alabama, Tennessee, and Georgia. They presented detailed schedules of trees per acre, basal area, mean tree height, and cubic-foot yields in eight volume categories by 1-inch diameter classes for all combinations of four site indexes at base age 25 years from seed (30, 40, 50, and 60), seven ages from seed (10, 15, 20, 25, 30, 35, and 40 years), and six planting densities (750, 1,000, 1,250, 1,500, 1,750, and 2,000 trees per acre). These results depict the early development of unthinned shortleaf pine plantations on old-fields throughout the Interior Uplands. Predictions were extended 5 years beyond the oldest sampled stands, and all relationships appeared biologically valid. Stand development can best be understood by plotting the various stand characteristics with respect to age, site index, and number of trees planted per acre. Figures 2, 3, 4, and 5 are examples of these plottings. A summary of trends follows.

Survival--On all sites, survival percentage decreased as planting density and age increased (fig. 2A). With an increase in site index, however, survival was slightly higher at early ages and, because competition intensified on better sites, lower at older ages.

Diameter distribution--Diameter distributions (fig. 3) form bell-shaped curves the peaks of which flatten and the widths of which gradually widen with time. The largest diameter trees were on the best sites at the lowest planting density at age 40. Maximum size of tree decreased with both an increase in planting density and/or a decrease in site. By age 25 some sawlog-size trees are obtained on the best sites even at a planting density of 2,000 trees per acre (equivalent to a spacing of 4 by 5 feet). Very few trees reach sawlog-size in 40 years on poor sites.

Quadratic mean diameter--As planting density increased, mean diameter declined for all ages and sites, but improvement in site always resulted in diameter increases (fig. 2B). On sites 30 and 40 at all planting densities, diameter growth was nearly linear past age 20. On sites 50 and 60 at all planting densities, diameter growth accelerated slightly beyond age 20.

Table 4.--Stand characteristics of shortleaf pines planted on old-fields in southern Illinois as affected by initial spacing and plantation age (from Gilmore and Gregory 1974; Arnold 1978, 1981)

Plantation age (yrs)	Spacing (ft) 4 by 4	6 by 6	8 by 8	10 by 10
	Survival (percent)			
11	86	92	95	93
13	82	91	95	93
18	73	86	91	92
20	73	86	87	92
25	52	79	82	88
31	25	55	64	71
	D.B.H. (in)			
11	2.8	3.8	4.1	4.4
13	3.2	4.3	4.8	5.3
18	3.9	5.1	6.0	6.9
20	4.0	5.3	6.3	7.3
25	4.6	5.7	7.1	8.2
31	5.9	6.7	8.1	8.9
	Basal area (ft^{2}acre^1)			
11	110	93	62	45
13	132	115	85	63
18	164	151	123	102
20	196	173	137	122
25	164	170	153	140
31	128	164	156	134
	Height (ft)			
11	22	20	20	20
13	25	25	24	24
18	33	38	38	33
20	39	45	45	46
25	42	47	50	51
31	55	60	63	62
	Merchantable volume (ft^{3}acre^{-1})[1/]			
11	1,032	870	567	406
13	1,403	1,230	951	641
18	2,363	2,353	1,995	1,701
20	2,884	3,206	2,726	2,383
25	3,408	3,803	3,477	3,190
31	3,197	4,455	4,382	3,707

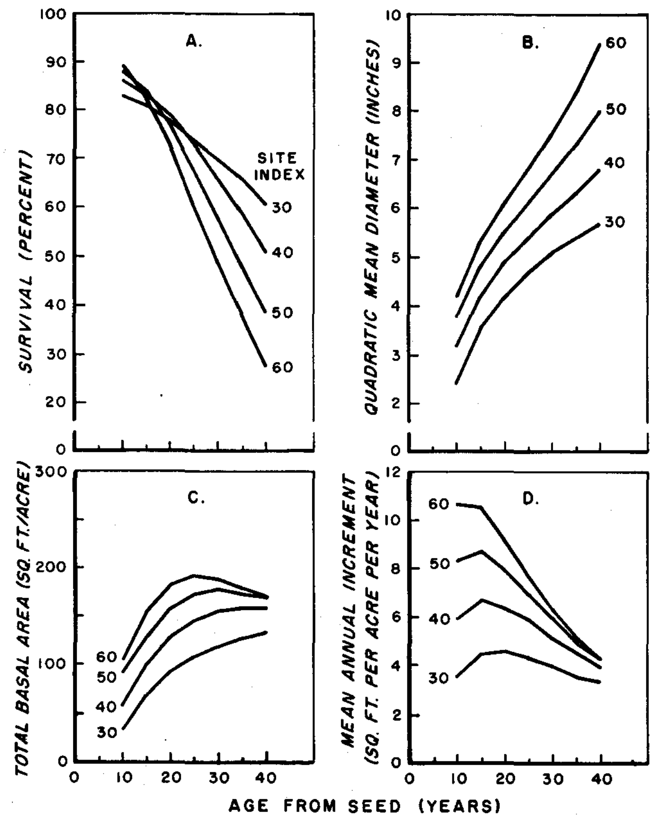

Figure 2.--Effect of age from seed and site index on (A) survival, (B) quadratic mean diameter, (C) total basal area, and (B) mean annual increment - total basal area of shortleaf pine plantations In the Interior Uplands at a planting density of 1,250 trees per acre (from Smalley and Bailey 1974).

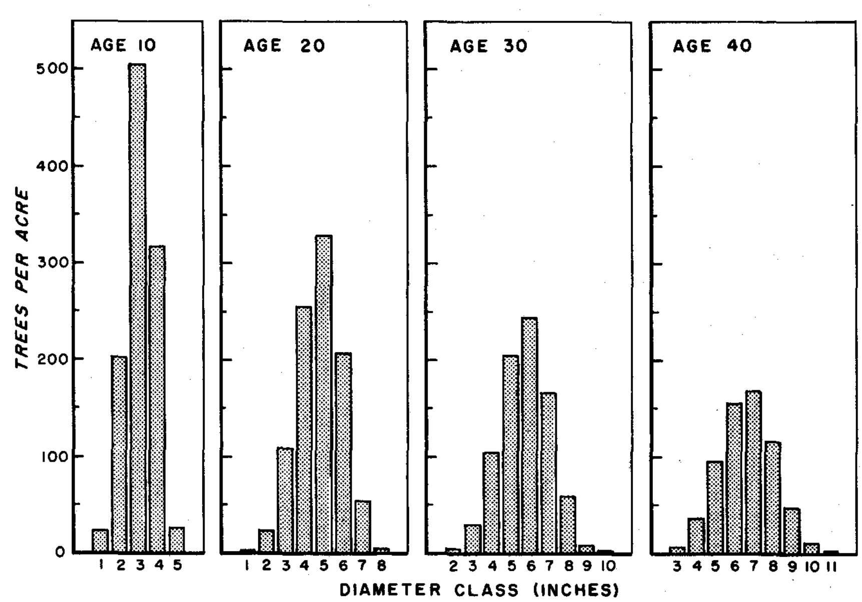

Figure 3.--Effect of age from seed on diameter distribution of shortleaf pine plantations in the Interior Uplands at a planting density of 1,250 trees per on site 40 (from Smalley and Bailey 1974).

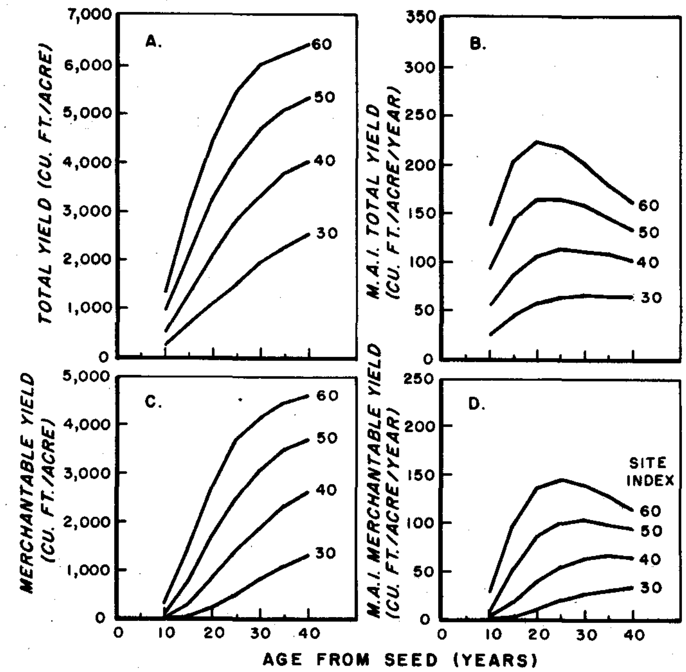

Figure 4.--Effect of age from seed and planting density on (A) total yield - VOBTOT, (B) mean annual increment (MAI) - total yield, (C) merchantable yield - VIB4INOB, and (D) mean annual increment (MAI) - merchantable yield of shortleaf pine in the Interior Uplands at a planting density of 1,250 trees per acre (from Smalley and Bailey 1974).

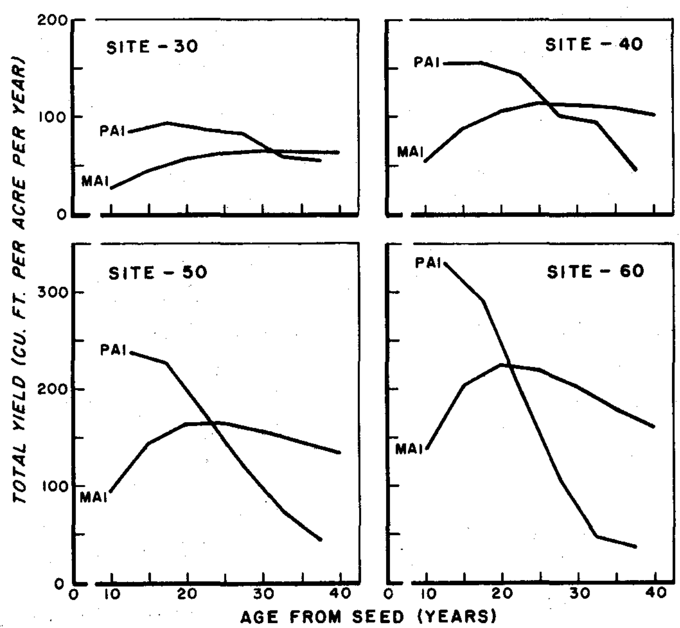

Figure 5.--Effect of age from seed and site index on mean annual (MAI) and periodic annuals increments (PAI) - total yield of shortleaf pine plantations in the Interior Uplands at a planting density of 1,250 trees per acre (from Smalley and Bailey 1974).

Basal area--Total basal area (trees of all sizes) for sites 50 and 60 culminated before age 40 for all planting densities (fig 2C). On site 40, culmination occurred at densities greater than 1,250 trees per acre. On poor sites culmination was projected at about age 50 for all planting densities except for 750 trees per acre where culmination will be closer to age 55.

Basal area increment--For total basal area, mean annual increment (MAI) culminated by age 20 for all sites and planting densities (fig. 2D). At low planting densities on best sites, MAI culminated before age 10. Increment at culmination increased with planting density up to 2,000 trees per acre on all sites. All periodic annual increment (PAI) curves for total basal area were descending within the range of data.

Yield--Total and merchantable cubic-foot yields increased with site and planting density, but the effect of density was small on poor sites (figs. 4 A and C). Yield increased with age for all planting densities on sites 30, 40, and 50. For a planting density of 2,000 trees per acre on site 60, yield culminated at about age 35 as the loss of volume from mortality had begun to exceed growth on the remaining trees.

Yield increment--For total volume, MAI culminated for all sites and planting densities (figs. 4B and 5). Age at culmination ranged from 30 years on poor sites to about 20 years on the best sites, regardless of planting density. Increment at culmination increased with planting density up to 2,000 trees per acre on all sites. By age 20, PAI culminated on sites 30 and 40 at all planting densities. All other PAI curves were descending within the range of data. Merchantable-volume increment culminated on sites 40, 50, and 60 at all planting densities (fig. 4D), but at older ages than for total volume--for example, age 35 to 40 for site 40 and age 25 for site 60.

THINNED PLANTATIONS

Highland Rim

Two thinning tests were made in southern Indiana on the Hoosier National Forest (Williams 1959, Phipps 1973), one on the Crawford Upland near Tell City in Perry County and the second on the Norman Upland near Houston in Jackson County. Initial spacing was 6 by 6 feet. Average height of dominants and codominants in both plantations was about 48 feet at age 25, which indicates a site index of 80 at 50 years from seed (USDA Forest Service 1929). The Tell City plantation was thinned at ages 14 and 21 by removing trees in all crown classes to basal areas of 80, 100, and 120 square feet per acre. Average basal area before thinning was 127 square feet per acre. Final age was 32. The Houston plantation was thinned at ages 17 and 22 by removing trees in all crown classes to basal areas of 70, 90, 110, and 130 square feet per acre. Average basal area before thinning was 165 square feet per acre. Final age was 29. Thinned trees were marketed as 7-foot fenceposts.

Stands lightly thinned to 110 square feet of basal area increased basal area growth rates and total merchantable yield over unthinned stands (fig.

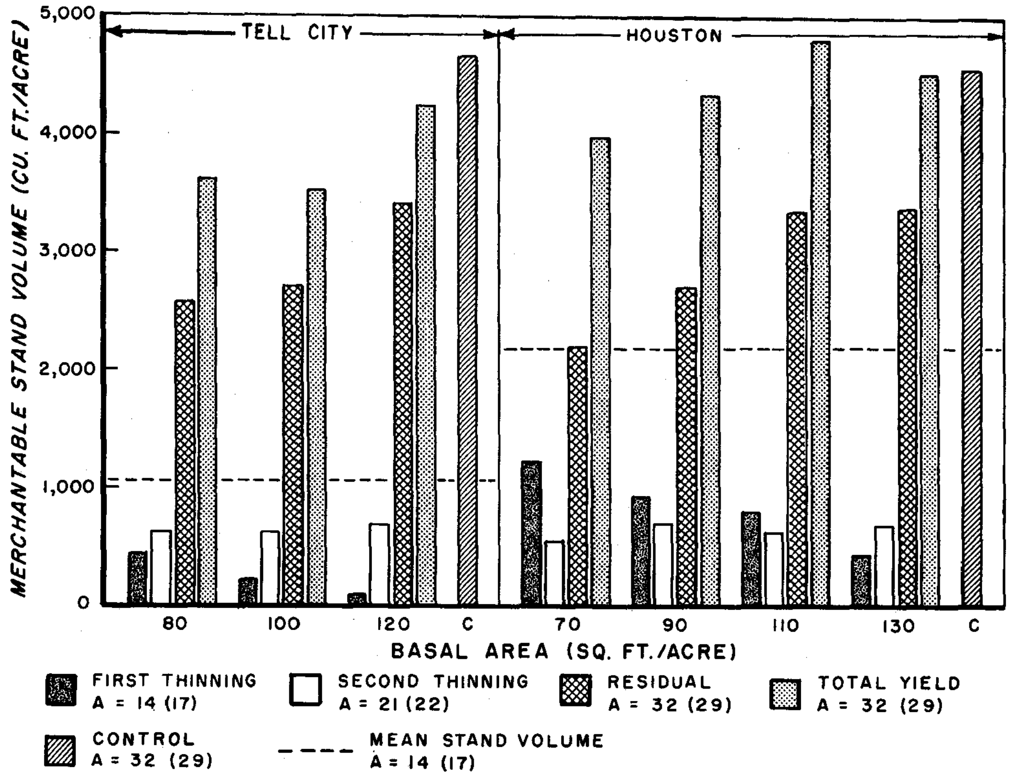

Figure 6.--Yield of two free-thinned shortleaf pine plantations established on old-fields of medium site quality in southern Indiana. Yield is expressed as merchantable cubic-foot volume inside bark to a 3-inch top inside bark. No minimum threshold diameter was given. Numbers in the residual and control bars are mean stand diameter in inches at final age. Ages in the legend are for the Tell City and Houston plantations respectively (from Williams 1959 and Phipps 1973).

6). Figure 6 varies somewhat from figure 1 in Phipps (1973) because of discrepancies in the data. Maintaining higher residual basal areas of 120 and 130 square feet increased basal area growth rates, but total merchantable yield was about the same as in unthinned stands. Thinning stands to residual densities of 100 square feet or less resulted in increased basal area growth, but total merchantable yields were 250 to 1,100 cubic feet per acre less than those in unthinned stands. At the conclusion of the tests, basal area of the unthinned plots exceeded 200 square feet per acre. Phipps suggested that free-thinning of shortleaf pine plantations before age 30 was of questionable value in improving growth rates and yields on medium-quality sites. Diameter distributions would have provided a more definite assessment of the merits of thinning these plantations.

Shawnee Hills

The effect of crown-thinning (thinning from above) was determined in two experiments in southern Illinois. The first (Boggess and others 1963) involved residual basal areas of 60, 80, and 100 square feet per acre and unthinned controls on three upland old-field sites. Good sites consisted of deep, well-drained loessial soils with no fragipan. Medium sites consisted of moderately well-drained and somewhat poorly drained loessial soils with a fragipan. Poor sites consisted of eroded phases of soils similar to those on medium sites.

The plantations were thinned once at ages 15 through 17, and results were reported only for the ensuing 5-year periods. At the time of thinning, basal area ranged from 100 to 155 square feet per acre, and merchantable cubic-foot volume (outside bark to a 3-inch top inside bark) ranged from 1,200 to 2,400 cubic feet per acre. No planting density was given. Site indexes based on average height of dominants and codominants at age 15 for good, medium, and poor sites were 85, 75, and 65 respectively at a base age of 50 years from seed determined from curves developed for second-growth natural stands (USDA Forest Service 1929) or 53, 45, and 37 respectively, at a base age of 25 years since planting determined from a regression developed for similar old-field plantations in southern Illinois (Gilmore and Metcalf 1961).

The second experiment (Burkhart and Gilmore 1967) involved residual basal areas of 70, 80, and 90 square feet per acre and unthinned controls on supposedly similar old-fields. Four crown-thinnings were made at ages 13, 16, 21, and 26. The study was terminated at age 30. Original planting density was given as 8 by 8 feet, but average number of trees and survival data indicated a spacing of 7 by 7 feet or closer. Because no information on tree height was given, it is impossible to estimate site index. However, the quality of these sites was rated as medium. The thinned trees were marketed as 7-foot fenceposts and small poles.

Based on the results of these two experiments, Burkhart and Gilmore recommended that crown-thinning on good and medium sites should be delayed until plantations are at least 20 years old. However, they cautioned not to delay the first thinning on these sites much beyond age 25, particularly if the trees are planted at spacings of 6 by 6 feet or closer (figs. 7 and 8). Although shortleaf pine will grow and persist in fairly dense stands, live-crown ratios become so small that residual trees will not respond to thinning. About 40 percent of the basal area was recommended for removal in the first crown-thinning.

On poor sites, they recommended that plantations be thinned 2 or 3 years earlier because net volume growth decreases sooner on poor sites than on better sites. This recommendation is valid only if a market for small-diameter trees, such as posts, is available. The consensus is to delay thinnings on poor sites up to 10 years until tree diameters are large enough to support a commercial pulpwood operation.

In the unthinned plantations, basal area culminated between ages 26 and 29. However, cubic volume was still increasing.

A row-thinning experiment was established in the same plantation as the second crown-thinning experiment (Gilmore and Boggess 1969). Advantages of row-thinning are lower marking and administrative costs, lower felling costs, and easier access into plantations for logging. A disadvantage of row-thinning is that no choice is made in the removal of trees--good quality trees are cut along with poor quality trees.

In the first thinning at age 14, every fourth row was cut and basal area reduced from 101 to 80 square feet per acre. In the second thinning at

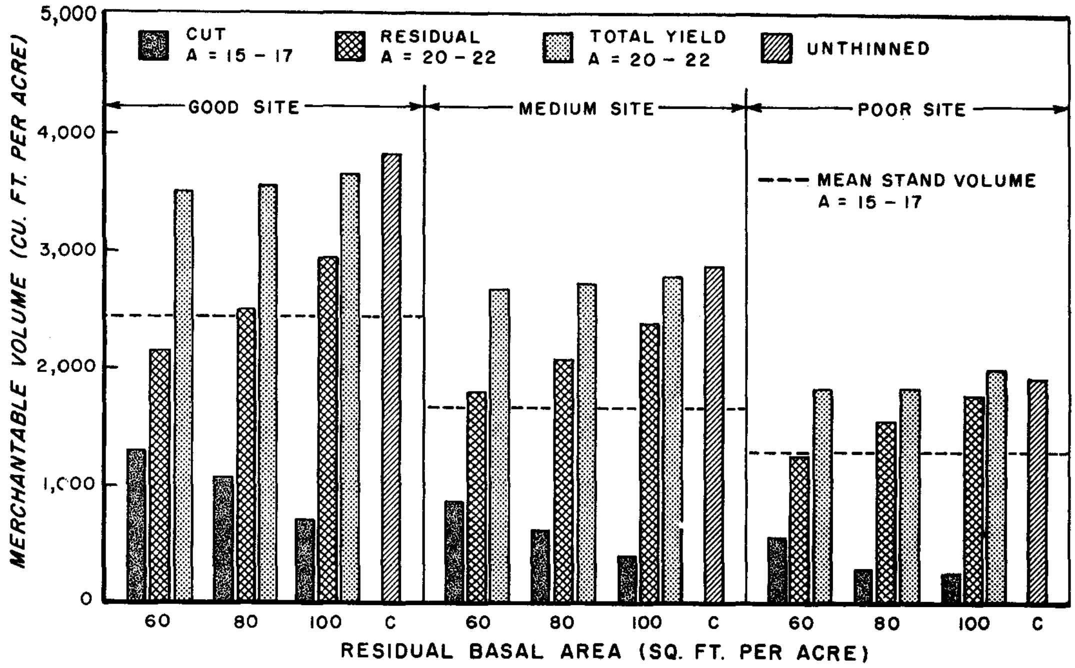

Figure 7.--Yield of crown-thinned shortleaf pine plantations established on old-fields of varying site quality in southern Illinois. Yield is expressed as merchantable cubic-foot volume outside bark, of trees $\geq$ 3.6 inches d.b.h., to a 3-inch top inside bark (from Boggess, Minckler, and Gilmore 1963).

age 18, the middle row of the remaining three rows was cut and basal area reduced from 104 to 71 square feet per acre. A third free-thinning was made at age 23, and the basal area was reduced from 116 to 80 square feet per acre. The study was terminated at age 30.

Row-thinned plots did not produce as much merchantable cubic volume as crown-thinned or unthinned plots, although row-thinning did provide an adequate number of crop trees of good form and size (fig. 8). Stand volume and growth rates were related to site quality differences in the test plantation, but stand density and site quality did not appreciably affect basal area growth.

Diameter distributions at age 30 of row-thinned, crown-thinned, and unthinned shortleaf pine plantations all displayed reasonable bell-shaped curves (fig. 9). Unthinned plantations had the highest peak (6-inch class) because of the much larger number of surviving trees (645). Row-thinned plantations had a lower peak (8-inch class) with 301 surviving trees. Crown-thinned plantations had the lowest peak (9-inch class) with 188 surviving trees. In row-thinnned plantations, 33 trees were 10 inches d.b.h. and larger, representing 11 percent of the total trees and 17 percent of total basal area. Comparable data are 95 trees, 50 percent, and 44 percent for crown-thinned plantations and 46 trees, 7 percent, and 13 percent for unthinned plantations. At age 30, crown-thinned plantations had twice as many sawlog-size trees as unthinned plantations and nearly three-times as many as row-thinned plantations.

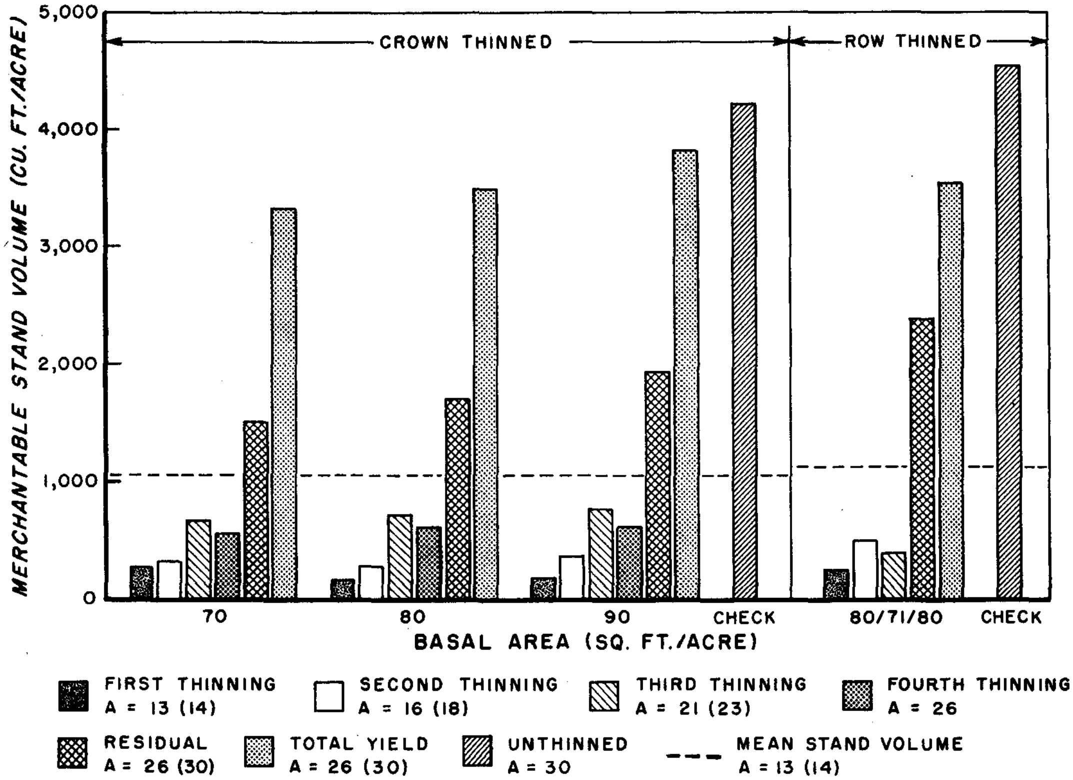

Figure 8.--Yield of crown- and row-thinned shortleaf pine plantations established on old-fields in southern Illinois. Yield is expressed as merchantable cubic-foot volume outside bark, of trees $\geq$ 3.6 inches d.b.h., to a 3-inch top inside bark. Numbers in the residual and control bars are mean stand diameters in inches. Ages in the legend are for the crown- and row-thinned experiments respectively (from Burkhart and Gilmore 1967 and Gilmore and Boggess 1969).

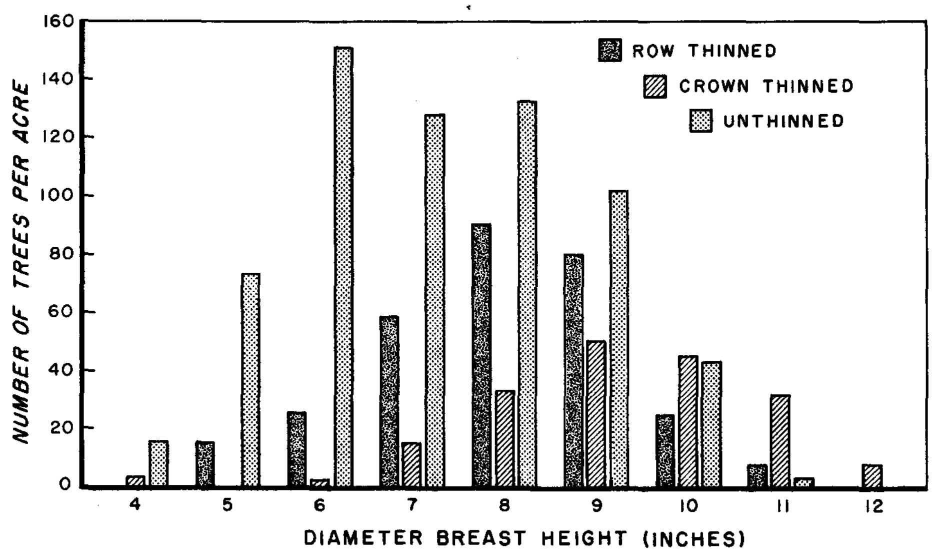

Figure 9.--Diameter distributions of row-thinned, crown-thinned (80 sq ft per acre of residual basal area), and unthinned shortleaf pine plantations in southern Illinois at age 30 (from Gilmore and Boggess 1969).

Coastal Plain

The thinning test in the North Central Hills Section of the East Gulf Coastal Plain was near Abbeville in Lafayette County, MS. Williston (1983) estimated the mean site index (base age 50 years from seed) of these test plantations to be about 75 according to Coile and Schumacher's (1953) curves developed for natural stands in the Piedmont. Eight thinning treatments were applied to 23-year-old shortleaf pine plantations. Although there were large differences in stand parameters among treatment regimes, differences were not statistically significant throughout most of the term of the test. Statistical analyses at age 48 were impossible because southern pine beetles (Dendroctonus frontalis Zimm.) had killed trees on several plots between 1976 and 1981 (ages 43 to 48). Consequently, only averages for all thinning regimes are reported (table 5).

Table 5.--Periodic annual growth and total yields per acre of thinned and unthinned shortleaf pine plantations in north Mississippi (from Williston 1983).

Treatment	Unit 1/	Period (plantation age-years) 0-23	24-28	29-33	34-38	39-43	44-48	Total yield 2/
Thinned	Cu ft	67	105	121	155	135	30 (46) 3/	4,285
Unthinned	Cu ft	63	117	81	169	77	-90 (35) 3/	3,212
Thinned	Fbm	--	38	240	850	1,390	563 (800) 3/	15,764
Unthinned	Fbm	--	140	345	700	924	-194 (549) 3/	9,577

1/ Pulpwood volumes are in cubic feet inside bark, of trees > 3.5 inches d.b.h., to a 3-inch top inside bark. Sawtimber volumes are in board feet, International 1/4-inch kerf.

2/ Total yield includes volumes removed in three thinnings at plantation ages 23, 28, and 33.

3/ Value of plot most heavily damaged by southern pine beetles is omitted.

Per acre production of all thinned plots averaged 4,285 cubic feet and 15,764 fbm. Periodic annual cubic volume growth culminated at about age 35. Among the plots not damaged by southern pine beetles, at age 48 the best per acre production of 5,402 cubic feet and 25,860 fbm occurred on a plot free-thinned successively to 120, 115, and 110 square feet of basal area per acre at ages 25, 28, and 33 respectively, with a site index of 84. At age 48, mean d.b.h. averaged 10.1 inches on thinned plots and 9.0 inches on unthinned plots, but crop trees averaged 11.3 inches and 10.5 inches respectively.

Total production on thinned plots was 4,122 cubic feet per acre; on check plots it was 3,685 cubic feet per acre. Since the first thinnings in 1957, the thinned plots grew 2,583 cubic feet, and the check plots grew 2,235 cubic feet--a difference of 348 cubic feet or about 17 cubic feet per acre per year.

Total production from the thinned plots was 13,070 fbm (International 1/4-inch kerf) per acre; from the check plots it was 10,547 fbm per acre. Comparative yields in the Doyle rule were 5,453 fbm and 4,380 fbm per acre.

PERSPECTIVES

The test plantings reported in this paper were established with seedlings grown from "woods run" seed that often was not collected locally. It is probably safe to assume that plantations established with genetically improved seedlings from best seed sources and on prepared sites would outproduce plantations described in this review.

Within the common range of shortleaf and loblolly pines, old-field plantations of loblolly pine grow better than shortleaf plantations for 40 to 50 years. Beyond 50 years, shortleaf pine yields apparently approach and perhaps exceed those of loblolly pine. Thus, when rotations are short and the main product is pulpwood, loblolly pine is the preferred species. In fact, the growth and yield pattern of shortleaf pine is not especially well suited to pulpwood rotations.

At longer rotations, when high-quality sawlogs are the management goal, shortleaf pine should be given more consideration than it has been accorded. Outside the common range of shortleaf and loblolly pines, shortleaf should be preferred. Shortleaf pine should certainly be preferred over loblolly where the frequency of glaze storms is high.

Shortleaf pine plantations grow better at higher basal areas than do loblolly plantations. However, overstocked shortleaf plantations, particularly those on poor sites, tend to stagnate. Results from studies reported in this paper are inconclusive concerning the best spacing. Spacings wider than the customary 6 by 6 feet used in many of the reported studies are necessary to concentrate production on as few trees as possible and to reduce planting and logging costs. In Illinois, Arnold (1981) was convinced that shortleaf pine did not fully occupy the site at spacings wider than 8 by 8 feet, and, consequently, he recommended moderate planting densities between 6 by 6 and 8 by 8 feet. However, with use of the best adapted seed sources, modest genetic gains in growth rate, and optimal site preparation, new plantations should probably be established at spacings of 8 by 8 feet or wider.

Even at wider spacings, thinning appears to be needed to capture mortality, to concentrate growth potential on fewer trees, and to meet an estimated goal of 14- to 16-inch trees in 60 years on medium and good sites. Trees removed in early thinnings would be suitable for posts, small poles, or pulpwood. Thinnings will probably reduce cubic yields below those of unthinned plantations but will maximize diameter growth on high-quality trees and provide periodic income. The first commercial thinning of shortleaf pine plantations on good sites can be made about age 20; on medium sites, between ages 20-25; and on poor sites, between ages 25-30. If a market for posts is available, thinning can be started 2 or 3 years earlier. But beware--thinning may increase the possibility of losses from Fomes annosus, particularly in plantations established on sandy soils low in organic matter.

Williston's management scenario for shortleaf pine plantations in north Mississippi seems apropos, with maybe slight modifications, to the entire range of the species. In order to attain a 60-year shortleaf pine rotation with a final harvest cut objective of trees averaging 16 inches d.b.h., Williston (1983) suggested that "the first two thinnings for pulpwood made 7 years apart when plantation are capable of growing 3 to 4 square feet of basal area per acre per year, would reduce the stand to a basal area equal to the site index (base age 50 years) and would remove the slow-growing and poorly formed trees. The third thinning, about 7 years after the second one, would remove the remaining pulpwood trees and some small sawlogs, A fourth thinning and the final harvest cut made at intervals of 8 to 10 years as diameter growth slows, would be composed entirely of sawlogs and poles. Landowners should avoid any temptation to clearcut for pulpwood and should manage their shortleaf stands for sawtimber because shortleaf does so well after age 20."

The acreage of shortleaf pine plantations established on old-fields is declining. Little agricultural land is being abandoned, and practically none is being planted to shortleaf. Owners are replanting harvested acres with the faster growing loblolly pine. Consequently, the available mensurational data seems adequate to manage this diminishing resource. However, the Conservation Reserve Program proposed in recently enacted farm legislation may spur the largest tree planting effort ever in the United States. If sizable acreages of shortleaf pine are established on former cropland under this program, there will be a need for more regional growth and yield information for unthinned and thinned plantations comparable to that available now for unthinnned plantations established on old-fields in the Interior Uplands (Smalley and Bailey 1974).

Currently, thousands of acres of shortleaf pine are being planted annually on eastern National Forests (particularly the Ouachita and Ozark) on recently harvested forest land. Planting follows a variety of site preparation methods ranging from all mechanical to all hand-applied chemicals. Although these non-old-field plantations will not be merchantable for 15 to 20 years, studies need to be initiated now so that the information necessary for prudent management will be available when needed.

ACKNOWLEDGEMENTS

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NON-WOODY WEED CONTROL IN PINE PLANTATIONS

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Bob Lowery[2]

ABSTRACT

The cost and benefits derived from controlling non-woody competitors in pine plantations were reviewed. Cost considerations included both the capital cost and biological cost that may be incurred when weed control treatments are applied. Several methods for reducing the cost of herbicide treatments were explored. Cost reduction considerations included adjustments in chemical rates and the amount of ground area that needs to be treated to increase survival and growth based on soil, plant, climate and chemical characteristics of the site.

Introduction

Most pines are classified as intolerant and thus do not grow well if they become overtopped by competing vegetation. In the first two years after outplanting, much of the competition for light, water and nutrients comes from non-woody type competitors such as grasses and weeds. After this the woody competitors become the major source of competition for the planted pine. The growth performance of the planted pine in years one and two will have an immediate influence on growth but can also impact the growth rate expected for the remainder of the rotation if long term hardwood competitors are left in the stand. This results because pine growth rate in the first few years after establishment will determine the crown position of the conifer relative to the hardwood and thus, the ability to compete for key resources for the remainder of the rotation.

This paper will briefly review the major chemicals available for weed control, the growth benefits that can be expected from non-woody weed control and the cost of these treatments. However, the major emphasis will be on how to control cost.

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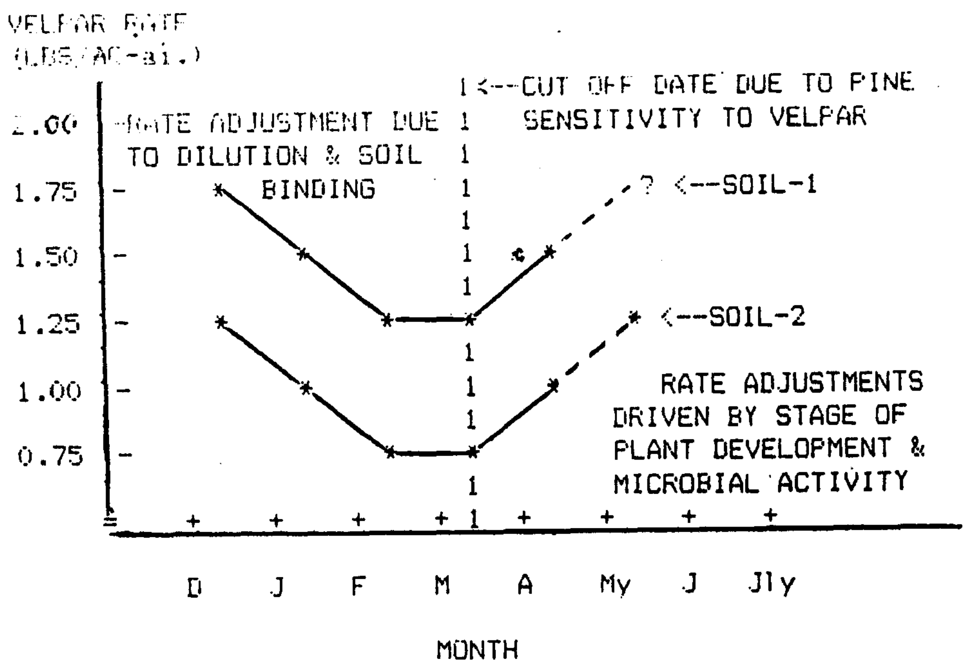
control chemical rates, down further and identifying the basic components of each which influence the rate of chemical needed. This has been done in table 1 and table 2.

As can be seen from tables 1 and 2, there are several factors which influence the rate of chemical that must be applied. Based on empirical data gained from timing x rate trails, it is impossible to say for a particular time of the year which soil, plant or climate component is having the greatest impact on activating or deactivating the applied herbicide. However, the general composite effect on the amount of herbicide needed on two different soils can be illustrated.



This would be a typical trend in the application rate of Velpar needed in the Mid-South (S.E. Okla.-W. Ark. region) for two different soil types. In other parts of the country the entire curve would shift to the right or left depending on whether growth starts earlier or later. Shifts up and down in the curve will also occur if rainfall is more or less than that received in the Mid-South and if the soil texture and organic matter are different. For instance, on soils with a deep decomposed organic horizon it may be necessary to apply later in the season after the competing vegetation is present and uptake rates are high. Otherwise, if applied earlier, the herbicide will be lost or bound up and not be effective unless extremely high rates are used.

Oust would follow a similar trend as those shown for Velpar. Usually the rates needed will vary from two to four ounces of active ingredient (ai.) per acre. For late season (May-June) application when the competing vegetation has developed considerably, it may require as much as six ounces per acre to get reasonable control. In most cases this rate

Chemicals Now Used For Weed Control In Pine Plantations

Several chemicals are now available for controlling weeds in pine plantations. However, the two major chemicals now applied are Velpar and Oust. Both of these chemicals have their advantages and disadvantages. In the following table we have listed the traits for which we have found Oust or Velpar to have an advantage in accomplishing the goals of a weed control program.

Trait	Oust		Velpar
Broad spectrum control	*[1]		
Seedling tolerance			
bareroot seedlings	*		
container seedlings			*
Window for application timing	*		
Foliar activity		?	
Growth promotion			*
Sensitivity to low temperature	*		
Low movement from target			*
Sensitivity to water quality			*
Ease of handling	*		
Storage after batching		?	
Safety	*		*
Rate sensitivity to soil and climate variables	*		

[1] * Indicates which chemical is best for the specified trait.

Oust and Velpar can be mixed and in fact appears to be a better treatment for optimizing vegetation control and pine growth response than using either chemical alone. The rates of each that may be necessary to get the desired results will be discussed in the following section.

Chemical Rates For Weed Control In Pine Plantations

It is generally reported that the rate of chemical required will vary by (1) soil type and (2) time of application. It is worth breaking these two factors, which would be cost prohibitive. With Oust there is no cut off date due to pine bare root seedling sensitivity as was shown for Velpar. The spring-summer cutoff date for Oust is more driven by the stage of development of the weeds and the probability of receiving enough rain to activate it. However, better weed control and pine growth will occur if the application is made prior to April for most areas with mineral soils.

Benefits From Weed Control Treatments

The two major benefits reported for weed control are increased survival and increased growth. Both of these aspects will be reviewed only briefly in the following paragraphs.

Increased seedling survival in the first two years have been reported (Holt et al., 1973 & 1975; Fitzgerald, 1976). Theoretically, one would expect this to be true because weed control significantly improves the seedlings water relations (Wittwer et al., in press; Nelson et al., 1981; Sands and Nambiar, 1984; Carter et al., 1984), nutrient availability (Carter et al., 1984) and undoubtedly their light regime. However, based on our experience with using Velpar with loblolly pine in a large spray program, even when rates and timing guidelines are critically adhered to, survival on the sprayed areas is about equal to that on the non-sprayed areas. This results because the sensitivity of loblolly to Velpar is increased when other agents of stress such as poor planting, poor drainage, or poor seedling quality are present. With Oust the interaction between the applied herbicide and other stress agents is not a severe problem and undoubtly reports of large increases in seedling survival during drought years will be reported in the future from the use of Oust or Oust-low Velpar mixes. For two trials in Southeast Oklahoma which compared survival for seedlings planted in 1985 (a dry year) on areas treated for weed control with Oust or not treated, survival was improved by 15-25 percent. In areas which have a high frequency of droughty years, Oust or Oust-Velpar mixtures will provide major benefits in successfully establishing pine seedlings and promoting early rotation growth.

Pine mortality after the first two years is often more related to competition with woody species than with weeds. Although weed control treatments which differentially accelerate pine growth over that of hardwoods would also probably reduce this mortality. In comparing the response of pine and hardwood clumps to broadcast Velpar weed control treatments (1 lb ai./ac), the hardwood clumps responded to the treatment as well as the pine.

TREATMENT	AVERAGE HEIGHT		PERCENT HEIGHT GROWTH	
	PINE	HARDWOOD	PINE	HARDWOOD
	(meters/ +- S.D.)			
VELPAR	1.78/.3	2.17/.5	26	21
CHECK	1.41/.2	1.8/.6		

It is likely that spot weed control treatments may favor pine growth over the hardwoods and thus also have an impact on pine survival even after ages one and two.

Growth Benefits

Increased height, diameter and volume has been reported for several studies (Knowe et al.; Wittwer et al., Nelson et al.; Glover and Dickens, 1985). Estimated gains of two to five feet in site index (25 years) have been projected. With the larger gains occurring on the better soils. These gains represent roughly a 7-16 percent increase in volume yield. Whether these gains are realized at the end of the rotation will depend on (1) if the projections have been made on a sound basis and (2) if the stand management regime for the remainder of the rotation is such that excessive between tree competition is regulated or not. If initial stocking is high and no intermediate thinnings are performed the entire early growth gain may not be maintained. But if stand density is regulated the gains should be maintained.

Cost of Weed Control In Pine Plantations

The range in cost for weed control is from about $12 to $60 per acre depending on chemical requirements, method of application and labor cost. More specifics about controlling the capital requirements for weed control will be discussed in the following section which addresses how to control cost. The remainder of this section will concentrate on the cost, in terms of higher risk to disease and insect attack, lower stem quality etc., that may result from weed control treatments. Much of this section will be pure conjecture because good studies designed with the objectives of looking at the impacts of weed control on increasing risk to damaging agents or lowering stem quality have not been conducted. The information available is mostly from field observations taken from growth response studies comparing herbicide treated and non-treated areas. One such study in Southeastern Oklahoma with loblolly indicated that tip moth damage for the fall assessment, averaged across twelve spray sites, was 29 percent for the non-sprayed seedlings and 41 percent for seedlings in the areas treated with herbicide. This differential may even be greater for shortleaf pine because it has been suggested to be more susceptible to tip moth than loblolly. The work by Stephen et al. (1982) does show a larger response of shortleaf to insect control than for loblolly.

The incidence of fusiform rust infection has been shown to increase with weed control and other intensive management treatments in a slash pine study in Louisiana (Burton et al., 1985). In this study the expected excess mortality due to rust infection will eliminate or severely reduce any growth gain due to weed control. Rust is not a problem with shortleaf but there may be other diseases that show a similar trend when herbicide is applied. There has been some recent suggestions that the incidence of pitch canker in loblolly may increase in areas receiving more intensive management and that this may be related to the level of tip moth damage. We must keep our eyes open and realize that the early apparent growth gains could be lost to insects and diseases that can increase with intensive management.

A second biological cost could be a reduction in stem quality. Undoubtedly more juvenile wood will be produced but a larger taller tree will also result. The additional volume added will likely far exceed in value any loss in value associated with a larger juvenile core. However, questions about whether increased branch size and frequency that can result from early grass control treatments will reduce wood quality needs to be addressed.

Capital Cost Control Considerations

Although some risks are associated with application of weed control treatments, the growth and survival gains justify considering the treatment if cost can be kept low. The two major costs are chemical cost and application cost. Careful consideration of the factors which control the rate of chemical necessary, as discussed earlier, will be the first step towards controlling chemical cost. Good guidelines which take into account soil, climate and plant factors have been developed by the Auburn vegetation management coop. The second major way of reducing cost is by treating only the ground area that is necessary to give the most economical increase in survival and growth. This aspect has not been investigated enough. The area needing treatment for weed control around each seedling will be largely a function of the type and height of competing vegetation that is expected to develop. This can be correlated with soil type and past land use history for a given geographical area. For instance, in the Mid-South the tallest competing vegetation will develop on high site upland and deep well drained bottomland soils. Competing vegetation on these soils can easily attain 6-7 feet in height. The imperfectly drained and excessively drained upland soils will usually develop a weed population that will be 4-5 feet in height. Sites that are poorly drained or shallow and eroded will normally develop a vegetation type that is only 2-3 feet in height; although the vegetation type that develops on the poorly drained soil will be of a totally different species makeup. On the very best sites which develop a weed population that reaches 6-7 feet in height, a broadcast weed control treatment will probably be required to be effective. On sites where weeds are expected to reach lesser heights, band or spot applications may be sufficient. The typical cost for a broadcast, band or spot treatment is shown in the following table for a plantation with 600 trees per acre, planted at an eight foot spacing between the rows and using one pound (ai.) of Velpar per acre.

METHOD	PERCENT OF EACH ACRE TREATED	ESTIMATED COST RANGE (DOLLARS)
AERIAL BROADCAST	100	30---40
GROUND BROADCAST	100	38---45
STRIP SPRAY	60	29---35
SPOT-4 FOOT DIAMETER	20	14---20

This range in cost represents a considerable savings in dollars spent if a spot treatment will provide almost as good a response as the broadcast treatment.

Weed control offers benefits in both growth and survival. These aspects have been well demonstrated. The major constraint to applying these treatments are cost and social concerns. Developing a better understanding of what method of control (broadcast, band or spot) is needed will help control cost and make weed control treatments more acceptable to the public.

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Table 1. The components embedded in soil type that influence the amount of chemical that must be applied and their impact on herbicide activity

Soil Component	Property	Range of Property	Impact on Herbicide Activity
*Texture (O and A Horizons)	Determines Cation Exchange Capacity	2 - 80 meq/100 g	1. Increased cation exchange capacity "binds" up the herbicide thus immobilizing it and requiring a higher rate of chemical to be applied to get the desired level of control. 2. Could increase the <u>duration of herbicide control</u> by keeping the herbicide within the zone of application.
Organic Matter	- Determines Cation Exchange Capacity	Content in mineral - Soil < 1% - 5% - Organic Soils	same as above
	- Serves as a physical barrier	CEC 100-200 meq/100g	
Soil Drainage	Determines dilution & removal rate	Excessive to Poorly Drained	As drainage decreases, the need for higher rates of herbicides in general increases. This is usually due to several confounding factors; the increase in finer texture component, an increase in organic matter, and a dilution impact due to surface water & suspended organics moving from the point of application.

Table 2. The components embedded in "time of application" which influence the amount of chemical that must be applied and their impact on herbicide activity

Time of Application Components	Property	Range of Property	Impact on Herbicide Activity
1. Stage of development & size of competing vegetation	• Physical barrier to getting the herbicide to the soil - May bind up some of the applied herbicide on the foliage • Plant sensitivity to herbicides? - Detoxifying capacity? - Foliar uptake capacity? - Root zone concentrated in high zone of herbicide concentration near the surface	Pre Emergence - Established Stand (0-100% Ground Cover)	The general trend is to have to increase the rate of herbicide applied as the vegetation gets larger & more dense.
2. Precipitation	• Media for movement of herbicide into the rooting zone	Usually requires 1-2" to effectively move the applied herbicide into the rooting zone	Increases herbicide activity if rainfall is not excessive.

	• Media for diluting & transporting herbicide out of the rooting zone	The amount of rain needed to cause movement out of the rooting zone will be determined by the soil texture, structure, organic matter, antecedent soil moisture, evaporative demand, and properties of the herbicide. Range - low on sandy soils - high on soil with clay	Decreases herbicide activity
3. Temperature	• Increases water mobility	• Low root hydraulic conductivity at soil temperatures near freezing - Increase as soil temperature increases	Increases herbicide activity over the range of temperatures experience from winter to early summer.
	• Increases seedling metabolism & catabolism processes	• At low temperatures, photosynthesis respiration and cell division are minimal. At high temperatures, the demand for the substrate whose synthesis is being blocked by the herbicide increases.	

	• Increase root growth	• e.g. Low at less than 10°C? High at 25°C? (Species Dependent)	
	• Increased microbial processes		• Increases breakdown rate of applied herbicides thus requiring higher rates of application.
4. Evaporative Demand	Increased water uptake capacity	Mid South PET[1/] Dec-Jan-0-1mm/day PET March-April ≅ 2-3 mm/day	When foliage is present, it probably increases herbicide activity by concentrating more herbicide into the target plants.
5. Pine Seedling Herbicide Sensitivity	Increases after bud break & as temperature begins to average near 20°C (i.e. as pine growth activities & water use increases)		*Requires a decrease in Velpar rates Sensitivity to Oust not a major factor

[1/]PET = Potential evapotranspiration

WOODY COMPETITION CONTROL

Robert F. Lowery[1]

ABSTRACT

Control of woody competition is necessary to maintain shortleaf pine (Pinus echinata Mill.) as an important component of natural stands and to maximize shortleaf pine plantation productivity in the Southeast. Competition control is key to maximizing timber production since growth is moisture-limited over much of its range. Volume growth gains of 40% have been reported following woody competition control in mature stands. Larger stem size gains can be expected from earlier treatment provided the released stand is thinned appropriately through time. Forage production also is stimulated by woody competition control; however early herbaceous competition control will further increase pine growth gains.

Mechanical control methods offer high individual stem selectivity but have the disadvantages of relatively high cost, high probability of human injury and rapid regrowth of most hardwoods. Fire is a relatively inexpensive, widely used woody competition control tool. Fire also offers only temporary control of small stems, reduces growth of pine residuals if crowns are scorched and requires careful smoke management. Herbicides offer positive control of susceptible species and may be used at any stand age. However herbicides are less selective than mechanical means, can be costly; and like fire, require specialized knowledge for effective use. Six herbicides are registered for shortleaf pine release in the Southeast.

INTRODUCTION

Hardwoods are the climax vegetation type on virtually all sites where shortleaf pine occurs naturally, therefore hardwood species must be controlled in some manner if shortleaf pine is to be maintained as a major component of southern forest types. A variety of methods are available for use in controlling encroaching hardwoods. The effort and cost expended in woody competition control, the tool or treatment used, application timing and frequency can vary widely among public, industrial and non-industrial private lands due to differing management objectives and philosophies.

A key consideration in selecting a given method is its selectivity in precisely controlling the targeted stand component(s) with minimal direct effect on the residual vegetation. Cost, treatment efficacy and environmental considerations also will constrain tool selection and use. Competition control is an active area of research with new or improved procedures reported frequently in technical papers and proceedings. Everyone involved in competition control activities can benefit greatly by staying abreast of changes in this technology and becoming more proficient in its use.

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The objectives of this paper are to examine (1) the reasons for woody competition control, (2) its timing relative to stand development and (3) the tools available for woody competition control in shortleaf pine management. Biologically, pine thinning is woody competition control but the topic will not be covered in this paper.

WOODY COMPETITION CONTROL RATIONALE

Shortleaf and the other southern pines are relatively shade-intolerant and hardwoods are the climax vegetation in most areas of the southeastern United States. Therefore woody competition control is necessary to maintain shortleaf pine as a major component of managed forests, be they naturally regenerated or planted forests. If the stands are being used for timber production, control is necessary to maintain good tree vigor for enhanced pine growth and resistance to insect attack.

All higher plants draw upon soil moisture reserves in approximate proportion to their contribution to total leaf area on the site. Growing season soil water availability is a major growth-limiting factor on many sites supporting shortleaf pine. In addition to floristic changes, competition control usually increases the vigor and growth of the remaining stand since additional moisture and other potentially limiting factors, e.g., light and nutrients are made available to the remaining stand. Ting and Chang (1985) reported less soil moisture depletion by 21-year-old shortleaf than by longleaf (*Pinus palustris* Mill) or loblolly (*Pinus taeda* L.) pine stands of the same age and density.

Bower (1968) found that equal increments of understory hardwood removal resulted in approximately equal increments of growth on the remaining 50- to 65-year-old shortleaf pine overstory. Complete removal of 33 square feet of hardwood understory increased residual stand basal area growth by 31% (.3 sq ft) over the five years following removal (Fig. 1). Rogers and Brinkman (1965) found a 40% increase in 30-year-old shortleaf pine volume growth 10 years following complete control of the hardwood understory which was composed of 900 stems/ac with 14 square feet of basal area and 3500 stems/ac less than 0.6 inches in diameter.

Removal of the hardwood understory from 53- and 47-year-old loblolly/shortleaf pine stands in southeast Arkansas resulted in a 14 year response of 359 cubic feet of volume and 9.9 square feet of basal area compared to untreated stands (Grano 1970). Shortleaf however does not respond as dramatically to release as does loblolly in mixed stands (Guldin 1985a). Smalley (1974) also clearly demonstrated the value of intensive stand improvement, primarily hardwood competition removal, on subsequent development of mixed shortleaf-loblolly pine stands over a 19-year period. Volume growth was 427 cubic feet on the check area versus 1498 cubic feet of growth on the intensively treated area.

Mature pines do not always exhibit increased growth following removal of a hardwood understory (McClay 1955, Russell 1961). In the case of the former investigator, the loblolly pines were 40 to 50-years-old when treated; in the latter, response was slight but non-significant. Such an outcome could be expected on site where soil water availability is not a growth-limiting factor.

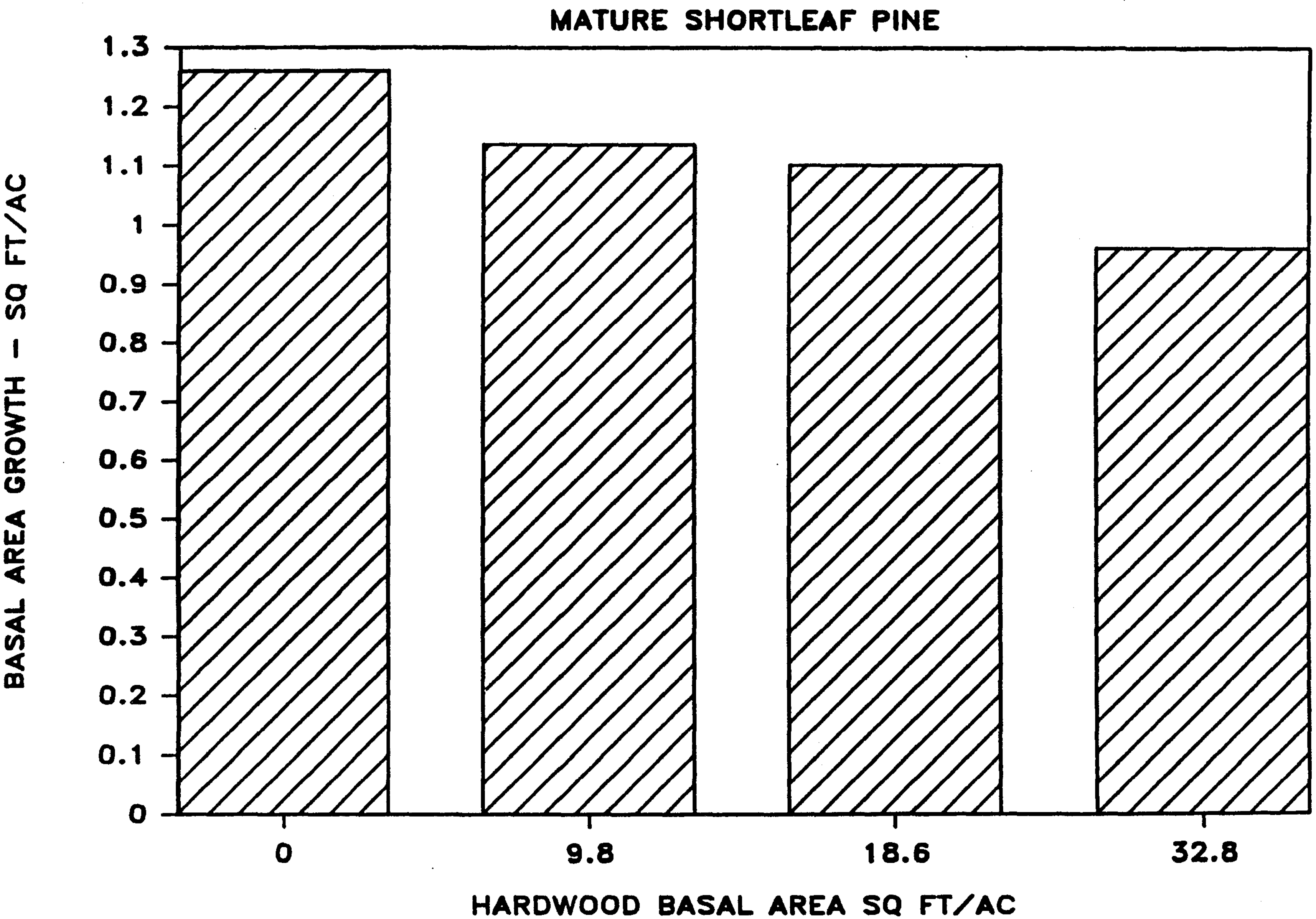

Figure 1. Five-year growth response of 50 to 65-year-old shortleaf pine to removal of varying levels of understory hardwood competition. From Bower (1968).

Control of woody competition from the time of stand establishment results in even more dramatic growth response than seen in the above examples. A replicated loblolly pine site preparation study in Fayette County, Alabama resulted in hardwood basal areas ranging from 0 to 100% of total stand basal area at age 24. Pine yields declined dramatically as the proportion of hardwood in the stand increased (Glover and Dickens 1985) (Fig. 2). These data indicate that pine yield in stands with 30% hardwood basal area was only 50% of that in stands with 4% hardwood basal area (Fig. 2). The percent hardwood basal area at age 24 was essentially the same as at age 11. Hardwood ingrowth and pine mortality combined to maintain this constant proportion in the face of more rapid growth of individual pines. Control of both the herbaceous and woody competition early in stand life will produce even larger growth gains (Glover and Dickens 1985).

Woody competition control benefits go beyond residual tree growth. Native grass growth was doubled following control of heavy hardwood brush in a natural shortleaf stand in southeast Oklahoma. However, the grasses were quickly suppressed where dense pine regeneration developed following the brush control (Elwell 1967).

Stand access and visibility for future silvicultural operations and cruising are additional major reasons for controlling woody competition in commercial forests. Thinning and final harvest costs or stumpage values are negatively impacted by the presence of non-commercial woody competition in the stand. Pine stands in South Carolina without dense hardwood understories tend to bring bids $5 to $10 higher per thousand board feet than brushy stands because of improved visibility and safer logging conditions (Guldin 1985b).

WOODY COMPETITION CONTROL TIMING

Woody competition control can be done at any time given the variety of tools available today; these will be covered later. Control should be done when: (1) woody competition is recognized as a problem in the context of management objectives, (2) a suitable control tool is available, (3) the benefit/cost ratio weighs clearly in favor of control, (4) resources are available to carry out the control, and (5) control is the highest alternative use of available resources.

In plantations targeted for wood production, woody competition control should be done when pine and hardwood crowns begin to form a continuous canopy. Earlier removal may be called for if the economics and biology of the intended procedure are favorable. But, a dramatic increase in the herbaceous component will likely result since herbaceous species are capable of faster response to release from hardwoods than the pines. In most cases the herbaceous competition is more detrimental to early pine survival and growth than the woody component. Bacon and Zedaker (1986) found maximum early pine growth response when hardwoods were reduced to a low level and herbaceous competition was controlled completely.

Elimination of woody competition for any length of time is virtually impossible with any single treatment application (Cain and Yaussy 1984). Control of all woody competitors at the time of pine establishment also may not be desirable biologically because of their ability to supress herbaceous competition development. Some species are particularly effective

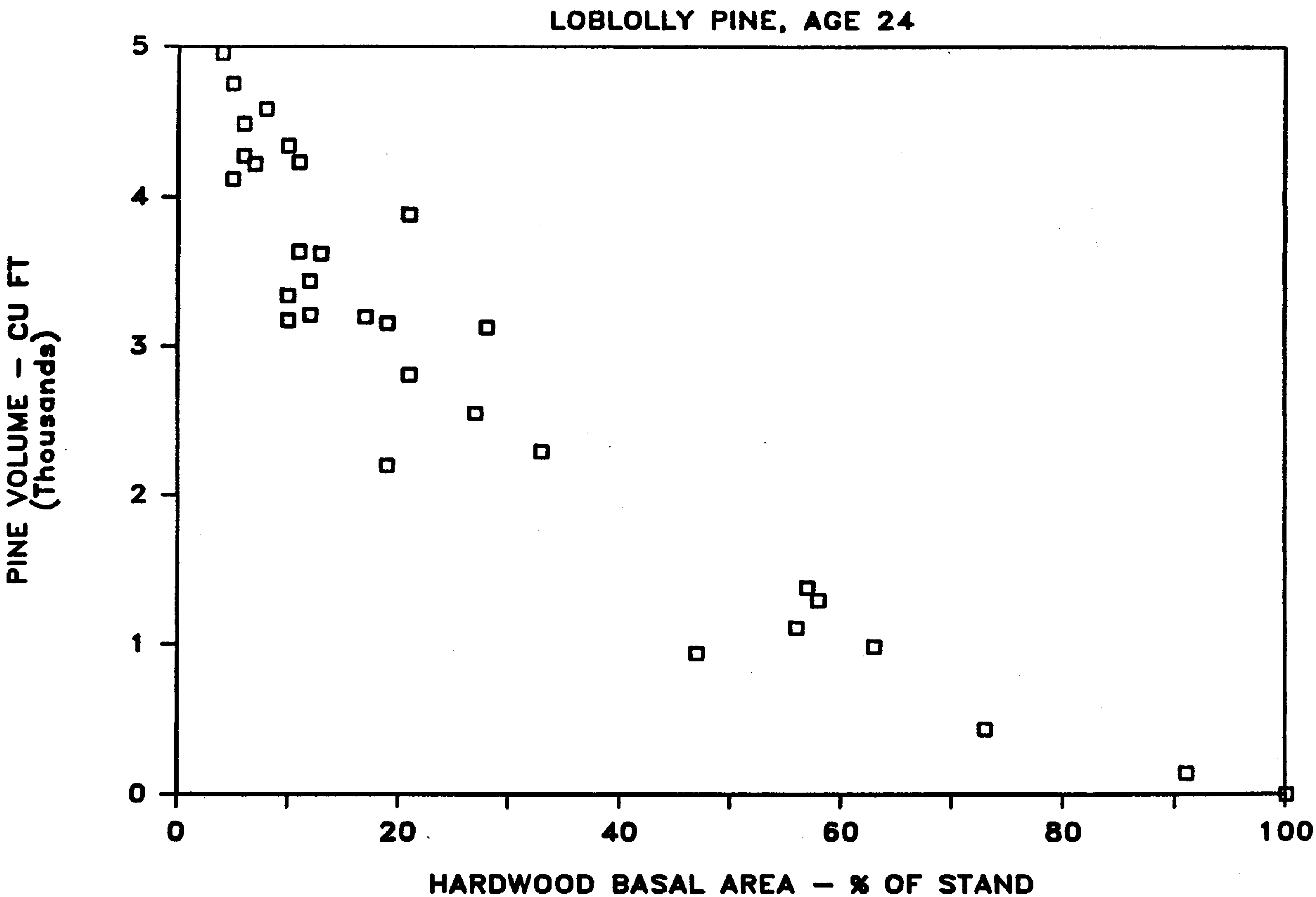

Figure 2. Impact of hardwood competition on loblolly pine yield 24 years after planting. From Glover and Dickens 1985.

against certain problem weeds, e.g., many prairie grasses will not grow under the relatively open canopy of winged sumac (Rhus copallina L.) (Petranka and McPherson 1979). Allelopathic effects of the sumac appeared to be the most important factor reducing density of the grasses. Grasses are major competitors and a fire hazard in many young pine plantations across the southeast; their control is often not attempted for lack of a cost effective treatment.

Woody competition control is best done prior to the culmination of mean annual height increment if the objective is to maximize timber production. This occurs relatively early in stand life, i.e., age 5 - 10 years. After this time the tree responds more slowly to release than if released prior to or during this period. Older shortleaf however are capable of responding to release (Guldin 1985b); also recall the data of Bower (1968) and Grano (1970) presented above. Control of a significant woody competition component in a pine stand will produce growth response at older ages but it will not be as large as if it had been done earlier and the stand maintained in a vigorous condition thereafter. However if the management objective is high quality saw timber and the stand is older and in need of release, woody competition control may still be an attractive investment since the incremental response will be in the form of high value wood and the investment can be recovered relatively soon. Elimination of woody competition control late in the rotation also has the potential of reducing or eliminating the need for control in the stand that follows.

Woody competition control for stand access reasons should be done the season prior to its need so regrowth will be minimal. However if safety hazards will be posed by large decaying stems, the control should be done three to five years prior to need. Natural regeneration needs can best be met by control the season prior to an expected good seed crop.

WOODY COMPETITION CONTROL METHODS

MECHANICAL

Woody competition can be controlled in existing stands by several means: mechanical, e.g., cutting; by use of prescribed fire; or through the use of herbicides. Mechanical control is perhaps the most positive in terms of immediate effect and can be highly selective. However if not used in combination with one of the other means it is least likely to provide more than temporary top-control. Most woody plant species in the southeast, including shortleaf pine, sprout profusely and can again become serious competitors shortly after cutting (Troth et al. 1986). Repeated annual or more frequent cutting will eventually kill the plant through depletion of root system reserves. However this is not practical in most forest land situations.

Mechanical control is effective and necessary for some purposes, e.g., improving access for harvesting, reducing stem sizes so that fire can be used for subsequent control or lowering browse levels and improving low-level game cover. This method is most likely to be used during thinning operations, especially in pre-commercial thinning where excess planted or naturally regenerated stems of the crop species are removed along with other unwanted woody competition.

The axe or saw is a highly selective tool, removing only the unwanted stems. The size and shape of the area impacted also is easily controlled. This infinitely variable effect on the timber stand in terms of the numbers and species removed, is limited only by the mental processes of its wielder. Its other strong advantages are that it can be used at almost any time of the year and in any terrain. Its chief disadvantages are high cost in some situations, the fact that top control is often all that is accomplished and the high probability of human injury associated with its use. Accidents in labor intensive forest work such as pre-commercial thinning and woody competition control with chain-saws are more frequent and severe than with most any other silvicultural operation. Newton and Dost (1984) report that the cost of accidents are approximately 10,000 times greater per unit area with such labor intensive vegetation management treatments than with aerial herbicide treatments.

FIRE

Fire is perhaps the most widely used silvicultural tool in the southeastern U.S.; some 6.5 million acres are burned annually. The primary reasons for such wide-spread use are low cost, its ability to "clear out" the understory, ecosystem resiliency to its use and human fascination with fire. However burning is not without some major disadvantages: (1) a limited number of days in the year when fire can be used successfully and legally, (2) difficulty in predicting fire behavior and thereby effects on target as well as residual plants (3) limited effectiveness on large stems in selective control applications, (4) need for trained, experienced personnel to conduct burns, and (5) potential liability for smoke impacts away from burn area.

None the less, prescribed fire is widely used in an attempt to selectively control woody competition in shortleaf and other southern pine stands. This selectivity of control derives from the differential morphological capacity of various species and size classes to insulate meristematic tissues from high temperatures produced by the passing fire, e. g., thicker bark provides better insulation. Like mechanical methods, fire usually only top-kills woody competitors by killing the cambium near the ground, thereby girdling the stem. However, unlike mechanical methods, fire is normally effective only against small diameter stems when safely used in established stands. It follows that small pine stems also will be top-killed in such fires though relatively thick bark offers a degree of protection. Small stem control can dramatically improve visibility within a stand though and greatly facilitate certain activities, e.g., cruising, marking and thinning.

Hardwoods with groundline diameters greater than 2 inches are rarely top-killed by winter fires (Lotti 1960) considered safe in stands less than 30 feet tall. However, a series of annual summer burns in taller pine stands can be very effective in eliminating small sprouting competitors (Lotti et al. 1960), particularly if the burns are conducted early in the growing season when root carbohydrate reserves are low (Hodgkins 1958). Summer burns are difficult to execute though when hardwood basal area exceeds 40% of total stand basal area; the same is true for repeat annual winter burns in stands containing many hardwoods (Brender and Cooper 1968).

Care must be exercised in prescribed burning not to excessively scorch crop tree crowns. Crown scorch at any age has a major negative impact on shortleaf and loblolly growth (Cain 1985), as well as the other southern pines (Bruce 1947, 1952; Johansen 1975; Muntz 1948), in proportion to the degree of live crown scorch. These effects may last several years as the crown is rebuilt and cambial damage repaired. If the scorch is severe, growth losses will more than offset the gains from competition control and stand access.

Smoke is becoming a troublesome by-product of fire which can create serious problems when it drifts into rural home sites, urban areas or onto public roads. The latter has contributed to serious vehicle accidents exposing the smoke generator to major liability claims. Prescribed fire use may decrease with time if regulations pertaining to emissions from silvicultural burning are tightened further. All who use fire in the forest have an obligation to improve smoke management practices, become more sensitive to public smoke management concerns and respond to them in a pro-active manner. Otherwise use of prescribed burning may be severely restricted.

HERBICIDES

Herbicides, like mechanical competition control, can be used at any stand age. But unlike control with fire or mechanical means, herbicides can provide complete kill of stems and root stocks from a single application. Herbicide use is far more closely regulated than is prescribed burning and, like burning, herbicides must be used carefully, i.e., careful planning, handling, application and attention to environmental considerations. However, because of the vast amount of information required to obtain use registration, herbicides applied in accordance with label recommendation are probably safer to use and give more predictable results than fire.

As a group, broadcast-applied herbicides are less selective in control than mechanical methods but, depending on the situation, more selective than fire. Selectivity tends to be expressed at the level of genera. Individual stem injection allows one to be very selective within all except the smallest diameter classes. Selectivity can be altered further by: (1) using directed instead of broadcast application to avoid application to susceptible crop species, (2) varying season of application to capitalize on target species susceptibility or minimize crop species susceptibility to damage, (3) use of adjuvants to increase target species susceptibility.

Herbicides can be applied in conjunction with mechanical operations to prevent sprouting of the cut trees. Troth et al. (1986) however found herbicide "flash-back" into residual shortleaf and loblolly pine following treatment of shortleaf stumps. Residual pines also suffered soil-active herbicide injury from hardwood stump treatments. These findings point out the importance of thoroughly understanding herbicide performance and behavior before making large-scale applications.

Some 20 herbicides are registered for woody competition control in southern pine stands. The seven formulations that can be used for pine release contain one of four active ingredients (Table 1). An additional promising pine release herbicide, Arsenal(tm) is available for use in 1986 only under an experimental use permit. Hexazinone formulations have the potential for producing the greatest growth response due to their activity against many herbaceous as well as hardwood competitors. Arsenal also controls many herbaceous plants.

TABLE 1. Herbicides currently registered for pine release in the southern United States and application methods.

Common Name	Trade Name	Application Method
Dichlorprop	Weedone(tm) 2,4-DP	Broadcast * Directed Spray
Glyphosate	Roundup(tm)	Broadcast Directed Spray
Hexazinone	Buckshot(tm) 10-PH	Broadcast
	Pronone(tm) 5G	Broadcast
	Pronone(tm) 10G	Broadcast
	Velpar(tm) L	Broadcast Grid Spot
Triclopyr	Garlon(tm) 3A	Directed Spray

* FIFRA Section 24-C labeling only for loblolly pine in AR, LA, MS, NC, OK and TN

None of these herbicides are a panacea for woody competition problems. But excellent results can be obtained in most situations if the prescription is developed with a thorough understanding of the limitations and behavior of the herbicide, if the herbicide is matched to stand and site characteristics, and if it is properly applied. A recently published silvicultural herbicide use guide (Cantrell 1985) should be of considerable value to those using herbicides in forestry.

SUMMARY

Woody competition control is necessary for the long-term maintenance of shortleaf and other pines in the natural forests of the Southeast. Control also is necessary to maximize timber production in both natural stands and plantations since growth is limited by soil moisture availability over much of its range.

Substantial growth gains have been reported following woody competition control in mature stands. Larger gains can be expected from earlier treatment provided the stand is appropriately thinned at later ages. Growth gains are inversely related to the proportion of total stand basal area that is woody competition. Forage production also is stimulated by woody competition control; however, herbaceous control early in stand life will produce substantial additional pine growth gains.

Mechanical control methods offer the most individual stem selectivity but have the disadvantages of relatively high cost, high probability of human injury and only temporary control of most sprouting woody plants.

Fire is a relatively inexpensive, widely used woody competition control tool. However fire provides only temporary control of small stems and reduces growth of residuals if crowns are scorched. Fire use also requires careful smoke management in many areas.

Herbicides offer positive control of susceptible species and may be used at any stand age, but are less selective than mechanical means and can be costly. Herbicides, like fire, require specialized knowledge for effective use. Six herbicides are registered for shortleaf pine release in the Southeast.

Forest competition control technology is a rapidly evolving field in the South. All using these practices should develop a good understanding of the basic principles involved, stay abreast of developments and use the technology in a responsible manner.

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GROWTH AND YIELD OF SHORTLEAF PINE

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ABSTRACT

A survey of available growth and yield information for shortleaf pine (Pinus echinata Mill.) is given. The kinds of studies and data sources that produce this information are also evaluated, and an example of how a growth and yield model can be used to answer management questions is illustrated. Guidleines are given for using growth and yield models, and needs for further research are outlined.

INTRODUCTION

Shortleaf pine (Pinus echinata Mill.) has the largest range of the southern pines and ranks second only to loblolly pine (Pinus taeda L.) in terms of inventory volume in the South. However, the quantity of growth and yield information for shortleaf is minuscule in relation to its importance as a resource and to the volume of information available for the other three major southern pines. Some information is available for natural stands and unthinned old-field plantations. The present data for natural stands need to be supplanted by better information, and new data must be developed for thinned plantations on both old-field and nonold-field sites. The main impediment to producing new information is the lack of data from well designed, comprehensive field investigations. Fortunately, there are efforts underway to install these desperately needed studies.

The benefits of growth and yield information are more difficult to quantify than the more tangible results from other research, such as forest genetics. Growth and yield results are used primarily as a basis for decisionmaking. But the conclusions reached with the benefit of growth and yield models can have far-reaching social and economic consequences. The selection of a rotation length, thinning schedules, harvest scheduling, choice of species, regeneration densities, growing stock levels, method of regeneration (natural, direct seeding, or planting), even mill or plant location--all depend on growth and yield data. Hopefully, the more complete and accurate the information, the more informed and accurate the final decision.

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CLASSIFYING GROWTH AND YIELD INFORMATION

Before taking a look at what information is available, it is instructive to look at how growth and yield studies can be classified. One way is to look at their purpose--descriptive, inferential, and predictive. Descriptive studies are the most elementary and are primarily observations of some unusual phenomenon, such as a description of a timber stand with exceptional stocking.

Inferential studies are statistically designed experiments for answering a question such as, "What residual basal area--60, 90, or 120 square feet per acre--results in the largest cubic-foot volume growth?" These studies are usually limited in the numbers of variables that are under investigation so that the field experiment does not become too large or expensive.

Predictive studies are designed to produce mathematical models; they are also statistically designed to observe the range of variables of interest. The models are used to project growth and yield given certain stand and site characteristics--such as stand age, stand density, and site quality. Predictive studies are more comprehensive than inferential ones; more variables are usually included. In an inferential study, site quality may be of no interest, and its effect may be controlled by blocking or some other statistical design technique. In a predictive study, site may be a primary variable, and plots will be located across the range of sites. Because predictive studies are more comprehensive, they are larger, more expensive, and require a large organizational commitment in terms of manpower, time, and money. It is not unusual for growth and yield studies to have more than 200 plots and span decades of time. Ideally, these studies should run through a rotation. Only rotation-length experiments will reveal definitively how a stand will respond over its life to a given thinning treatment. The great demand on resources is the main reason that few predictive studies have been installed. Their success depends upon the research sponsor having a long-time horizon.

Sometimes several inferential studies can be combined to produce a predictive study. But the data are usually not completely compatible, and important treatment combinations may be missing.

Both inferential and predictive studies are controlled experiments. But, as we have seen, they can be expensive and time consuming, especially predictive ones. Consequently, another strategy is to use inventory data to develop growth and yield models. These data usually come from continuous forest inventory systems that are maintained by government agencies or forest industries. Though the data may have been accurate and adequate for the original purpose, there are several limitations for growth and yield model development: (1) there are no plot isolations, (2) important variables may not have been measured, (3) a large number of plots must be available so that a sufficient number are left after they are screened to eliminate unwanted plots, (4) rare situations may not have been sampled, (5) there is usually a limited knowledge of the plot history, and (6) the growth and yield predictions of the models may not be those that can be realized from managed stands.

Despite these limitations, these data are invaluable for obtaining interim results. Models can be developed immediately for conditions for which there are no installed studies, and subsequent controlled studies can be designed better using the knowledge gained by developing these interim models. There is a considerable time lag from when a study is installed until growth information is available. If the remeasurement period is 5 years and the study is installed over a 3-year period, then it may be 8 to 10 years before results are available. Models developed from inventory plots can be used during the interim.

Another topic related to data is that some models have been developed using temporary plot data, while others have used permanent plots. You have to make judicious and sometimes heroic assumptions (to borrow a phrase from the economists) to use these models for projections.

Models can be classified into three main types--stand level, size-class distribution, and individual tree. Stand-level models need only a few variables but usually give yields on a aggregate stand basis. For example, a natural even-aged model might require input values of age, site, and density, but will project only cubic- and board-foot volumes on a per-acre basis.

Size-class distribution models may require more input variables, but will provide more detailed information in terms of stand and stock tables. Individual tree models are the most data demanding. Individual-tree measurements--such as diameter and height--must be provided, but individual tree identities are maintained and their attributes are projected. More detail is provided than is probably needed by the casual user. Size-class and individual-tree models do possess an advantage over the stand-level ones with regard to model development. It is much easier to expand the models to include other variables--such as the effects of genetics, disease, or fertilization.

AVAILABLE INFORMATION

The following discussion will be confined to either comprehensive predictive studies or long-term inferential studies as outlined in table 1. Williston's selected growth and yield bibliography (1975) gives a good account of growth and yield information up to about 1974, but this publication is almost out-of-print. Thus, for the reader's convenience, Williston's citations for shortleaf pine are included in the reference section at the end of the paper with some exceptions: references in which loblolly pine was the predominant species have been deleted. An effort was also made to include all papers published since 1974 to provide a current, comprehensive bibliography on shortleaf pine growth and yield.

Natural Even-aged Stands

The grandfather of all southern pine growth and yield information for natural even-aged shortleaf pine is the venerable USDA Forest Service Miscellaneous Publication 50 (USDA Forest Service 1929). It is based on the concept of normal stocking, which is the density at which a stand is producing the maximum cubic-foot volume of wood. Yields are given by age and site index classes in a series of tables. The information is from 188 temporary plots scattered across the South (table 1). Miscellaneous Publication 50 (Misc. Publ. 50) has been supplanted by more recent studies, but its site index curves are still used and it also serves as a valuable reference for research purposes.

The second major growth and yield model for shortleaf was Schumacher and Coile (1960). The equations were much easier to use than the tabular data of Misc. Publ. 50, but there were also some weaknesses. Like Misc. Publ. 50, it uses a somewhat subjective stocking standard that Schumacher and Coile called "well stocked". The data are from 74 temporary plots from a small geographic locality (table 1). It can be used for projections provided you are willing to make some assumptions about how stocking percentages develop over time. Despite its limitations, it has been widely used since its availability to the public.

The use of a stocking standard, such as normality, was abandoned by growth and yield researchers in favor of presenting yields by an array of densities instead of an idealized one. Until Murphy and Beltz (1981) and Murphy (1982), variable density yield information for a variety of sites and ages had not been available for natural even-aged shortleaf pine. The data came from permanent inventory plots maintained in Arkansas, Louisiana, east Oklahoma, and east Texas by the Forest Inventory and Analysis Unit of the Southern Forest Experiment Station (table 1). Given stand basal areas, stand age, and site index, the equations can give projected basal areas and current and projected stand volumes. The models have the limitations of those based on inventory data, which have already been described.

The preceding models have been stand level ones. An individual tree model has been developed by the USDA Forest Service, North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, MN 55108, for Indiana, Illinois, and Missouri. Available in a microcomputer software package called TWIGS (table 1), it was also developed from inventory data.

An inferential study that has provided valuable information over the years has been one maintained by the North Central Forest Experiment Station on the Sinkin Experimental Forest in Missouri (Brinkman and others 1965, Sander and Rogers 1979, Rogers and Sander 1985). Four residual basal area treatments and a control were replicated three times on a 30-year-old natural shortleaf pine stand (table 1).

Natural Uneven-aged Stands

Until recently, information was very skimpy for growth and yield of uneven-aged stands of either pure shortleaf pine or where shortleaf pine predominated. Gibbs (1958) reported on the 10-year growth of mixed shortleaf-loblolly pine stands in east Texas. Other reported information has been for Coastal Plain stands in which loblolly predominates by a wide margin. Murphy and Farrar (1985) have recently published an uneven-aged shortleaf growth and yield stand-level model. Given site index and initial merchantable and sawtimber basal areas, one can obtain projected basal areas and current and projected cubic- and board-foot volumes. It was developed from inventory data and should be used with this fact in mind.

Plantations

Models for plantations can generally be categorized by being for old-field versus nonold-field (or forest) sites and for thinned versus unthinned stands. The first models were for unthinned old-field plantations. Large acreages of abandoned agricultural fields were planted to pine, but were not usually thinned. We are just beginning to see models being developed for thinned plantations on nonold-field sites.

The first plantation model was developed by Ralston and Korstian (1962) for predicting pulpwood volumes of unthinned plantations in the North Carolina Piedmont. Only 18 of the 66 plots in the study were from shortleaf plantations: the rest were loblolly plantations. The combined data from the two species were used to derive the model. It is a stand-level model and uses number of trees, basal area, average stand diameter, and cordwood/basal-area ratios associated with different dominant stand heights.

The most comprehensive shortleaf pine plantation model was developed by Smalley and Bailey (1974) for unthinned old-field stands in the Tennessee, Alabama, and Georgia Highlands. It is a size-class distribution model and gives stand and stock tables for different sites, planting densities, and ages from seed.

In addition to these two models, results from a variety of inferential studies have been published over the years. Arnold (1975, 1981), Boggess (1958), Boggess and Gilmore (1963), Boggess and McMillan (1953), Boggess et al. (1963), Gilmore and Boggess (1969), Gilmore and Gregory (1974), and Gilmore and Metcalf (1961) have reported on studies in southern Illinois. Williston has written of studies in Tennessee and north Mississippi (1959, 1963, 1967, 1972, 1983, 1985). Williston and Dell (1974) provide periodic annual increment equations for plantations in north Mississippi for ages 20 to 35 based upon two 5-year remeasurements of a field survey established by the Yazoo-Little Tallahatchie Flood Prevention Project in 1959.

Tree Volume and Biomass Equations

Determining individual tree product volumes and biomass is a necessary adjunct to growth and yield. Several references about this subject are listed in the bibliography. Baldwin (1982), McNab and others (1982), and Phillips (1982) provide excellent bibliographies on biomass estimation of individual trees. Walters (1982) gives taper, green weight and volume equations for shortleaf pine in east Texas. A comprehensive taper function will be published soon for shortleaf pine in natural stands for Louisiana, Arkansas and east Oklahoma (Farrar and Murphy in preparation).

AN EXAMPLE

Some possible applications of growth and yield information have already been mentioned. The following example shows how a growth and yield model can be used in decisionmaking. The recently published uneven-aged model (Murphy and Farrar 1985) for shortleaf pine will be used as an illustration. The input variables are initial merchantable and sawtimber basal areas and elapsed time (or cutting cycle).

Many private nonindustrial timberlands brought under management are understocked. The problem is to increase stocking while simultaneously providing the landowner a periodic income under a variety of constraints. One common harvesting constraint is that there must be an operable cut of, say, at least a 1,000 board feet per acre (Doyle rule). The models can be used to derive a management strategy with these objectives and constraints.

For example, suppose a tract of uneven-aged shortleaf pine is to be brought under management. The site index for shortleaf is 70 feet (base age 50) on the property, and the current stand has 45 square feet per acre in merchantable basal area and 25 square feet per acre in sawtimber basal area. The desired management regime is a 7-year cutting cycle and residual densities of 60 and 45 square feet for merchantable and sawtimber basal areas, respectively. How might this property be managed to bring the stand up to these stocking goals while providing a periodic cut that is at least 1,000 board feet (Doyle rule)?

A proposed strategy is to maintain a 7-year cutting cycle, cut 75 percent of growth, and see if the harvesting constraint is observed. To use the model for this problem, future basal areas are projected first. The basal area that can be cut is computed from growth, and then residual basal area is found by subtraction. Before- and after-cut stand volumes are calculated using basal area and site index in the stand volume equations. A table of before-cut, cut, and after-cut basal areas and volumes can then be calculated for the planning period.

The stand will be allowed to grow for 7 years before the first harvest. The periodic growth for the first 7-year period is 61.1 minus 45.0, or 16.1 square feet. If 75 percent of periodic growth is to be harvested, then 12.1 square feet of merchantable basal area will be cut, with 49.0 square feet remaining. The whole process is repeated for subsequent cutting cycles until the stocking goal is reached. The following tabulation summarizes the cyclic harvests and residual densities for merchantable basal area:

	Merchantable Basal Area		
Growth period	Before cut	Cut	After cut
years	ft^2		
0	45.0	-	45.0
7	61.1	12.1	49.0
14	64.9	11.9	53.0
21	68.7	11.8	56.9
28	72.3	12.3	60.0
35	75.1	15.1	60.0

The residual stocking goal for merchantable basal area is reached in 28 years, and regular cyclic cuts for merchantable basal area and volume take place after that.

The cutting schedule for sawtimber basal area is computed next. The projected sawtimber basal area in 7 years, given initial basal areas of 45 square feet for merchantable trees and 25 square feet for sawtimber trees, is 39.1 square feet. The periodic growth is 39.1 minus 25.0, or 14.1 square feet per acre, and the first cycle cut for sawtimber basal area is 75 percent of periodic growth: 10.6 square feet. Values for subsequent cutting cycles are determined in the same manner. The following tabulation may be constructed,

Sawtimber Basal Area			
Growth period	Before cut	Cut	After cut
years	ft^2		
0	25.0	-	25.0
7	39.1	10.6	28.5
14	42.9	10.8	32.1
21	46.6	10.9	35.7
28	50.3	11.0	39.3
35	53.9	11.0	42.9
42	57.6	12.6	45.0
49	59.7	14.7	45.0

The residual stocking goal for sawtimber basal area is reached in 42 years, two cutting cycles later than for merchantable basal area. The cyclic harvest for maintaining sawtimber basal area is 14.7 square feet after the stocking goal is reached.

Now that merchantable and sawtimber basal areas have been determined, volumes can be calculated. With an initial volume of 853 cubic feet, the volume in 7 years would be 1,201, and the residual volume would be 938 cubic feet. The harvest is determined by subtracting after-cut from before-cut volumes. The remaining values are determined in a like manner. The following tabulation can now be constructed for merchantable cubic-foot volume:

Merchantable Cubic-foot Volume			
Growth period	Before cut	Cut	After cut
years	ft^3,i.b.		
0	853	0	853
7	1,201	263	938
14	1,285	260	1,025
21	1,370	261	1,109
28	1,451	274	1,177
35	1,514	337	1,177

After the stocking goal is reached in year 28, the cyclic harvest for merchantable volume would approximate 337 cubic feet; periodic annual growth, 48 cubic feet.

The initial cubic volume for sawtimber is 469 cubic feet. When subsequent volumes and cuts have been calculated, the following table can be developed:

Sawtimber Cubic-foot Volume			
Growth period	Before cut	Cut	After cut
years	---------ft^3, i.b.-----------		
0	469	0	469
7	786	241	545
14	875	249	626
21	962	255	707
28	1,051	260	791
35	1,139	264	875
42	1,230	306	924
49	1,281	357	924

After the stocking goal for sawtimber is reached in year 42, the periodic cut would be about 357 cubic feet for sawtimber; periodic annual growth, about 51 cubic feet.

When the board-foot volumes (Doyle rule) for the the planning period are calculated, the following tabulation can be assembled:

Doyle Board-foot Volume			
Growth period	Before cut	Cut	After cut
years	--------------fbm--------------		
0	1,722	0	1,722
7	3,072	1,032	2,040
14	3,464	1,084	2,380
21	3,855	1,124	2,731
28	4,256	1,164	3,092
35	4,655	1,191	3,464
42	5,072	1,387	3,685
49	5,313	1,628	3,685

After the residual stocking goal is reached, the periodic cut would be 628 board feet (Doyle rule), and the periodic annual growth would approximate 233 board feet per acre. Notice that all the cuts are more than 1,000 board feet, so the harvesting constraint is satisfied by this management strategy.

The following harvest schedule is for sawtimber volume using the Scribner rule:

Scribner Board-foot Volume			
Growth period	Before cut	Cut	After cut
years	-----------------	fbm	-----------
0	2,734	0	2,734
7	4,746	1,533	3,213
14	5,321	1,600	3,721
21	5,892	1,650	4,242
28	6,474	1,698	4,776
35	7,051	1,730	5,321
42	7,652	2,008	5,644
49	7,998	2,354	5,644

The periodic cut would be 2,354 board feet (Scribner rule) after the residual stocking goal is reached, and periodic annual growth would average 336 board feet.

The board-foot volumes, International 1/4-inch rule, are:

International 1/4-inch Board-foot Volume			
Growth period	Before cut	Cut	After cut
years	---------------	fbm	-------------
0	3,084	0	3,084
7	5,361	1,736	3,625
14	6,013	1,812	4,201
21	6,660	1,869	4,791
28	7,320	1,925	5,395
35	7,973	1,960	6,013
42	8,655	2,277	6,378
49	9,047	2,669	6,378

After the cyclic harvest levels are stabilized, the periodic cut would average 2,669 board feet (International 1/4-inch rule). Periodic annual growth would approximate 381 board feet.

A variety of other strategies could have been used to rehabilitate the stand. For example, half the growth could be cut provided that the harvest were at least 1,000 board feet (Doyle rule). If an operable volume were not present, the cycle cut could be deferred. The cutting cycle length in this case would be variable. This example is only one of infinitely many ways that growth and yield models can be used.

CAVEATS FOR THE USER

Some users have become disappointed or disillusioned after using models that predict yields greater than what can be expected in practice or what they may consider unrealistic. These shortcomings can be rectified by following certain practices.

Before using a model, read the instructions and carefully observe which variables are being used. Is site index or height of the dominant stand used for the site quality variable? For plantations, is the age calculated from planting or from seed? Are the data used in the model from your geographic area or are they from another part of the South? If the study was done elsewhere, beware. Validate some of the predictions before you place your trust in the model.

Remember that models predict averages, not for the individual. Hopefully, as the number of cases increase, the average will be close to that predicted for the model.

If models are going to be applied to specific stands, you should do the following (Burkhart 1982): (1) stratify the area into reasonably homogeneous stands according to the variables used by the model (for example, age, site, and basal area), (2) make your growth and yield projections separately for each stand, (3) observe the same merchantability standards that are used by the model, (4) deduct nonproductive areas (like large openings) before expanding per-acre estimates to a stand basis, and (5) deduct for cull and defect since estimates are for gross volumes.

INFORMATION NEEDS

It is obvious that much remains to be done. The published data for natural even-aged stands comes from inventory data or temporary plots: there is a serious need for the establishment of a permanent plot growth and yield study for predictive purposes in managed stands of shortleaf pine. This same need exists for uneven-aged conditions. There is also an acute need for the same kind of study in both old field and nonold-field thinned plantations.

New models that will be developed should be capable of producing stand and stock tables, similar to Smalley and Bailey (1974), for merchantability standards specified by the user. There will also be an increasing demand for models that can predict the effects of more intensive management, such as the use of genetically improved planting stock and fertilization. The recent concern over atmospheric deposition has highlighted the need to produce models that can incorporate additional variables so that atmospheric deposition and other effects can be addressed. Permanent plots from controlled studies can also provide valuable baseline data for investigating these kinds of problems.

Despite the past neglect of shortleaf by the research community, some encouraging trends should be noted. The USDA Forest Service has a cooperative study underway between Region 8, headquartered in Atlanta, GA, and the Southern Forest Experiment Station, headquartered in New Orleans, LA, to establish a long-term growth and yield study for natural even-aged shortleaf pine in the Ozark and Ouachita National Forests. There is also an effort by Southern Forest Experiment Station researchers to combine shortleaf plantation data from several older studies in an attempt to develop a model for thinned stands. Southern Forest Experiment Station researchers involved in shortleaf pine reforestation studies are designing their outplantings of families and mixed families so that growth and yield information may also be gathered.

With these and other efforts, perhaps the forgotten species of the major southern pines will attain a much deserved better status in terms of research knowledge.

Table 1.--Summary of major growth and yield studies of shortleaf pine.

Author or publication[1]	Location	Plots[2]	Study type	Model type
		---Natural even-aged---		
Misc. Publ. 50 (1929)	12 southern states	188-T	Controlled Predictive	Tables
Schumacher & Coile (1960)	NC Piedmont	74-T	Controlled Predictive	Stand level
Murphy (1982) Murphy & Beltz (1981)	AR, LA, OK, TX	153-P	Inventory Predictive	Stand level
TWIGS	IN,IL,MO	1500 trees	Inventory Predictive	Individual tree
Brinkman et al. (1965) Sander & Rogers (1979) Rogers & Sander (1985)	Missouri thinning study	5-P	Controlled Inferential	
		---Natural uneven-aged---		
Gibbs (1958)	East Texas	5-P	Controlled Inferential	
Murphy & Farrar (1985)	Central Arkansas	149-P	Inventory Predictive	Stand level

[1]See the text for the appropriate citation.
[2]Number denotes number of plots; P=permanent plots; T=temporary plots.

Table 1.--Summary of major growth and yield studies of shortleaf pine (continued)

Author or publication[1]	Location	Plots[2]	Study type	Model type
		---Plantation---		
Ralston & Korstian (1962)	NC Piedmont	66-T	Controlled Predictive	Stand level Unthinned, old-field
Smalley & Bailey (1974)	AL,GA,TN Highlands	104-T	Controlled Predictive	Size-class Unthinned, old-field
Arnold (1975, 1981) Boggess (1958) Boggess & Gilmore (1963) Boggess et al. (1963) Gilmore & Boggess (1969) Gilmore & Gregory (1974) Gilmore & Metcalf (1961)	Southern Illinois	P	Controlled Inferential	
Williston (1959, 1963 1967, 1972 1983, 1985)	north MS, TN	P	Controlled Inferential	
Williston & Dell (1974)	MS, YLT	88-P	Inventory Growth survey	Growth equations

[1]See the text for the appropriate citation.
[2]Number denotes number of plots; P=permanent plots; T=temporary plots.

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ECONOMICS OF STAND MANAGEMENT

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ABSTRACT

This paper sets out to demonstrate the importance of considering the wealth represented by the growing stock in economic analyses of stand management alternatives, and to demonstrate the role of thinning in the manipulation of the efficiency of growing stock in the management of shortleaf pine (*Pinus echinata* Mill.). These goals are achieved through a demonstration of the impact of four (4) simulated thinning regimens on the growth, yield, and economic performance of four (4) stands of shortleaf pine of varing ages and site classes in western Arkansas. The analysis demonstrates that thinning may reduce total yield and periodic annual increment following treatment. However, economic performance as measured by the value of total yield and periodic annual increment will be improved by thinning if the stand has sufficient time to recover from treatment. Economic efficiency of the growing stock is also improved by thinning if the stand has sufficient time to recover from treatment.

INTRODUCTION

Economics of shortleaf pine management in the Western Gulf Region. The current shortleaf pine (*Pinus echinata* Mill.) inventory in the Western Gulf Region, of Arkansas, Louisiana, Oklahoma, and Texas of 8.8 billion cubic feet has a growth rate of 495 million cubic feet per year (Murphy, 1975, 1976, 1977; van Hess, 1980).

Table 1. Growing Stock and Growth of Shortleaf Pine in the Western Gulf Region

State	Growing Stock	Growth
	(cu ft x 10^6)	(cu ft x 10^6)
Arkansas	938.7	51.9
Louisiana	4089.7	208.7
Oklahoma	2539.1	149.2
Texas	1217.4	85.1
TOTAL	8784.9	494.9

From: Table 13 in Murphy 1975, 1976, 1977; van Hess 1980.

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The current value of this inventory, based on average 1984 stumpage prices (Hussey, 1985), is $6.1 billion. The growth produced by this inventory, if valued at the same price, is $343 million.

Table 1. Growing Stock, Growth, Value of Shortleaf Pine in the Western Gulf Region

State	Western Gulf Region Growing Stock	Growth	Price	Growing Stock Value	Value of Growth
	(cu ft x 10^6)	(cu ft x 10^6)	($/cu ft)	($ x 10^6)	($ x 10^6)
Arkansas	938.7	51.9	0.76	713.412	39.444
Louisiana	4089.7	208.7	0.79	3230.863	164.873
Oklahoma	2539.1	149.2	0.61	1548.851	91.012
Texas	1217.4	85.1	0.56	681.744	47.656
TOTAL	8784.7	494.9		6174.87	342.985

From: Table 13 in Murphy 1975, 1976, 1977; Van Hess 1980 and Hussey, 1985.

In other words an asset worth approximately $6.2 billion is increasing in value at a rate of $343 million per year. This is a rate of 5.5 percent (5.5%) per year. At the same time the current alternative rate in this nations financial markets is from 7 to 9 percent. If this asset were to increase in value at a rate between 7 and 9 percent (7% - 9%) the value of the annual growth would range from $434 to $558 million. Can we as a profession ask our society to invest in the management of shortleaf pine when we have a record like this with the resources in our current inventory?

Economics of stand Management. Conventional economic evaluation is based on inputs and outputs in the form of cash flow. This concentrates the economic analysis of stand management on inputs and outputs of the forest stand, and tends to ignore questions of efficiency related to the use of growing stock in the management of these stands.

This paper proposes to examine the economics of stand management in terms of the stock of wealth created through forest growth and the stock of resources required to create this wealth. An economic analysis of investments associated with stand management in terms of wealth, a stock, instead of cash flows is consistent with the generally accepted economic theory of investment choice (Lewis, 1976). By following this pattern of analysis the concentration will be on the economic efficiency of the growing stock, which is the major resource utilized in the management of forests.

Objectives. The objectives of this paper are first to demonstrate the concept of "wealth" ("Present Certainty Equivalent Value") (Lewis, 1976) as an appropriate criteria for economic evaluation in stand management. Second to demonstrate the economic role of thinning in the management of shortleaf pine.

To achieve these objectives examples based on stand statistics from four different stands of shortleaf pine in northwestern Arkansas will be examined. These examples were selected from sample plot data collected by Dr. Thomas B. Lynch, Oklahoma State University, Department of Forestry, as part of study of

"Growth and Yield of Thinned Natural Shortleaf Pine on the Ouachita and Ozark National Forests", and include the following:

Stand Age (yr.)	Site Class (ht @ age 25)	Initial Volume (CCF/ac)
30	45	32
40	50	39
50	35	32
90	45	64

(Note: Site Classes are based site index curves developed by Graney and Burkhart (1973)).

Each of these examples will be examined in terms of yield and the economic efficiency of the growing stock given current stand conditions, and yield, and economic efficiency following a simulated thinning regimen. The yields for both the thinned and unthinned conditions are based on analyses by Murphy (1982), Murphy and Beltz (1981), and the U.S. Forest Service (1976). Based on these examinations some conclusions will be drawn regarding the "Economics of Stand Management for Shortleaf Pine".

GROWING STOCK EFFICIENCY IN UNTREATED SHORTLEAF PINE

Age 30, Site Class 45. The example of a 30 year old stand of shortleaf pine, site class 45, having an initial volume of 32 cunits per acre is expected to grow at an average rate of 74 cubic feet per acre per year during the 70 year period till it reaches age 100. At that time it is expected that the stand will have a standing volume of 84 cunits per acre.

In terms of economic performance, the growing stock in this stand has current value of $500 per acre, and is expected to increase in value at an average rate of $13 per acre per year during the 70 year period till age 100. At that time the growing stock is expected to have a value of $1,400 per acre. This is an average return on investment of 1.5 percent (1.5%) per year on the initial growing stock valued at $500 per acre.

Age 40, Site Class 50. The example of a 40 year old stand, site class 50, having an initial volume of 39 cunits per acre is expected to maintain an average growth rate of 69 cubic feet per acre per year during the 60 year period until the stand reaches age 100. At that time the stand is expected to have a standing volume of 80 cunits per acre.

The economic performance of this stand is forecast to be similar to the 30 year old stand. The growing stock in this example has an estimated stumpage value of $1,500 per acre, and is expected to increase in value at an average rate of $38 per acre per year. By age 100 the stand is estimated to be worth $3,800 per acre. This represents an average return on the invested growing stock of 1.6 percent (1.6%) per year.

Age 50, Site Class 35. The 50 year old stand, site class 35, having an initial volume of 32 cunits per acre is expected to grow at an average rate of 41 cubic feet per acre per year up to age 100 when the stand is expected to contain 52 cunits per acre of total volume.

This stand has an estimated value at the present time of $1,100 per acre and is expected to increase at a rate of $19 per acre per year for fifty years when the growing stock is expected to be worth \$2,100 per acre. This represents an average return of 1.2 percent (1.2%) per year on the \$1,100 worth of growing stock invested for the 50 years.

<u>90, Site Class 45</u>. The 90 year old stand, site class 45, has a current growing stock inventory of 64 cunits per acre. In 30 years when this stand is 120 years old its estimated volume will be 75 cunits per acre and the stand will have maintained an average growth rate of 38 cubic feet per acre per year during the 30 year period.

The 64 cunits of the current inventory have an estimated stumpage value of \$4,900 per acre and in 30 years when the stand is 120 years old the growing stock will have an estimated value of \$6,300 per acre having increased in value at the rate of \$45 per acre per year over the 30 year period. This will be an average rate of return on the invested growing stock of one percent (1%) per year.

<u>Summary</u>. The four examples range in age from 30 to 90 years in age and represent site classes ranging from 35 to 50 feet of height at age 25. These four stands have initial growing stock volumes ranging from 32 to 64 cunits per acre and are expected to achieve volumes ranging from 52 to 84 cunits per acre by age 100 while maintaining periodic annual increments ranging from 41 to 74 cubic feet per acre per year. In economic terms these examples represent growing stock investments ranging form \$500 to \$4,900 per acre and final yields ranging from \$1,400 to \$5,400 per acre at age 100. The value increases resulting from this growth range from \$13 to \$50 per acre per year. However, as investments these examples represent rates of return ranging from one to two percent (1% - 1.6%).

Summaries of this information on these four stands is given in Figures 1-5.

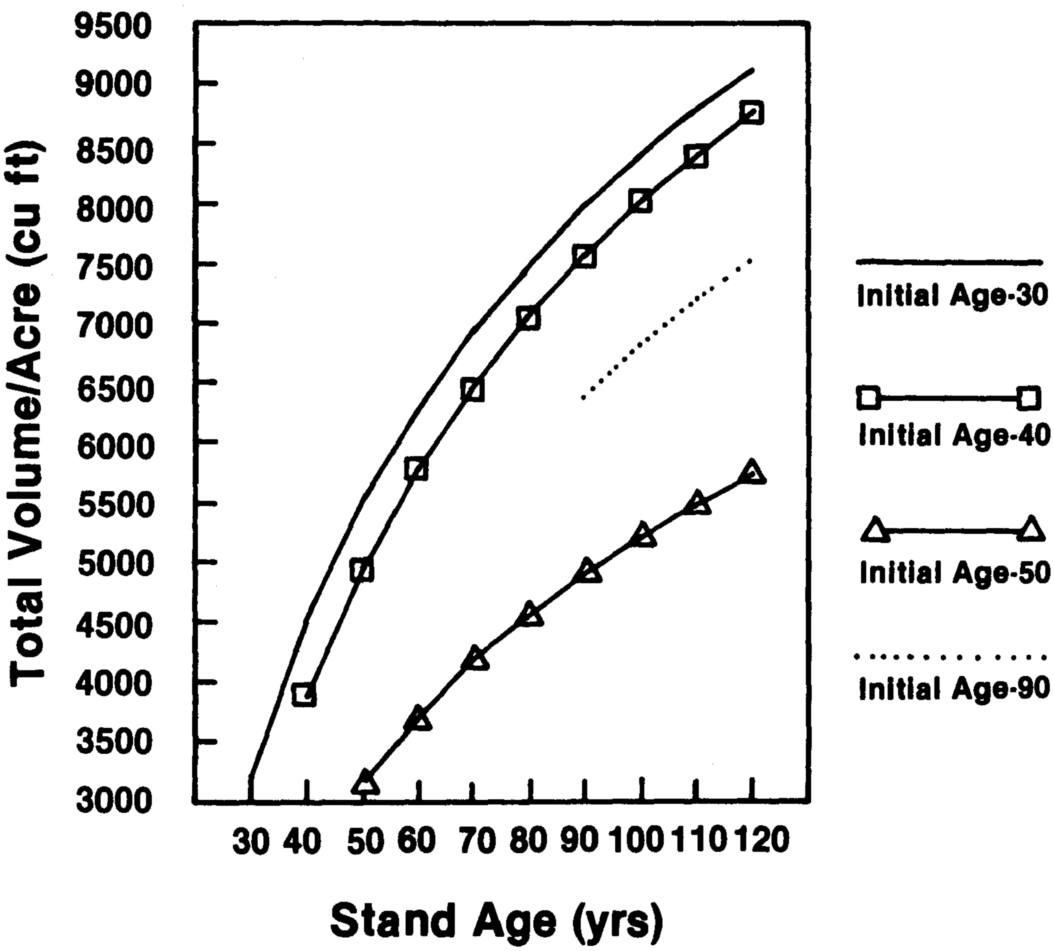

Figure 1. Total Stand Yield Per Acre by Stand and Age

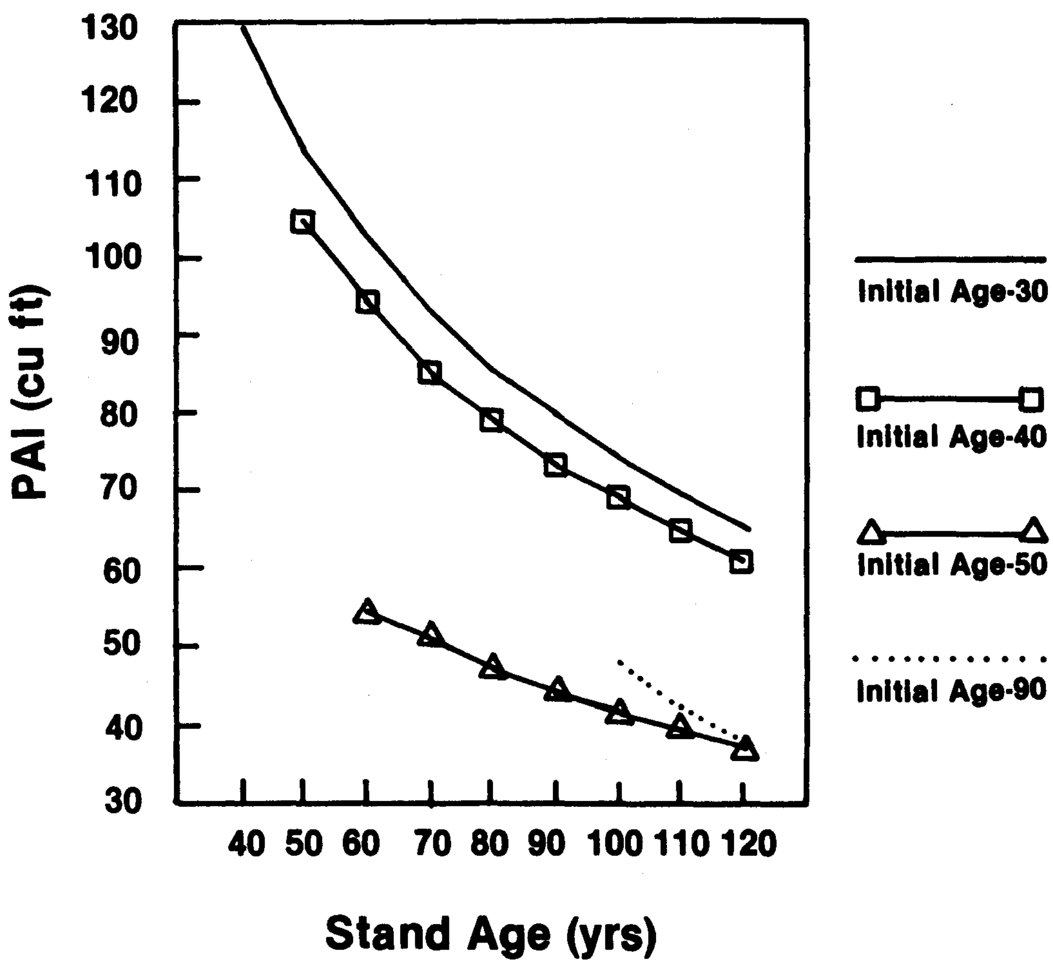

Figure 2. Periodic Annual Increment Per Acre by Stand and Age

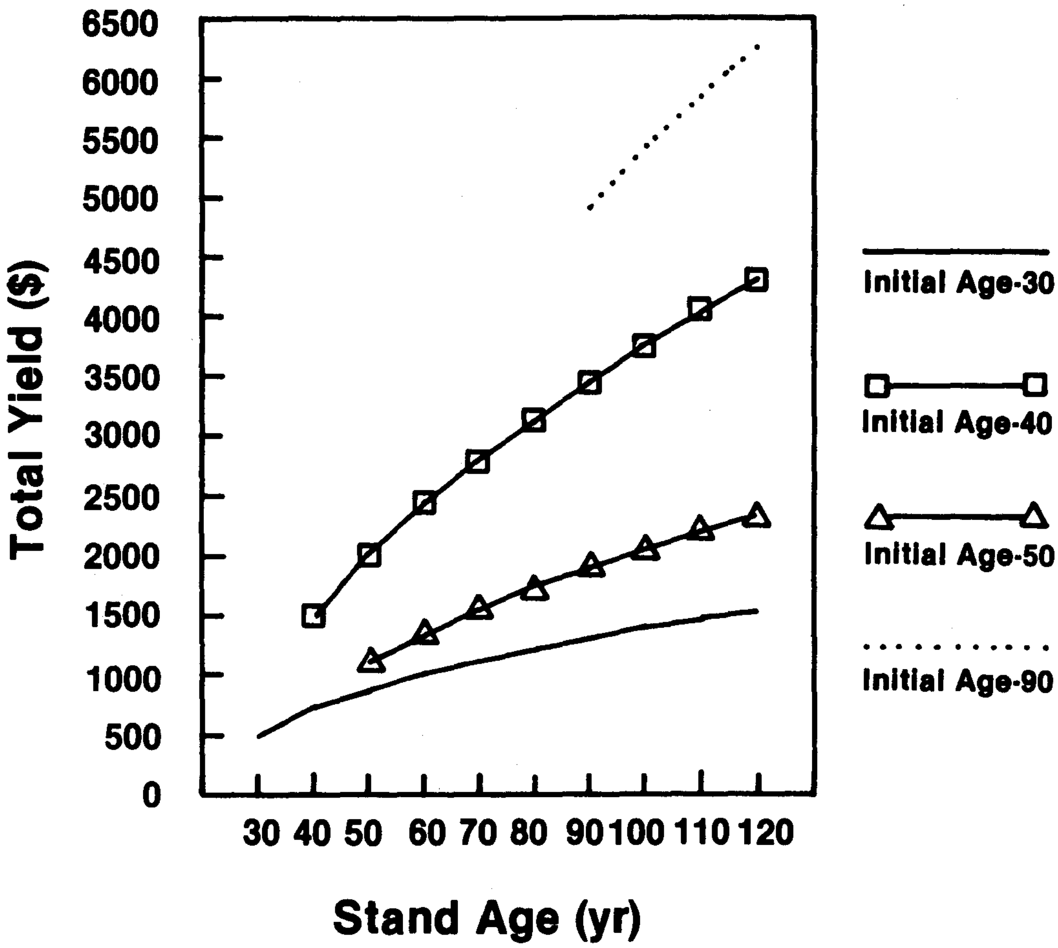

Figure 3. Yield Value Per Acre by Stand and Age

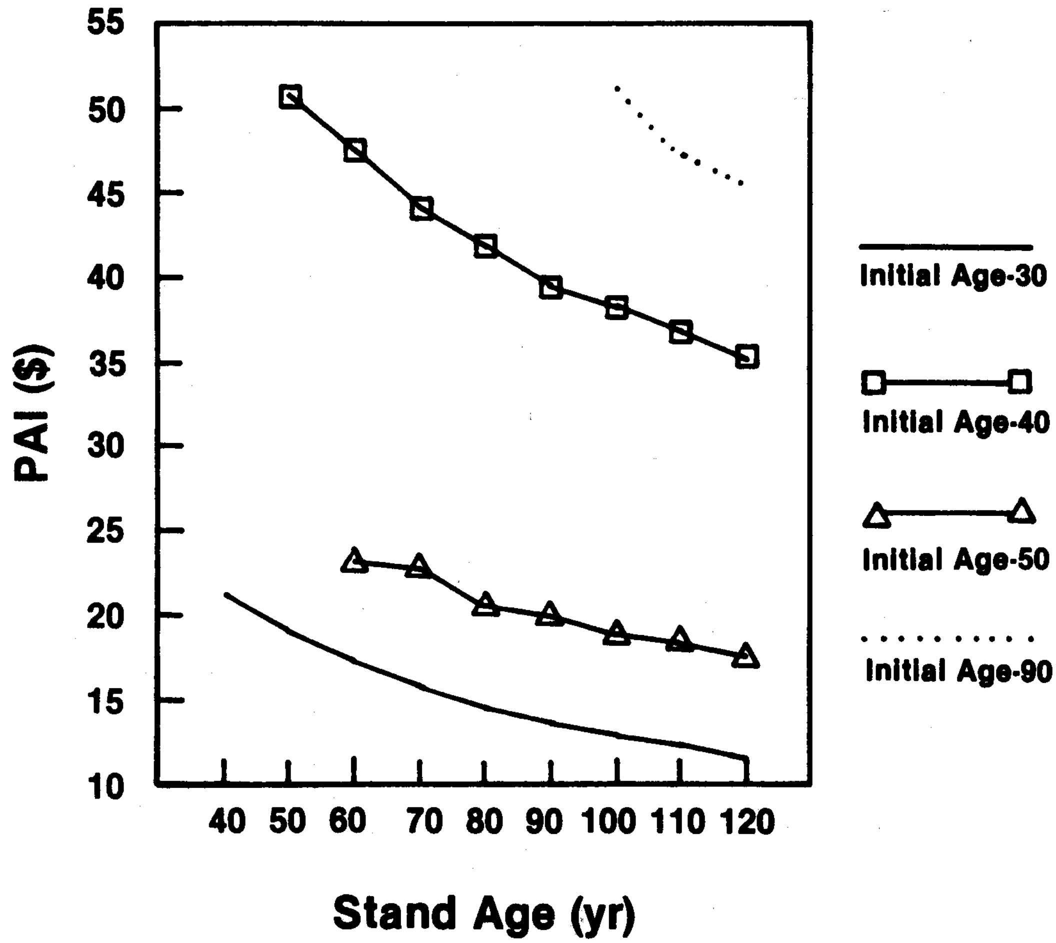

Figure 4. Periodic Annual Value Increment Per Acre by Stand and Age

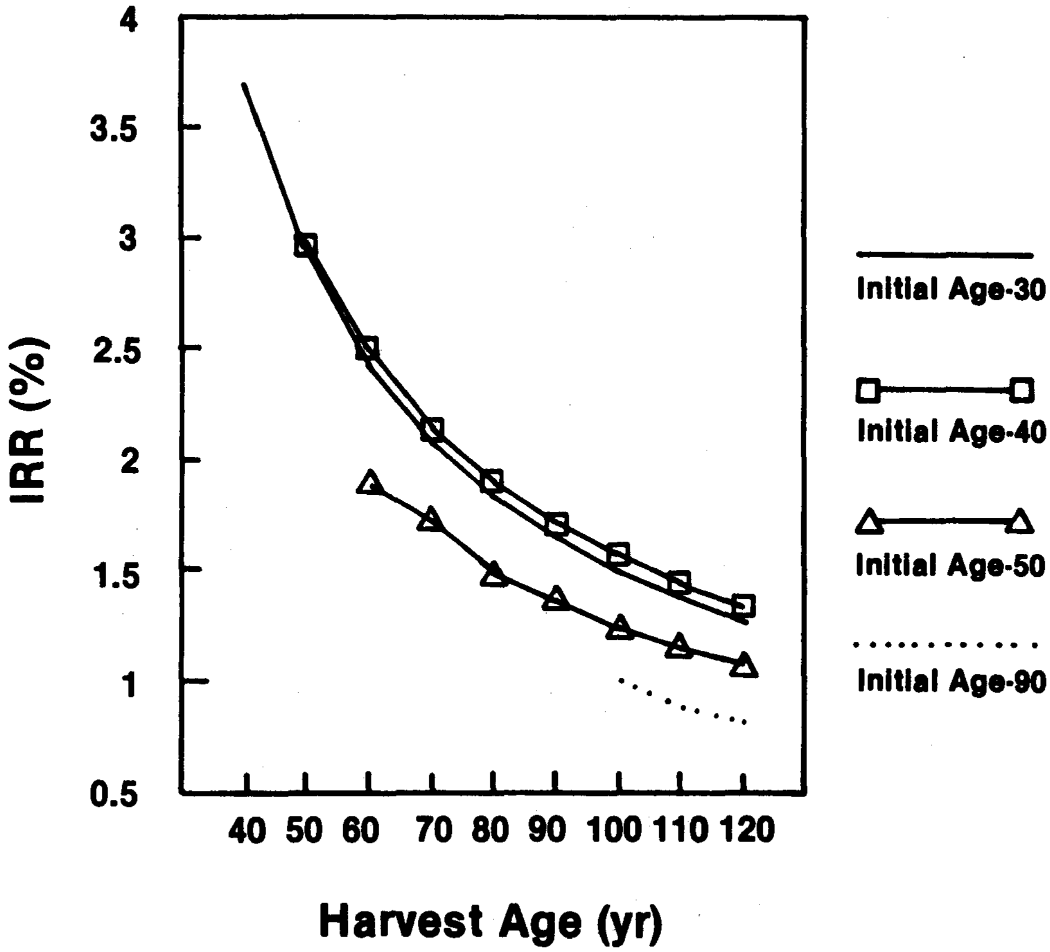

Figure 5. "Internal Rate of Return" From Initial Age to Final Harvest by Stand and Age of Final Harvest

IMPACT OF THINNING ON GROWING STOCK EFFICIENCY

To demonstrate the impact of thinning on the economic efficiency of the growing stock in these stands, each of the four stands will be subjected to three simulated low thinnings at ten year intervals, each of which will remove thirty percent (30%) of the growing stock basal area at the time of thinning. The effect of this thinning regimen on total yield, periodic annual increment, total value yield, periodic value increment, and internal rate of return will be examined.

Age 30, Site Class 45. After thinning at age 30; 30 and 40; and 30, 40, and 50 the total yield of the stand, including thinning removals, at age 100, is forecast to be 83, 82, and 82 cunits respectively. This compares to 84 cunits total yield at the same age in the unthinned case.

During the 70 years between the current age and age 100 the stand is expected to maintain periodic annual increments of 73, 72, and 71 cubic feet per acre periodic annual increment total yield respectively in comparison to the unthinned condition of 74 cubic feet per acre per year.

The value of total yield, including thinnings, for the three thinning regimens, with a final harvest at age 100, are $1,500, $1,500, and $1,600 per acre respectively These compare with a total yield value without thinnings at age 100 of $1,400 per acre.

The impact of these thinning regimens on periodic annual value increment is to increase it for the 70 year period from age 30 to age 100 to $14, $15, and $15 per acre per year for the thinnings at age 30; 30 and 40; and 30, 40, and 50 respectively.

The "Internal Rate of Return" is increased to 1.7, 1.8, and 2.0 percent (1.7%, 1.8%, and 2.0%) respectively as a result of the thinnings at age 30; 30 and 40; and 30, 40, and 50.

Age 40, Site Class 50. After thinning at age 40; 40 and 50; and 40, 50, and 60 the per acre total yield of the stand, including thinning removals, at age 100, is 80 cunits regardless of thinning regimen.

During the 60 years between the current age and age 100 the stand is expected to maintain periodic annual increments of 68, 68, and 69 cubic feet per acre in total yield. This is in comparison to the unthinnned condition of 69 cubic feet per acre per year.

The values of total yield per acre, including thinnings, for the three thinning regimens, with final harvest at age 100, are $4,100, $4,600, and $5,200 per acre respectively. These compare with $3,800 per acre expected without thinning.

The impact of these thinning regimes on periodic annual value increment per acre per year is to increase it for the 60 year period from age 40 to age 100 to $43, $51, and $62 for the thinnings at age 40; ages 40 and 50; and ages 40, 50, and 60 respectively. This is in comparison to the unthinned case which increased in value at a rate of $38 per acre per year during the 60 year period from age 40 to 100.

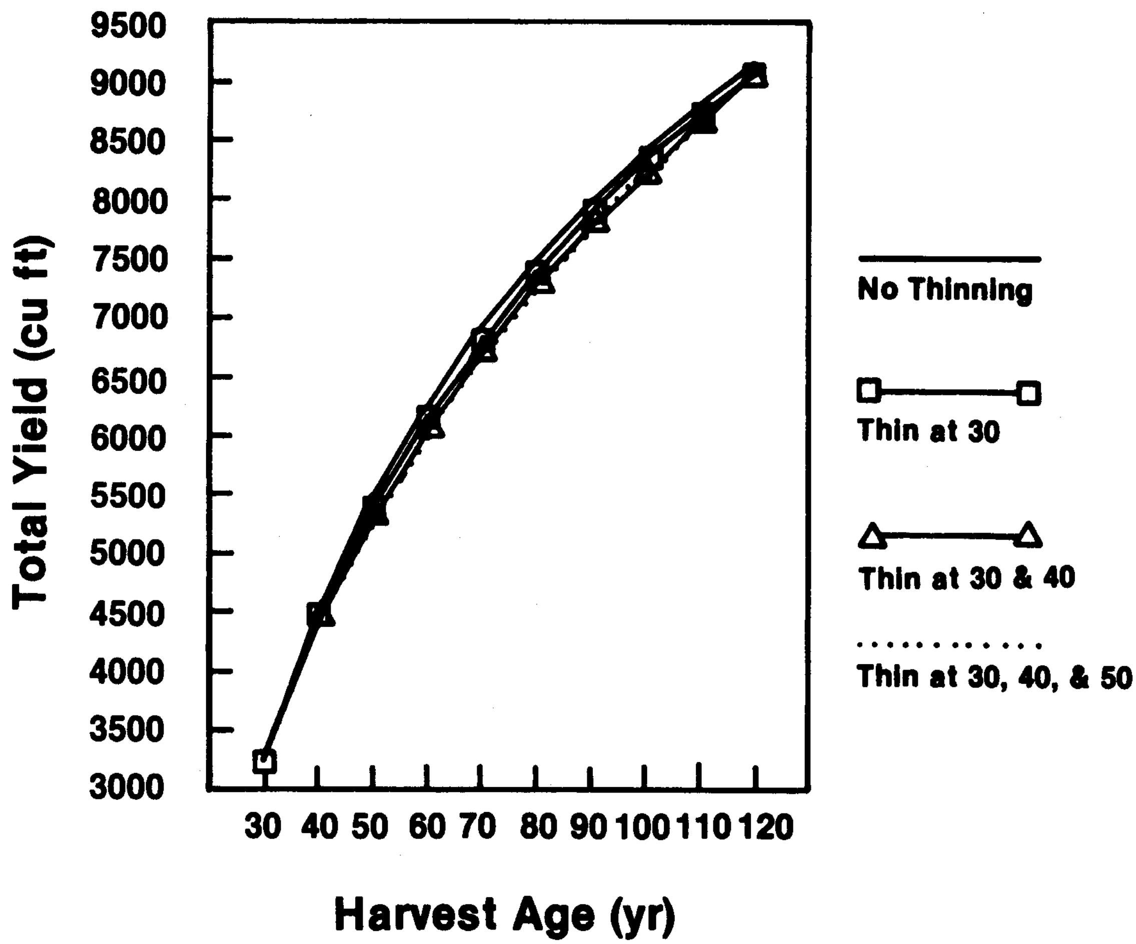

Figure 6. Total Stand Yield (Including Thinnings) Per Acre for Age 30, Site Class 45 by Thinning Regimen and Age at Final Harvest

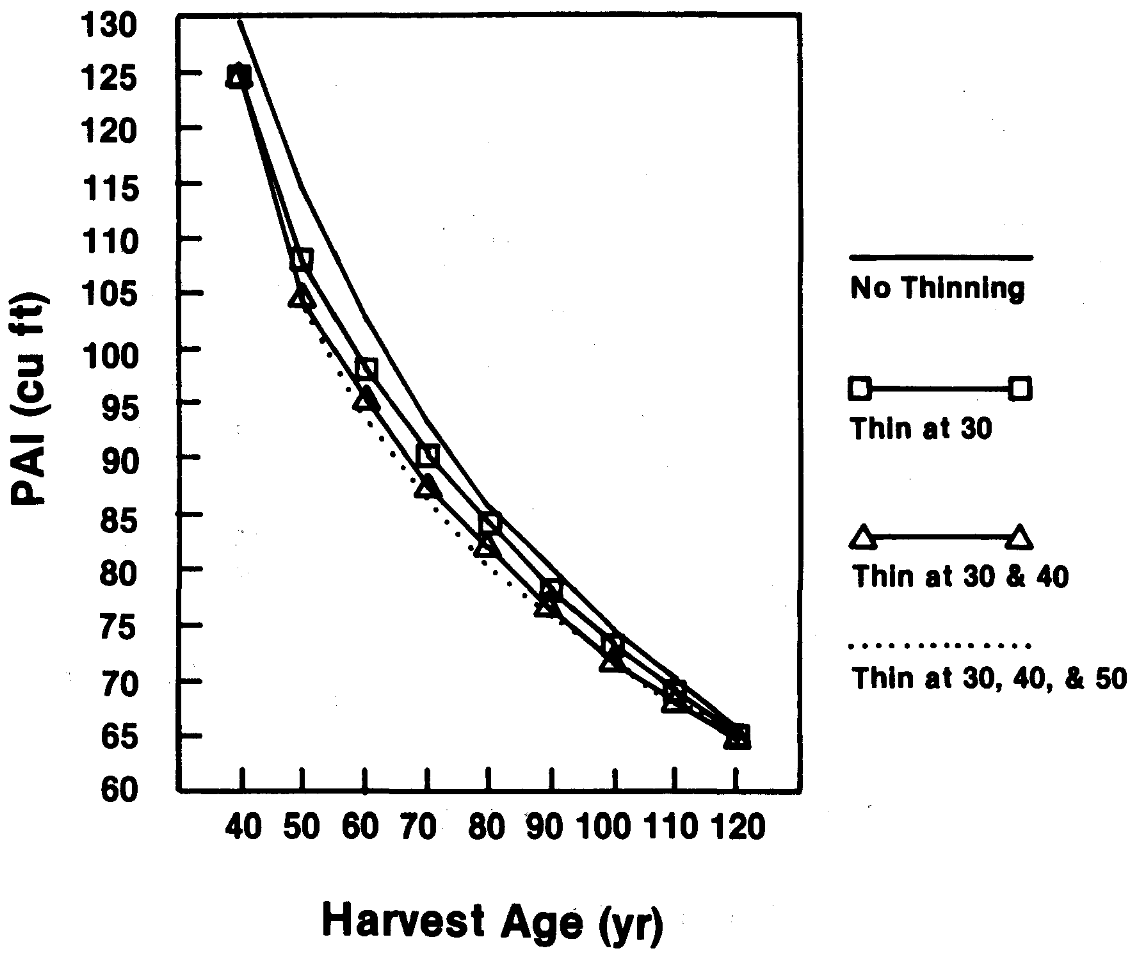

Figure 7. Periodic Annual Increment Total Yield Per Acre for Age 30, Site Class 45 by Harvest Age and Thinning Regimen

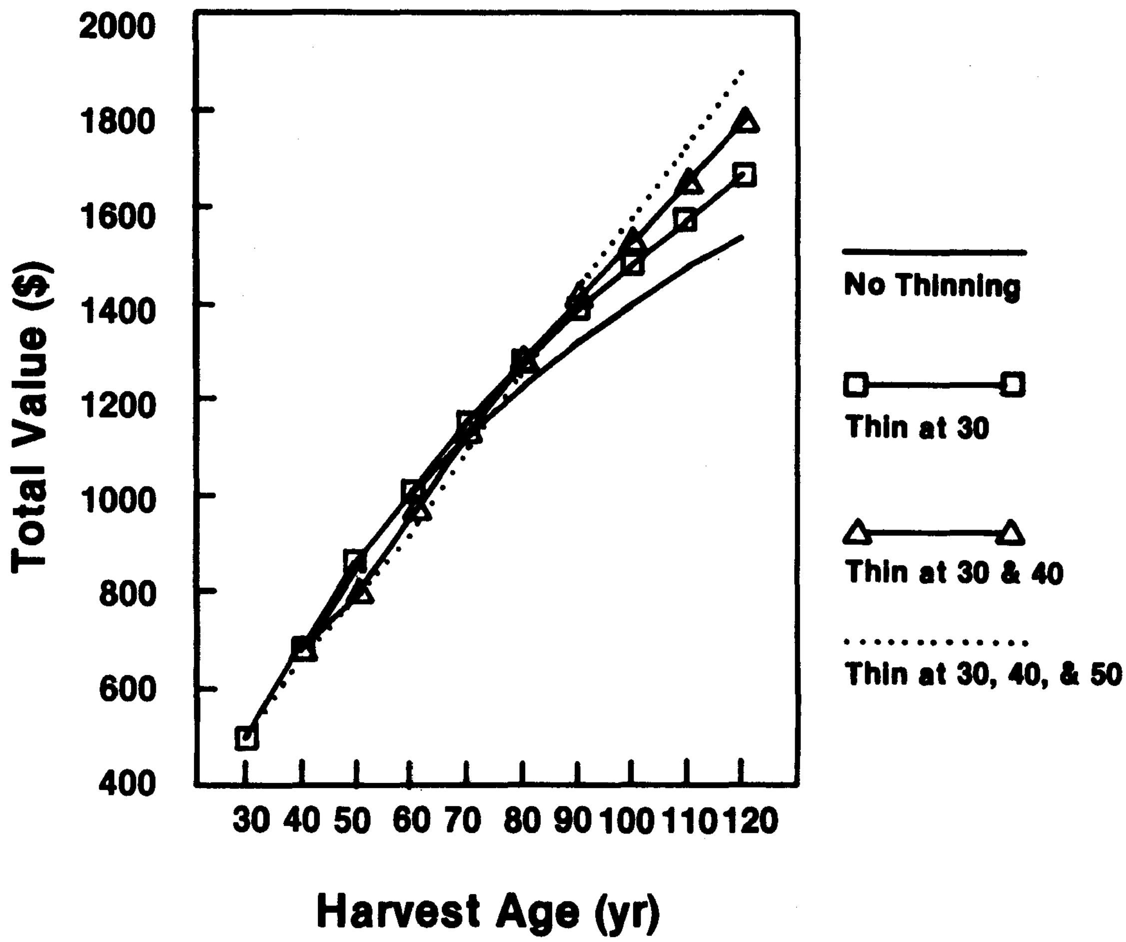

Figure 8. Value of Total Yield (Including Thinnings) Per Acre for Age 30, Site Class 45 by Thinning Regimen and Harvest Age

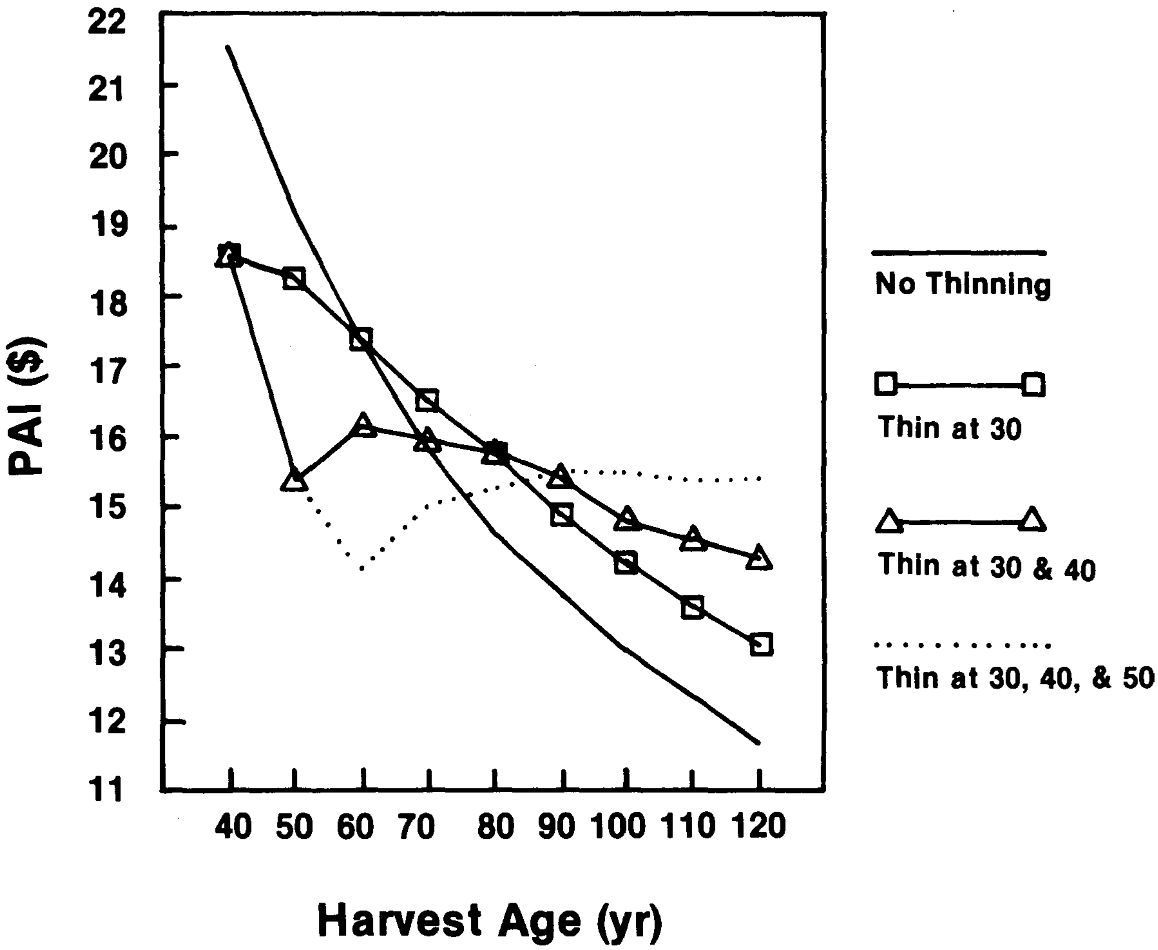

Figure 9. Periodic Annual Increment in Total Value Per Acre Per Year for Age 30, Site Class 45 by Thinning Regimen and Harvest Age

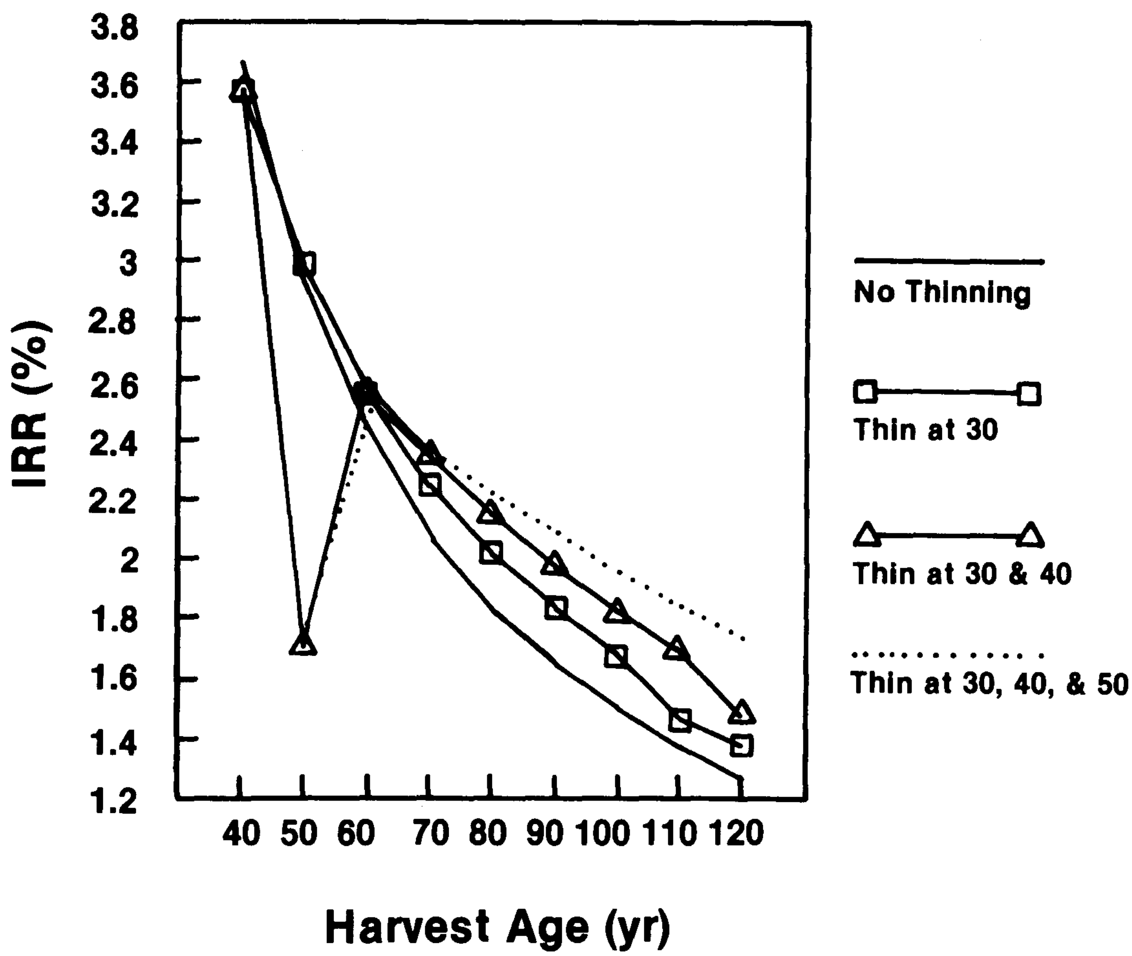

Figure 10. Internal Rate of Return for Age 30, Site Class 45 by Harvest Age and Thinning Regimen

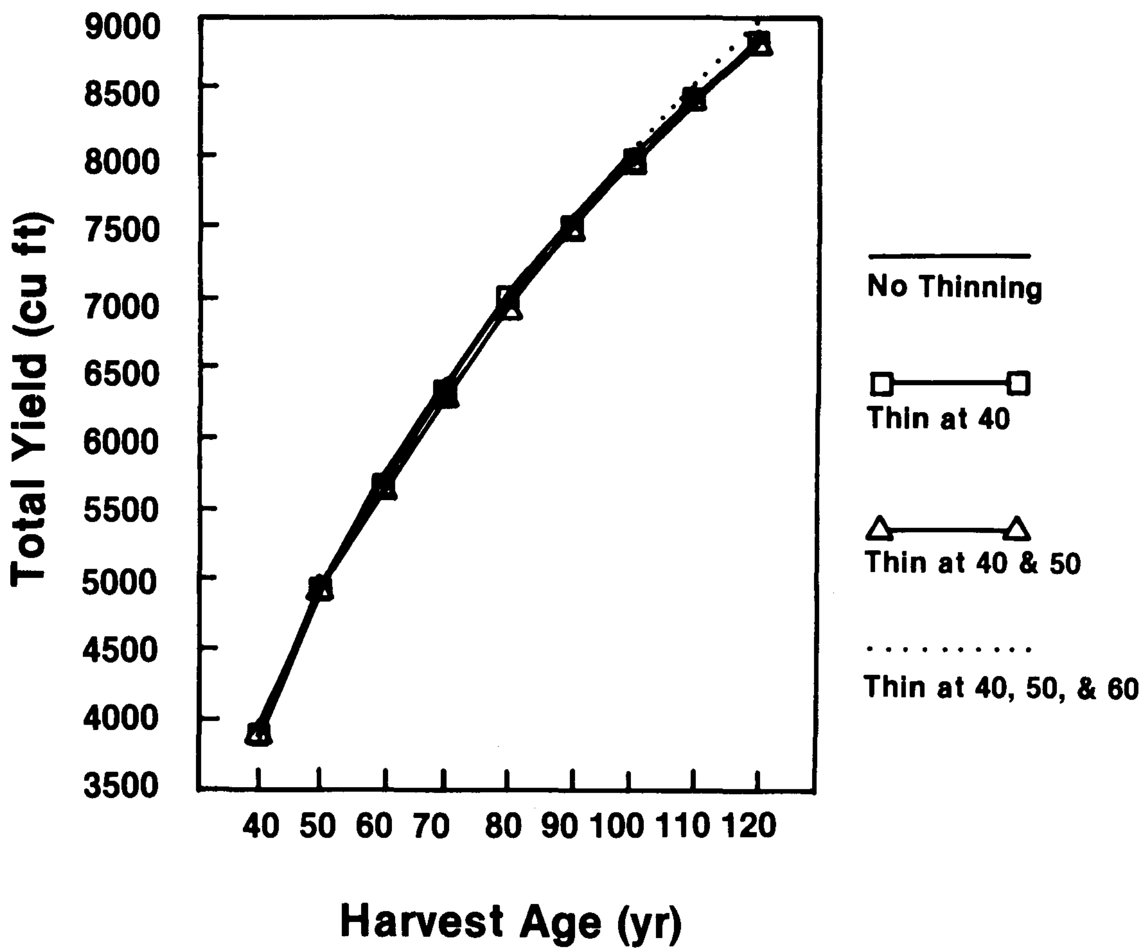

Figure 11. Total Stand Yield (Including Thinnings) Per Acre for Age 40, Site Class 50 by Thinning Regimen and Age at Final Harvest

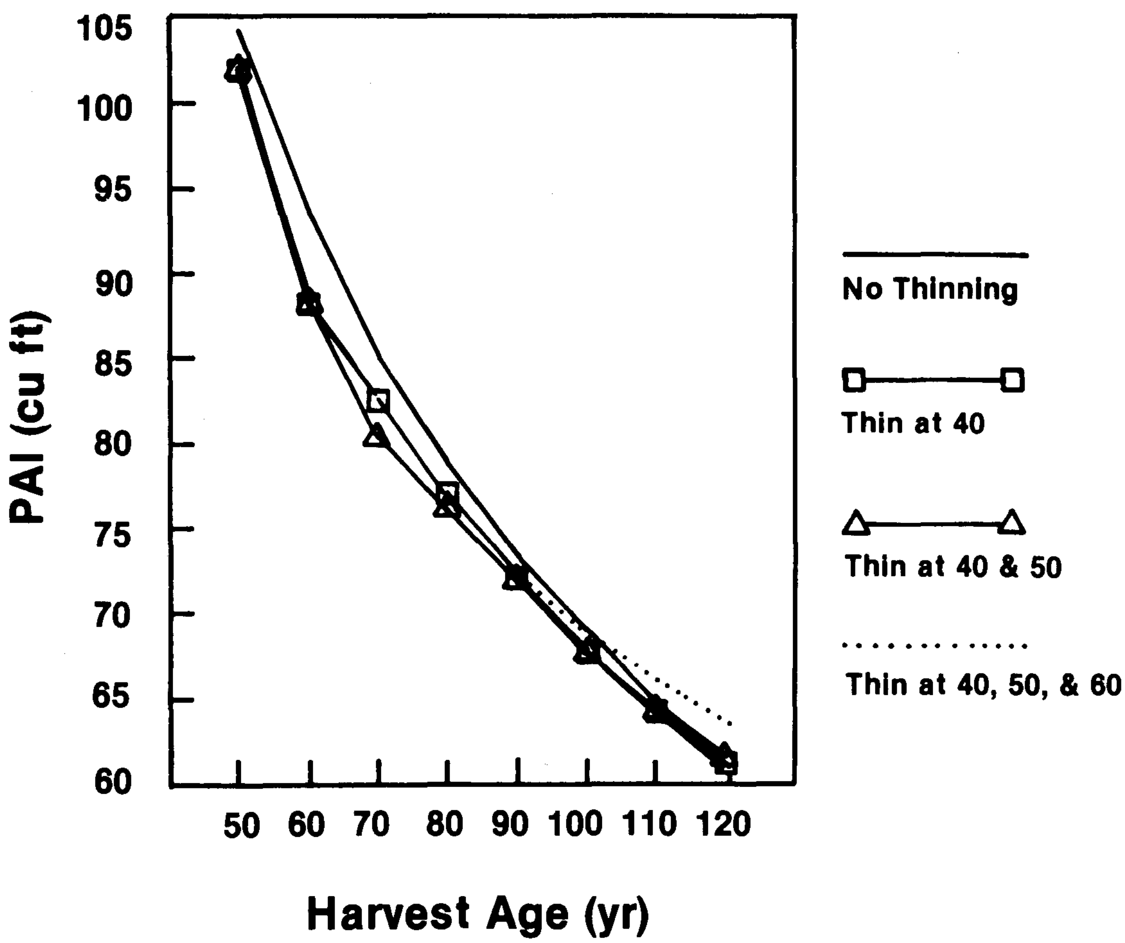

Figure 12. Periodic Annual Increment Per Acre Per Year Total Yield for Age 40, Site Class 50 by Harvest Age and Thinning Regimen

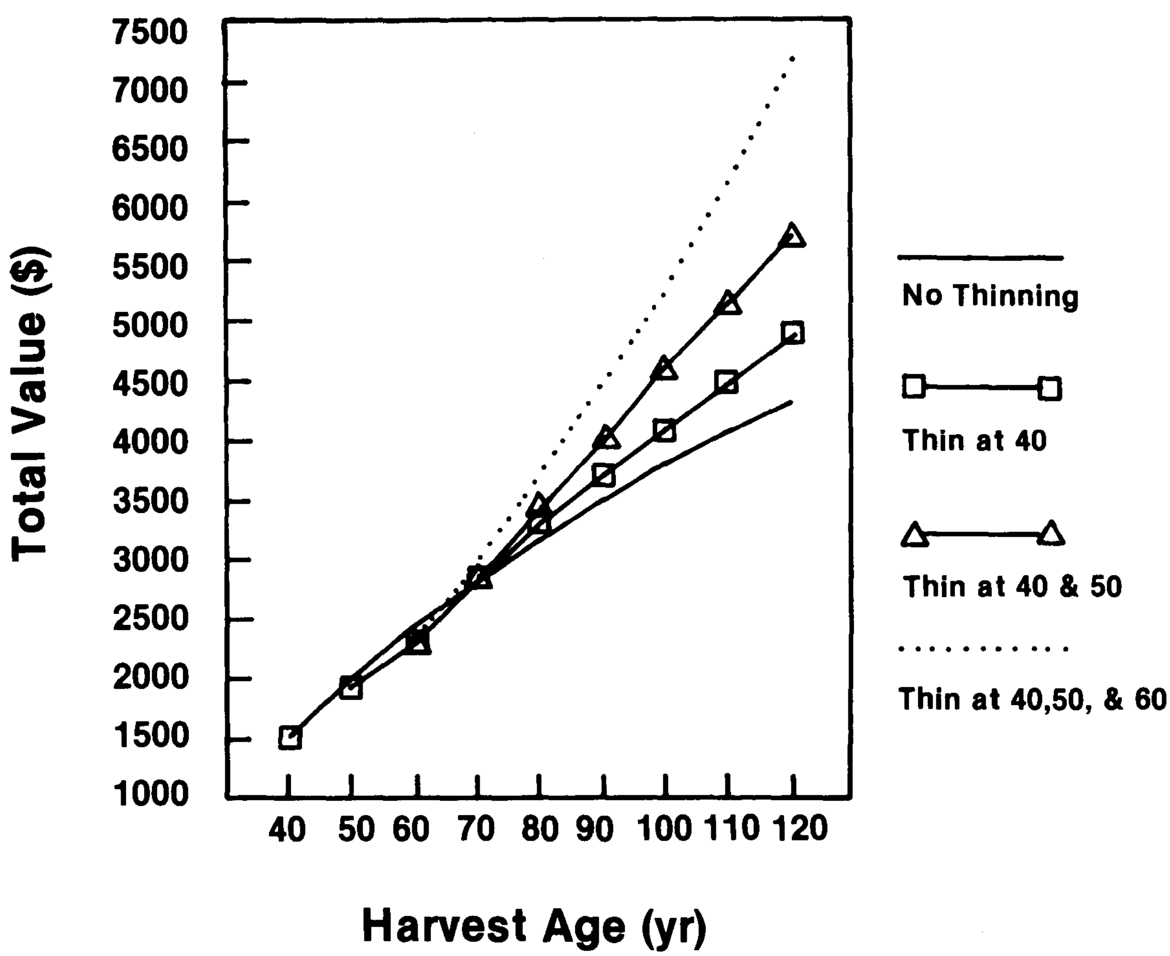

Figure 13. Value of Total Yield (Including Thinnings) Per Acre for Age 40, Site Class 50 by Thinning Regimen and Harvest Age

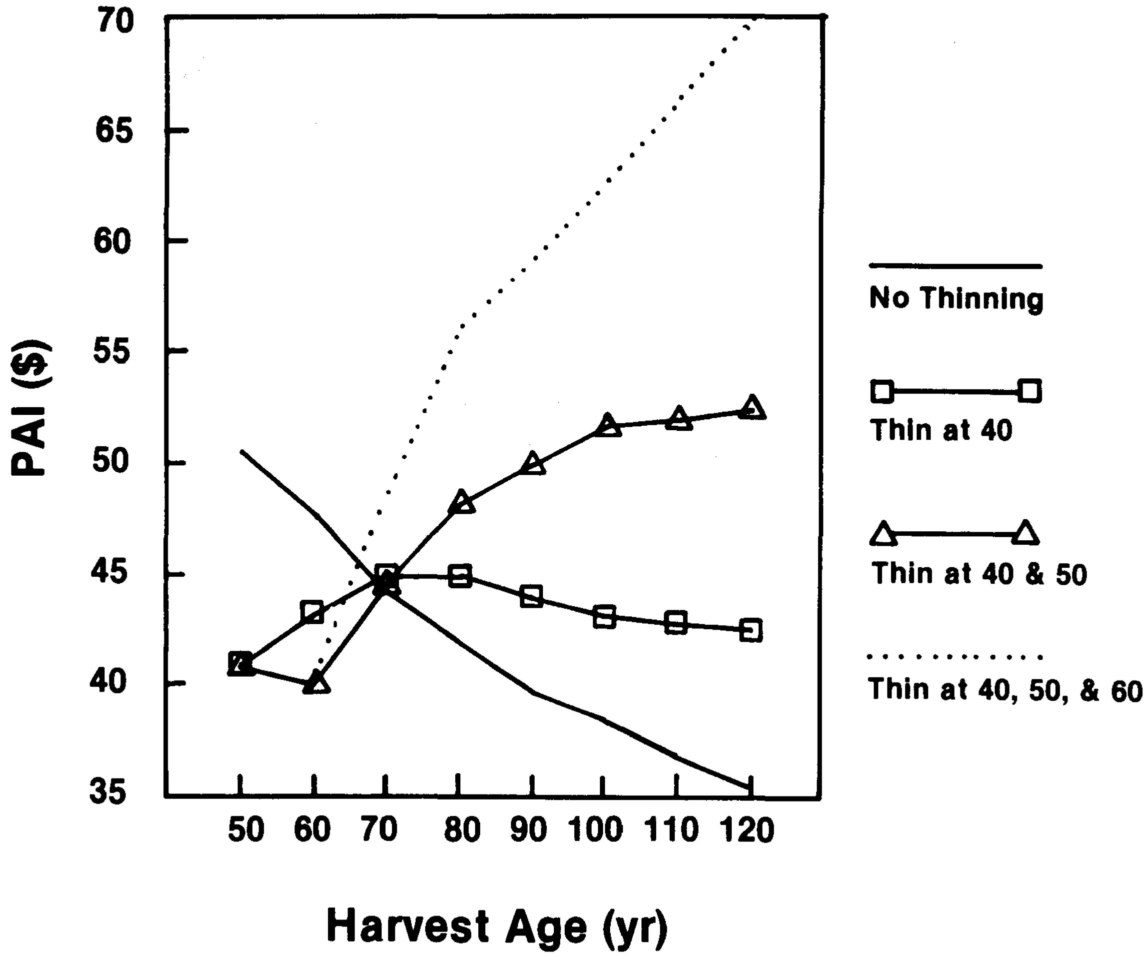

Figure 14. Periodic Annual Increment in Total Value Per Acre for Age 40, Site Class 50 by Thinning Regimen and Harvest Age

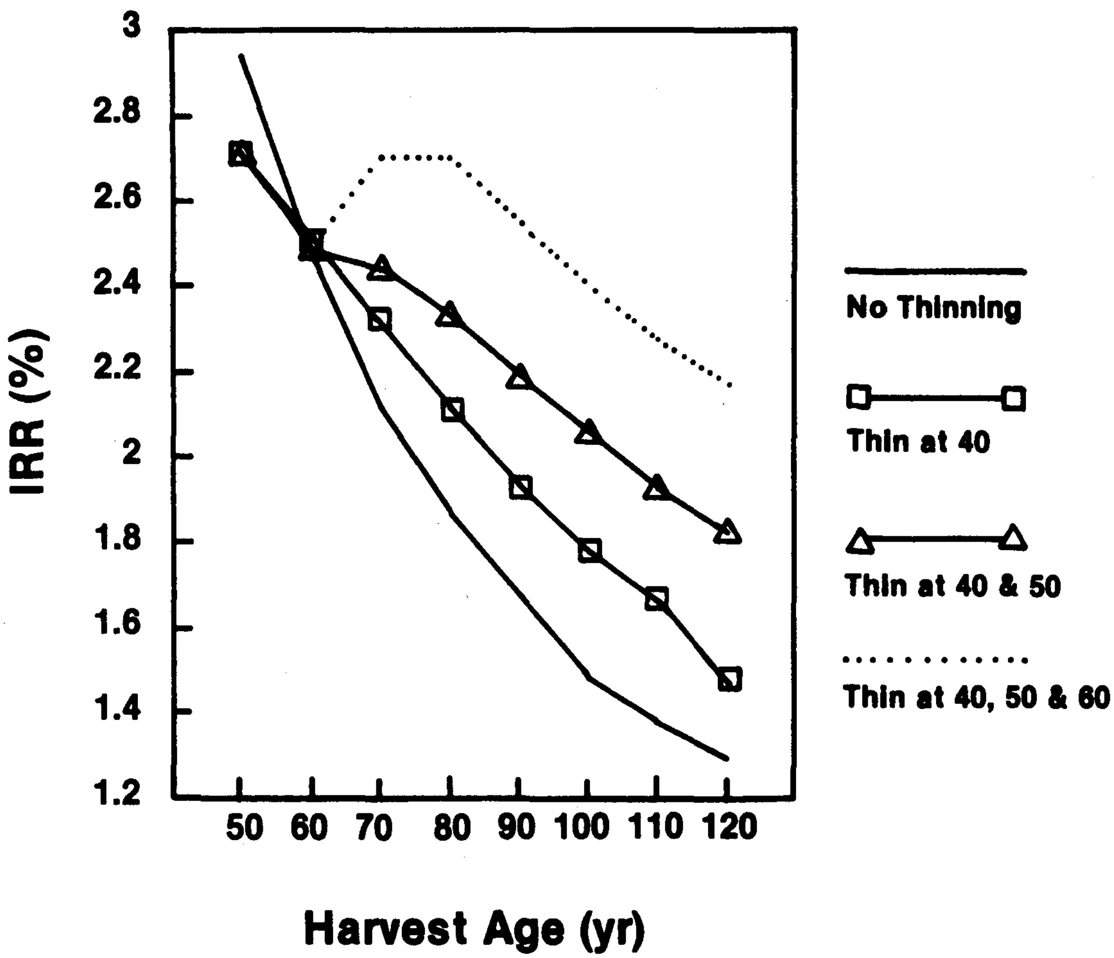

Figure 15. Internal Rate of Return for Age 40, Site Class 50 by Harvest Age and Thinning Regimen

The "Internal Rate of Return" is increased to 1.8, 2.1, and 2.4 percent (1.8%, 2.1%, and 2.4%) respectively as a result of the thinnings at age 40; 40, and 50; and 40, 50, and 60. Again this is in comparison to the unthinned case of 1.6 percent (1.6%).

Age 50, Site Class 35. After thinning at age 50; 50 and 60; and 50, 60, and 70 the total yield of the stand, including thinning removals, at age 100, is forecast to be 52, 51, and 52 cunits per acre respectively. This compares to 52 cunits per acre total yield at the same age in the unthinned case.

During the 50, years between the current age and age 100 the stand is expected to maintain periodic annual increments of 40, 40, and 42 cubic feet per acre periodic annual increment total yield respectively in comparison to the unthinned rate of 41 cubic feet per acre per year.

The value of total yield, including thinnings, for the three thinning regimens, with final harvest at age 100, are $2,200 $2,500, and $2,800 per acre respectively. These compare with $2,100 per acre expected without thinnings, at age 100.

The impact of these thinning regimens on periodic annual value increment per acre is to increase it for the 50 year period from age 50 to 100 to $21, $28, and $33 per acre per year for the thinnings at age 50; age 50 and 60; age 50, 60, and 70 respectively. For the same period the unthinned example increased at a rate of $19 per acre per year.

The "Internal Rate of Return" is increased to 1.4, 1.8, and 2.1 percent (1.4%, 1.8%, and 2.1%) respectively as a result of the thinnings at age 50; 50 and 60; and 50, 60, and 70.

Age 90, Site Class 45. After thinning at age 90; 90 and 100; and 90, 100, and 110 the total yield of the stand, including thinnings, at age 120, is forecast to be 75, 76, and 76, cunits per acre respectively This compares to 75 cunits per acre total yield at the same age in the unthinned case.

During the 30 years between the current age and age 120 the stand is expected to maintain periodic annual increments of 40, 41, and 42 cubic feet per acre respectively in comparison to the unthinned rate of 41 cubic feet per acre.

The value of total yield, including thinnings, for the three thinning regimens, with final harvest at age 120, are $6,300, $6,300, and $6,100 per acre respectively. These compare with $6,100 per acre expected without thinnings, at age 120.

The impact of these thinning regimens on periodic annual value increment per acre is to increase it for the light thinnings and reduce it for the heavy repeated thinnings over the thirty year period from age 90 to age 120. The periodic annual value increments per acre for the three thinnings simulated for these examples are $48, $46, and $42 per acre respectively. This compares to $45 per acre for the unthinned example.

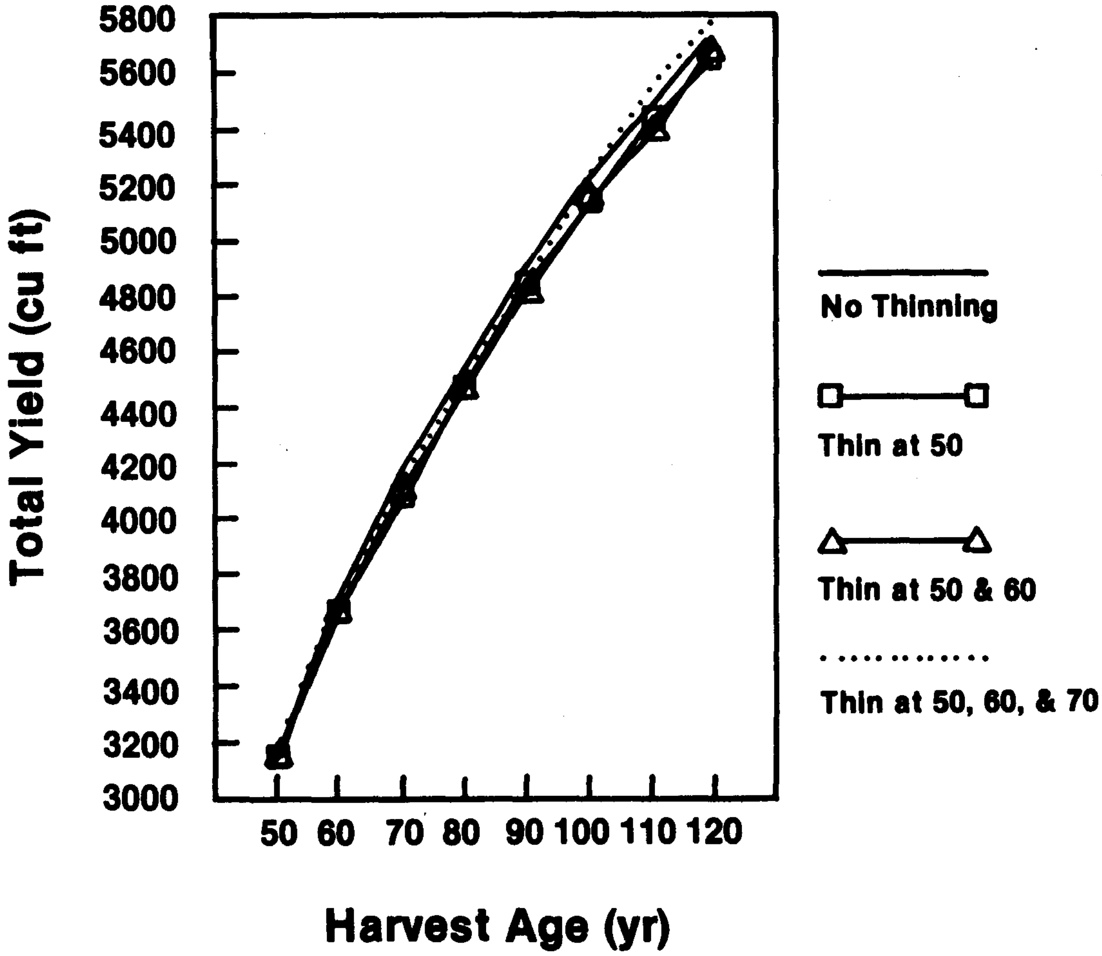

Figure 16. Total Stand Yield Per Acre (Including Thinnings) for Age 50, Site Class 35 by Thinning Regimen and Age at Final Harvest

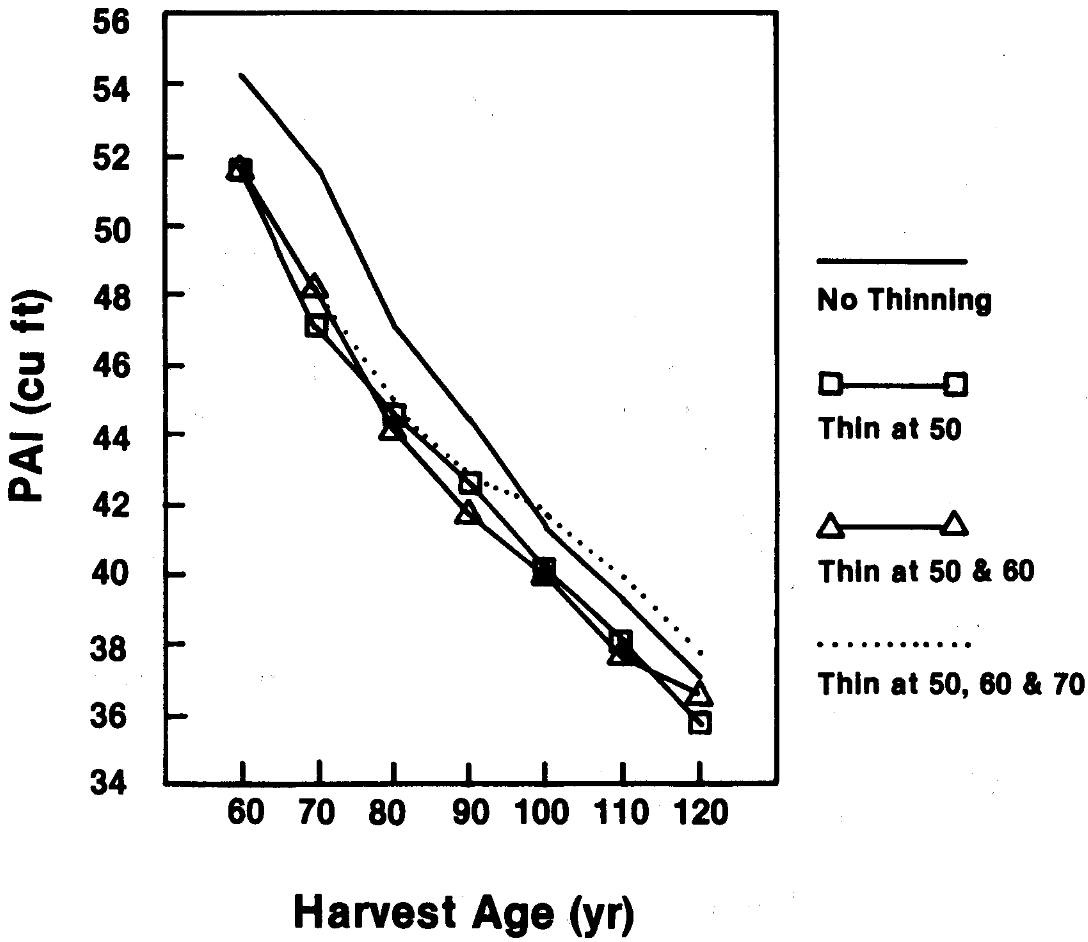

Figure 17. Periodic Annual Increment Per Acre Total Yield for Age 50, Site Class 35 by Harvest Age and Thinning Regimen

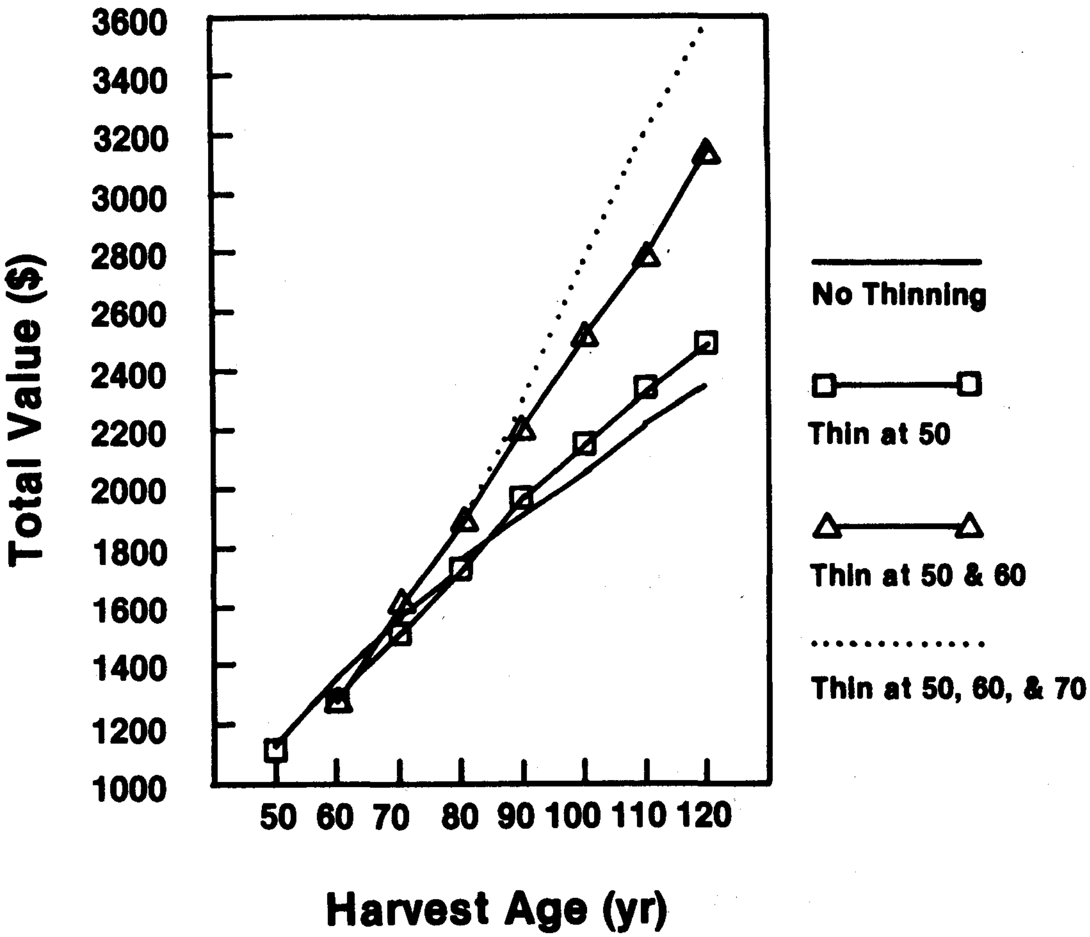

Figure 18. Value of Total Yield Per Acre (Including Thinnings) for Age 50, Site Class 35 by Thinning Regimen and Harvest Age

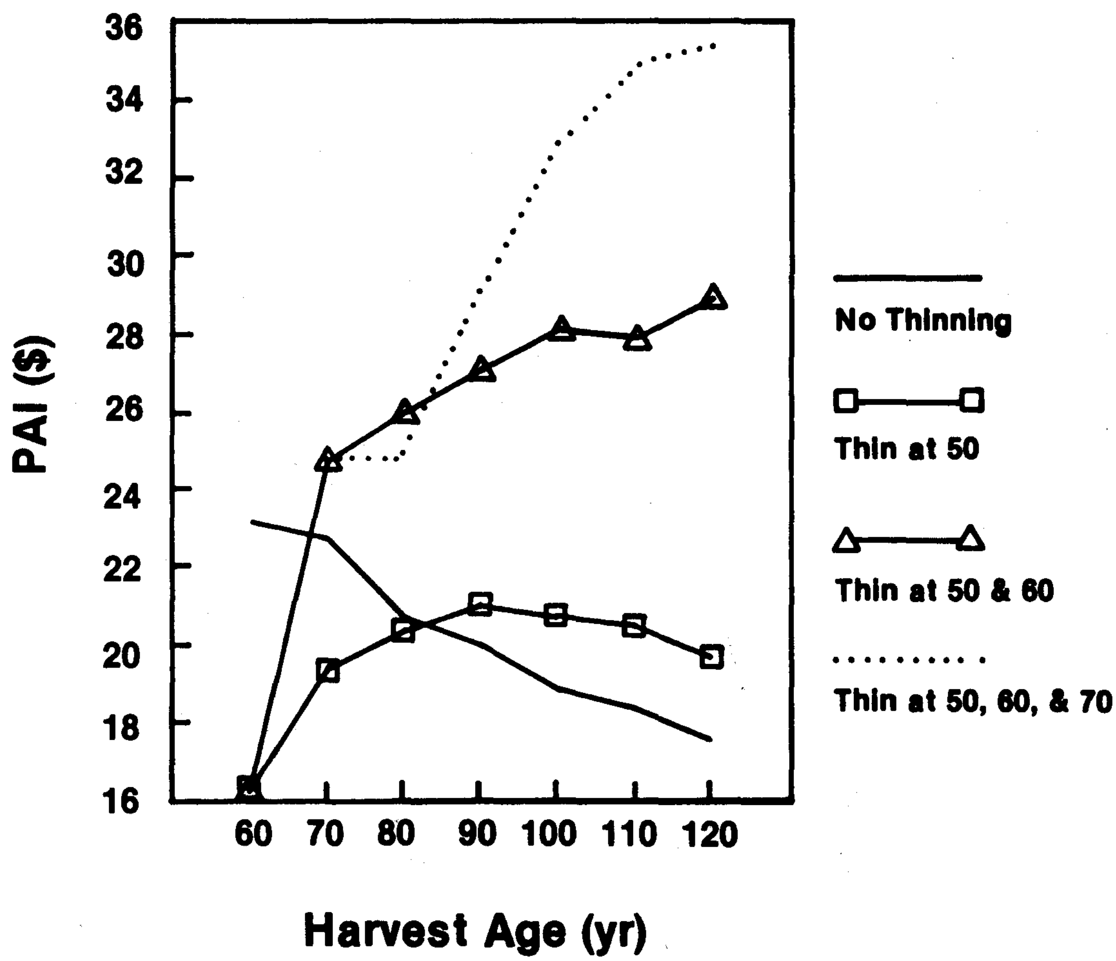

Figure 19. Periodic Annual Increment in Total Value Per Acre for Age 50, Site Class 35 by Thinning Regimen and Harvest Age

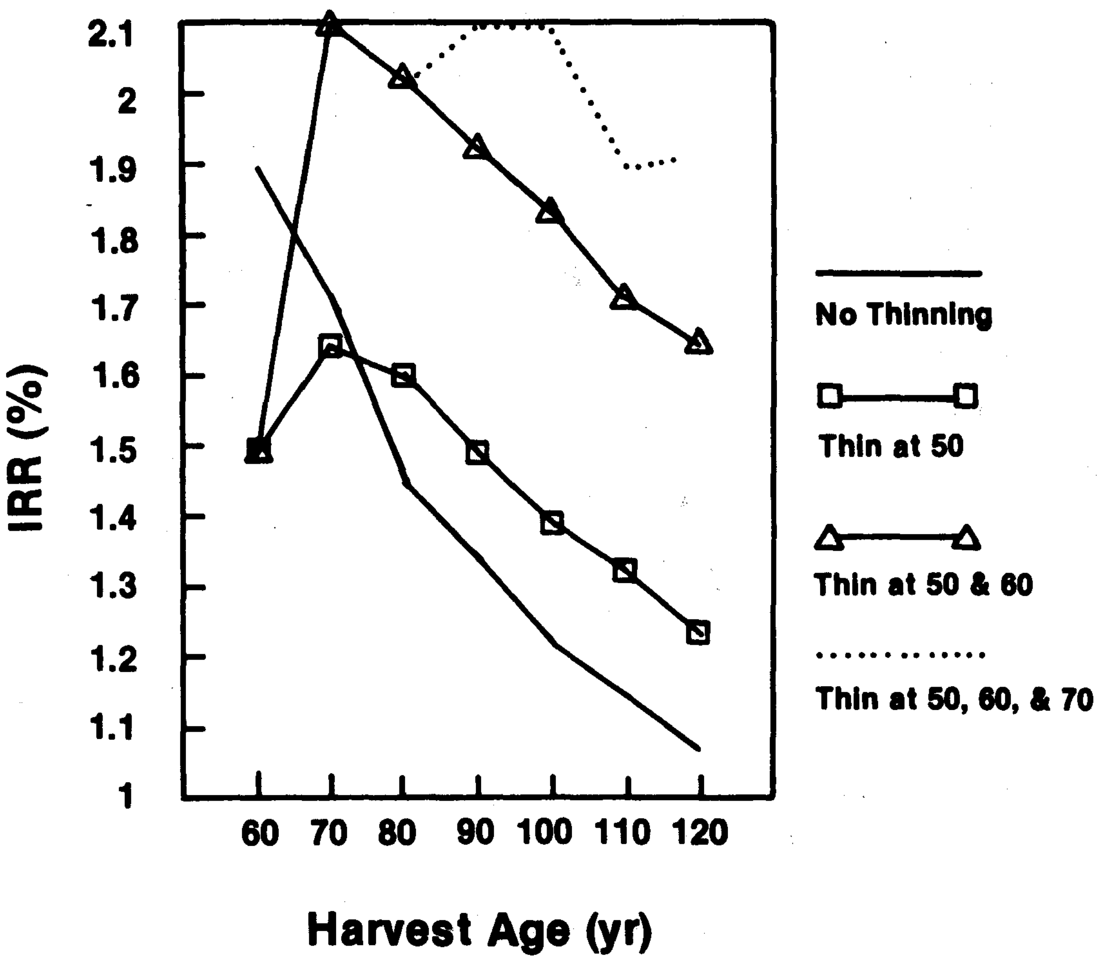

Figure 20. "Internal Rate of Return" for Age 50, Site Class 35 by Harvest Age and Thinning Regimen

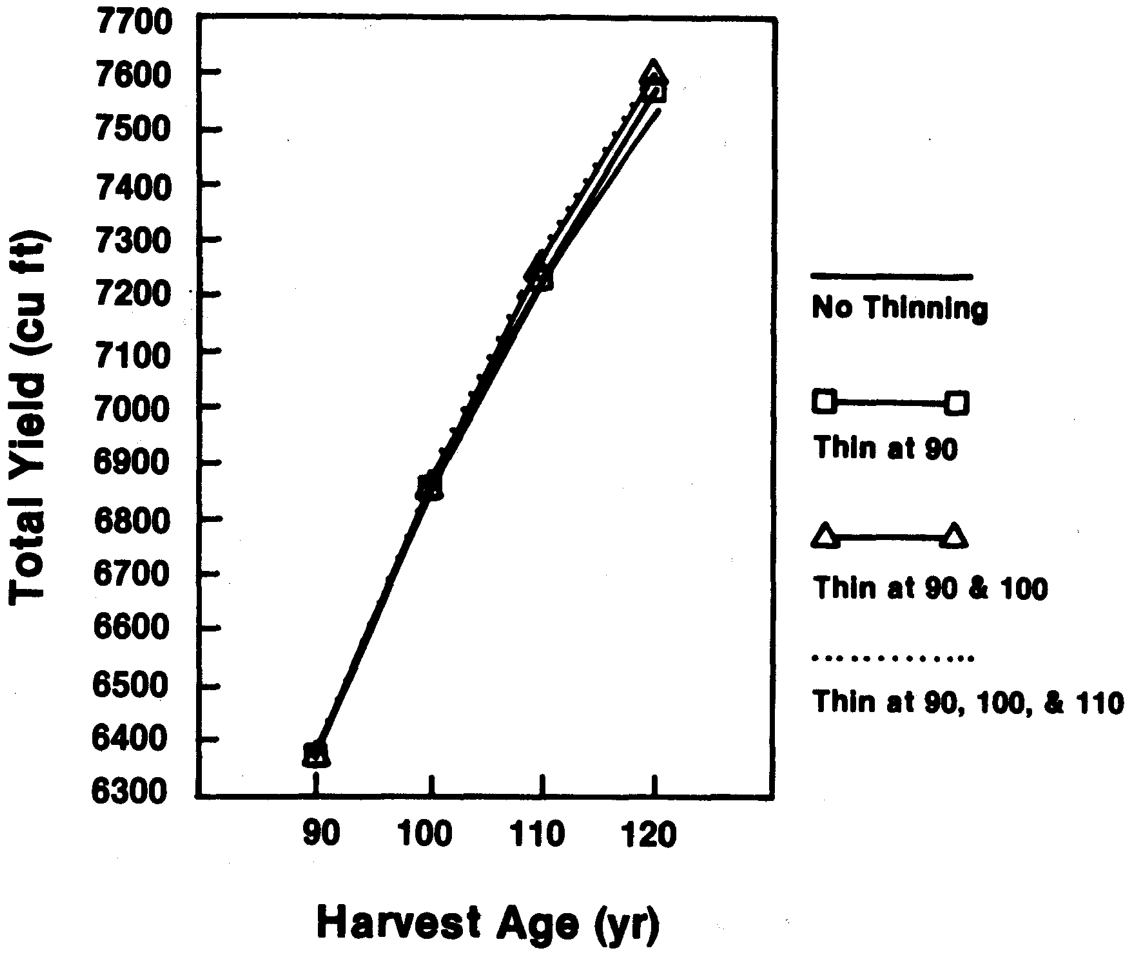

Figure 21. Total Stand Yield Per Acre (Including Thinnings) for Age 90, Site Class 45 by Thinning Regimen and Age at Final Harvest

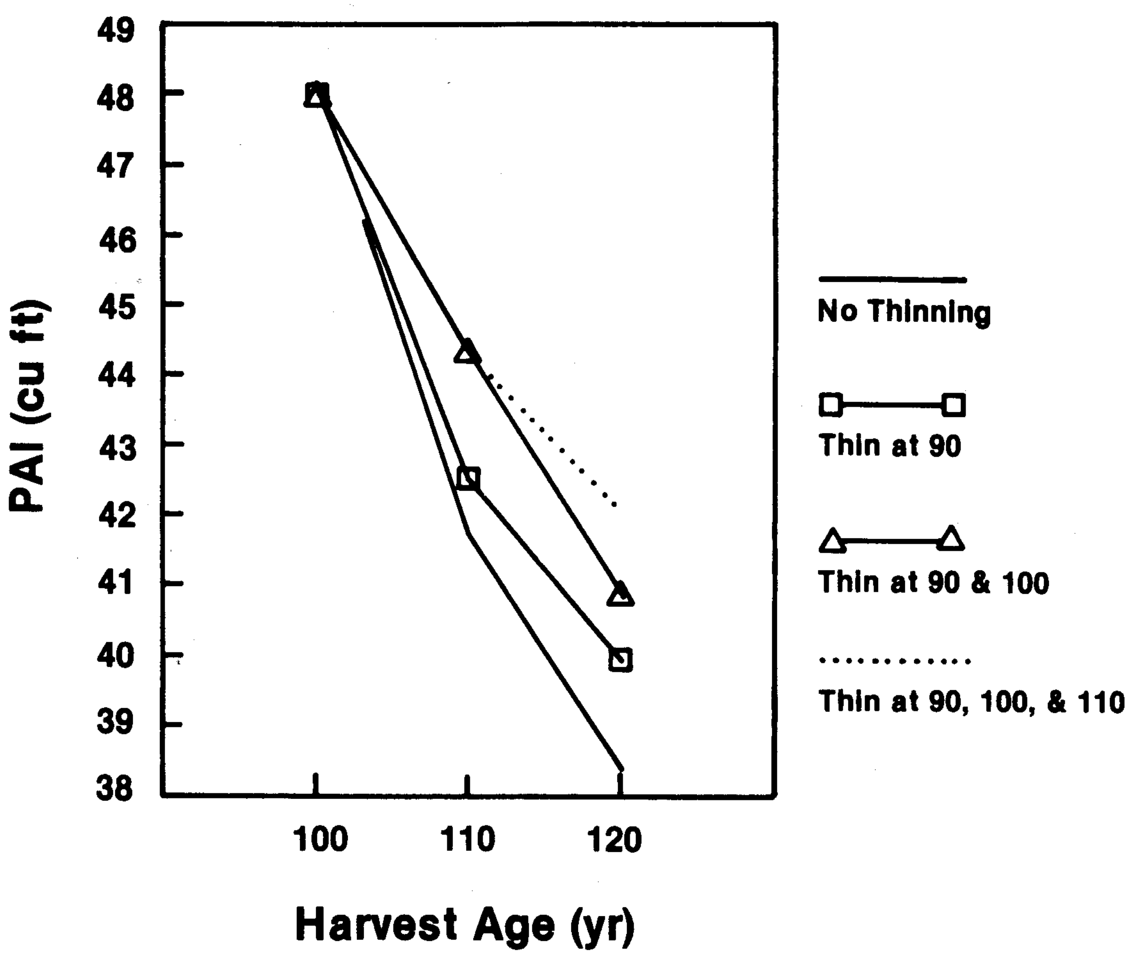

Figure 22. Periodic Annual Increment Per Acre Total Yield (Including Thinnings) for Age 90, Site Class 45 by Harvest Age and Thinning Regimen

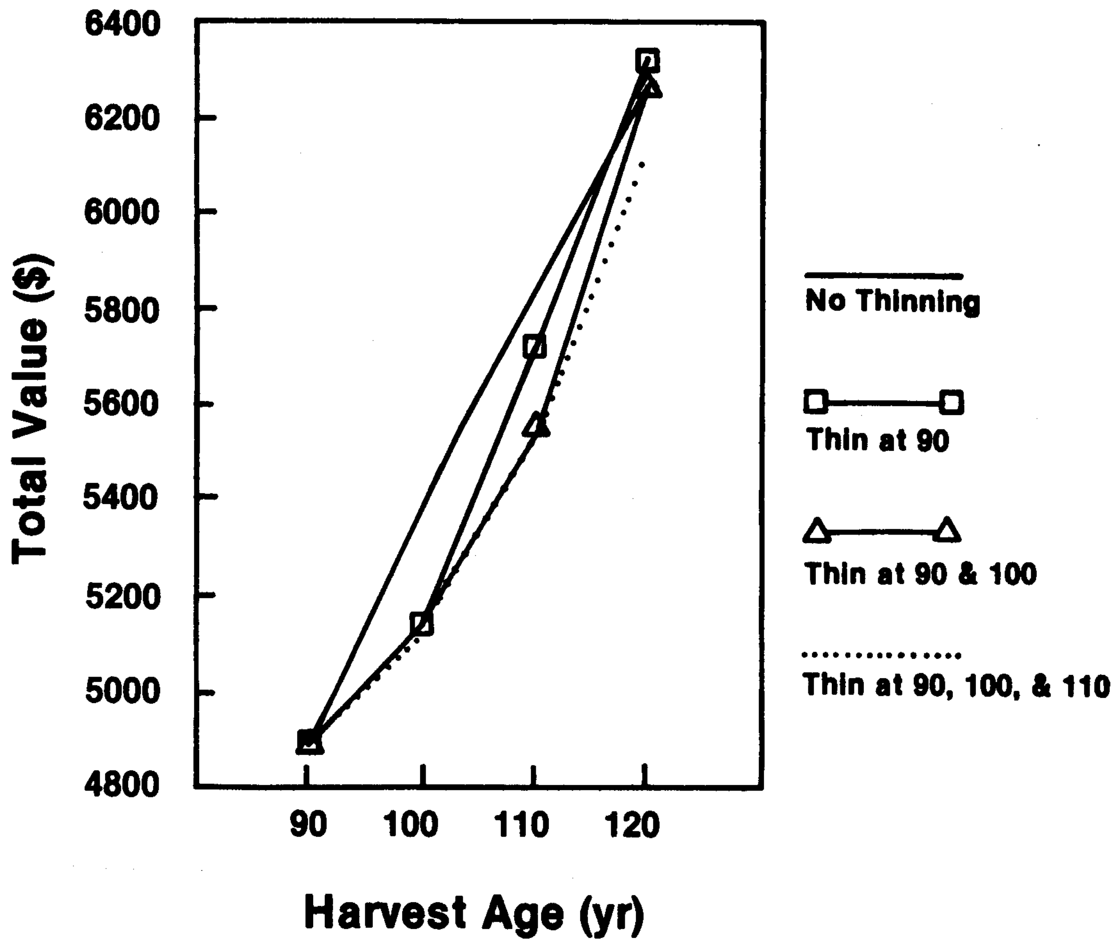

Figure 23. Value of Total Yield Per Acre (Including Thinnings) for Age 90, Site Class 45 by Thinning Regimen and Harvest Age

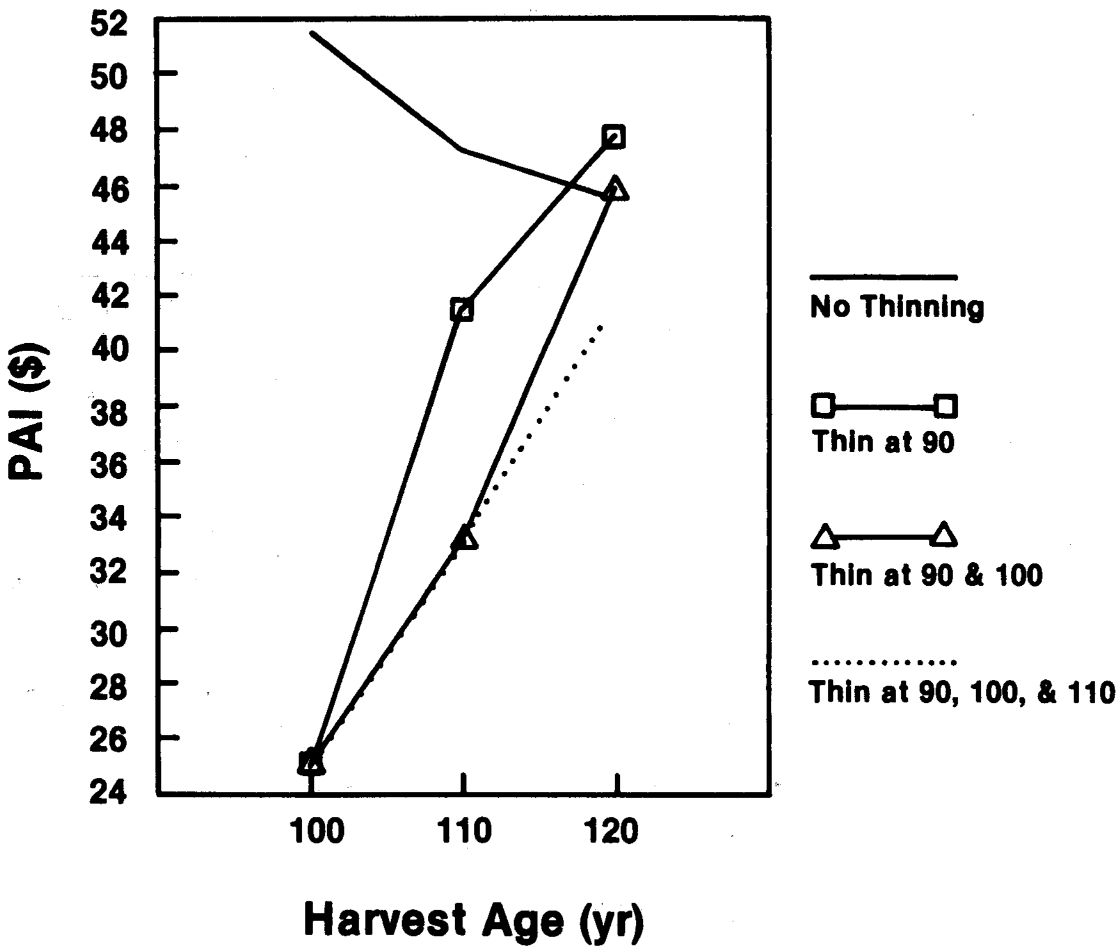

Figure 24. Periodic Annual Increment in Total Value Per Acre for Age 90, Site Class 45 by Thinning Regimen and Harvest Age

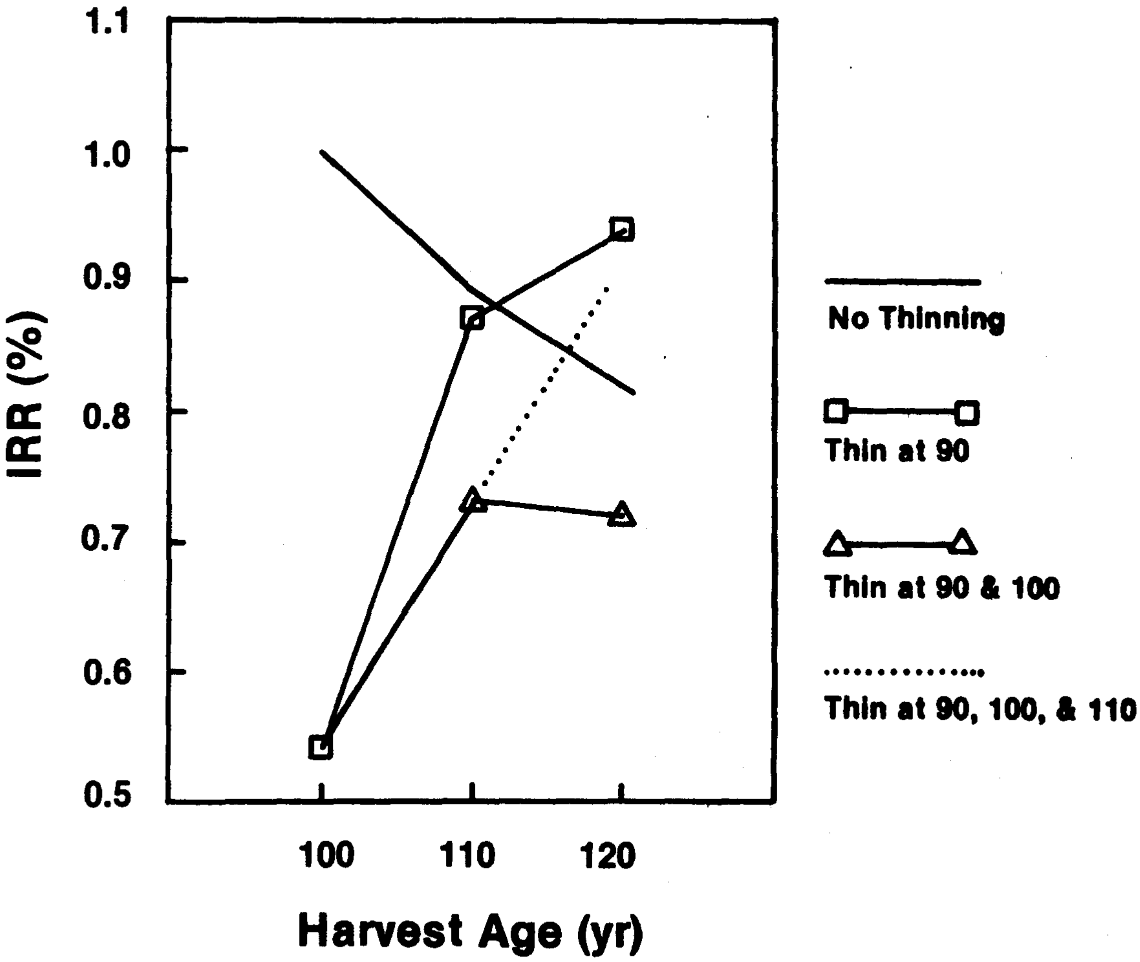

Figure 25. Internal Rate of Return for Age 90, Site Class 45 by Harvest Age and Thinning Regimen

The "Internal Rate of Return" for the 30 year period from age 90 to age 120 appears to be sensitive to the level of residual growing stock and the time since last thinning because the rates of return for the three thinning regimens are 0.9, 0.7, and 0.9 percent (0.9%, 0.7% and 0.9%) respectively This compares to 0.8 percent (0.8%) for the unthinned example.

SUMMARY AND CONCLUSIONS

Summary. Over the range of stand conditions and thinning treatments examined in this paper the thinning treatments reduced total yield (including thinnings) per acre at age 100 from zero to four (0 - 4) cunits. Periodic annual increment in these same examples is also reduced from zero to three (0 - 3) cubic feet per acre per year.

In terms of value, under the conditions of this analysis, the results are quite different. In the stands with initial ages of 30, 40, and 50 years the increases in the value of total yield at age 100 range from one to eight thousand dollars ($1,000 - $8,000) per acre In the case of the 90 year old stand the value of the total yield at age 100 is reduced by three thousand ($3,000) dollars per acre. This is due to the inability of the stand to make up the reductions resulting from the heavy thinning at age 90. Observe the trends in Figure 23. The trends in periodic annual value increment per acre are similar. In the stands with initial ages of 30, 40, and 50 the increases range from two to twenty four dollars ($2 - $24) per acre per year. In the 90 year old stand the periodic annual value increment was reduced by $26 per acre per year for the same reason that the value of the total yield was reduced.

The trends for "Internal Rate of Return", a measure of the efficiency of invested growing stock, are similar to the trends for the value of total yield and value increment. In the stands with initial ages of 30, 40, and 50 the increases in IRR ranged from 0.2 percent to 0.9 percent (0.2% - 0.9%). The IRR in the 90 year old stand was reduced by 0.5 percent (0.5%) following thinning.

Conclusions. The major consideration in the economics of stand management for shortleaf pine is the value of the growing stock required to produce the growth desired. In the examples considered in this analysis that investment ranged from $1,400 to $5,000 per acre. This exceeds by orders of magnitude any other investment in forest management during the life of the stand. Because of the size of this element of the forest management investment it is important to look beyond the cash flows in the economic evaluation of forest management and concentrate on treatments to increase the efficiency of invested growing stock.

One of the most important forest management tools available to increase the efficiency of invested growing stock in forest management are thinnings expressly designed to concentrate the growth on the tallest and best formed individual trees. In the examples, examined, in this paper there were reductions in total yield and periodic annual increment as a result of the thinning regimens simulated. However, there were also increases in the value of total yield and the periodic annual increment in value following thinning if there was sufficient time for the stands to create the more highly valued volume following treatment.

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SOIL AND WATER MANAGEMENT IN THE SHORTLEAF PINE ECOSYSTEM

Edwin L. Miller[1]

ABSTRACT

The opportunities for achieving watershed management goals in the process of timber management in the range of shortleaf pine are excellent. Water yield increases may occur with forest harvest but with little or no adverse watershed effects. Peak or flood flows for major storms are little affected by forest harvest. Serious erosion potentials exist when inappropriate silvicultural treatments are applied on erodible sites but prudent managers have many harvest and site preparation options which will not cause serious erosion problems when properly applied. Erosion from roads poses the greatest potential for water quality degration. Excellent opportunities exist for trapping road sediments on vegetated slopes when roads are properly located and drained. Stream crossings deserve special sediment control consideration. Streamside management zones (SMZ) are needed to stabilize stream beds and banks, protect flood zones and provide shade for stream temperature maintenance. SMZ's can meet watershed objectives and be managed for other timber - and non-timber outputs.

INTRODUCTION

Watershed management is defined as the use of natural resources of a drainage basin in a way that protects or enhances the water based resources. There is nothing particularly unique about shortleaf pine (*Pinus enchinata* Mill.) that either enhances or detracts from the foresters ability to practice good watershed management in the process of managing shortleaf for timber production. It is the physiographic variability of sites across the range of shortleaf pine and the nature of specific silvicultural practices used on those sites which must be examined and understood in terms of the regional water balance and the needs for water quality protection.

In this brief paper I have outlined what I believe are some of the more important forest watershed management considerations and generalized the direction of response to some broad forest management activities. Water yield, peakflows and water quality, including suspended solids and water temperature are considered in response to forest harvest and site preparation, forest roads and streamside management activities in the Ouachita Mountains.

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Water Yield

A number of studies have been conducted to determine the streamflow response to forest stand removal in the southeastern United States. Generally, when the transpirational surface is reduced or removed from a watershed area by forest harvest, that portion of rainfall inputs not subject to evapotranspiration (Et) losses, including interception, evaporation and transpiration, are available for streamflow. In coniferous forests, Et reductions and subsequent streamflow increases can average about 1.5 inches per 10% reduction in forest cover (Hewlett 1982). Complete forest removal could therefore result in streamflow increases of from 7 to 20 inches the first year following harvest.

Lawson (1975) measured runoff before and following partial and complete forest stand removal on shortleaf pine-hardwood catchments in the Ouachita Mountains of Arkansas. First year runoff increases were 4.3 and 10.9 inches for the partial and complete harvest treatments respectively. No increases in stormflow were detected by Miller (1984) following clearcutting of shortleaf on three small watersheds in the Ouachita Mountains of Oklahoma. In this case, site preparation activities included a deep soil ripping treatment on the contour which may have affected the hydrologic response of the watersheds.

The nature and timing of streamflow increases is a function of watershed characteristics such as the depth of soils and geology as well as the vegetation. Most studies have shown that increases in flow following forest harvest occur during periods of normally low streamflow, and that the duration of response ranges from 7 to 10 years with prompt and full forest restocking (Douglass and Swank, 1972). Replacement of hardwood stands with pine at the Coweta hydrologic research watersheds, reduced streamflows below the original base levels (Swank and Douglass, 1974), a factor to consider when converting from mixed pine-hardwood to pure fully-stocked pine. Year-around interception losses by pine and a longer transpirational season are largely responsible for the increased water use by pine (Zahner, 1955).

Peakflow

The effect of forest harvest on flooding has and continues to be a topic of high interest and poor understanding by the general public. As with water yields, an excellent research record is available and forms the base of our understanding. Lull and Reinhart (1972), Stone et al. (1978) and Anderson et al. (1976) reviewed the results of numerous studies on forest harvest and flooding in the United States and concluded that extreme floods occur when soils are recharged (saturated) on harvested and uncut areas and floods resulting from rainfall are therefore little affected by normal forest operations. Watershed characteristics such as area, slope, soils and geology, which vary by physiographic province, are the key factors in determining the regional variation in peakflows. For smaller storms or for storms which occur during periods of high evapotranspiration, peaks on harvested areas may be larger than on forested areas as soil moisture levels will generally be greater on harvested areas and less soil water storage available when it rains. These smaller storms however are not the cause of flood damage.

Studies in Oklahoma and Arkansas confirm the general relationship between forest harvest and large peakflows. In the Ouachita Mountains of Oklahoma, Miller (1984) found no significant difference in peakflows between forested and clearcut harvested watersheds for the eight largest runoff events recorded in a three year period following harvest. In Arkansas, Miller et al. (1986) measured no significant difference in peakflow between clearcut, selection cut and uncut watersheds for a storm which exceeded the 100 year return period. In these cases, storms occurred when soils were fully recharged on all watersheds regardless of vegetative cover and very little storage available for rainfall.

The nature of streamflow and peakflow responses to forest management are not unique for shortleaf pine. That a lower intensity of harvest and site preparation practices, which may be more common with shortleaf pine, will be uniformily favorable in the case of flood flows does not hold true and sound intensive evenage management of shortleaf has not been shown to necessarily increase peakflows from extreme rainfall events.

Erosion

The physiographic variability across the range of shortleaf pine, the nature of the soil erosion processes and the variability in the application of harvest and site preparation practices, limit our ability to generalize about the absolute levels of erosion and sedimentation which may occur due to silvicultural practices. It is accepted that small and temporary increases in erosion and suspended sediment transport will normally occur as a result of carefully conducted harvest and site preparation activities (Patric, 1978). It is also accepted that the form of harvest and regeneration activities evenaged or unevenaged has little direct influence on erosion and sedimentation in the long term (Stone et al. 1978). Increases in erosion due to silvicultural activities are largely a function of the site, appropriateness of the treatment and the operator.

Baseline rates of erosion from forest lands in the United States are low. Soil losses from 812 erosion measurements were summarized by Patric et al. (1978). Erosion rates ranged from 0.01 to 1.09 tons/ac/yr and three-fourths of the observations did not exceed 0.25 tons/ac/yr. Sediment yields from undisturbed forest lands in the eastern U.S. were reported to range from 0.05 to 0.10 tons/ac/yr (Patric 1976). In one respect these low base levels present a dilemma in that environmentally acceptable rates of erosion due to forest management activities may appear large in comparison to baseline erosion rates.

Focusing on the Ouachita Mountains of Oklahoma and Arkansas, Miller (1984) and Miller et al. (1985) reported the results of two studies in which soil losses were measured following various methods of forest harvest and regeneration and compared to losses from forested areas. In the Oklahoma study soil losses averaged 0.126, 0.016 and 0.007 tons/ac the first three years following clearcutting and intensive site preparation while soil losses from control areas averaged 0.02, 0.004 and 0.002 tons/ac in respective years. In Arkansas soil losses averaged 0.105, 0.040 and 0.080 tons/ac from clearcut and site prepared watersheds, 0.015, 0.017 and 0.035 tons/ac from selection cut watersheds and 0.005, 0.075 and 0.031 tons/ac from control watersheds, the first three years following harvest treatments. Obviously the erosion rates measured in these studies were very low regardless of treatment and presented no threat to the long term productivity of the watersheds.

In contrast to the low rates of erosion measured in the Ouachita Mountains, Beasley (1976) measured much higher rates following harvest and site preparation treatments on highly erodible soils on steep slopes in north Mississippi. First and second year sediment losses with mechanical site preparation, which included shear and pile and contour bedding, averaged about 6 and 2.5 tons/ac in comparison to undisturbed rates of 0.28 and 0.05 tons/ac respectively. When inappropriate treatments are applied on erodible soils unacceptable rates of erosion will occur.

A few general principles concerning silvicultural practices and erosion which apply across a range of physiographic and vegetative types can be summarized. One key to preventing erosion is to maintain soil cover and high infiltration rates which precludes overland flow. Erosion cannot occur when sediment transport mechanisms are not provided. Ephemeral channels should not be disturbed. Stream channels are normally a ready source of sediment and their stability should be maintained. A large percentage of the annual sediment load produced from a watershed is normally the result of a few and occasionally only a single intense rainstorm. Protecting sites from large storm events may be possible if they occur seasonally. Finally there is great variability in the application of given silvicultural treatments. Good operators are therefore a key element in effective and efficient operations.

Suspended Sediment

As with erosion both the baseline levels of water quality and the potentials for water quality degradation vary greatly across the physiographic divisions of the southern U.S. and water quality maintenance is not directly a function of the species under management. Even as the potential for sediment to reach a stream course varies greatly, acceptable levels of instream sediment loading necessary for the maintenance of aquatic communities varies. Nutter and Douglass (1978) observed that lower levels of erosion are generally required to maintain good water quality, as measured by low levels of total suspended sediment, than are required to maintain site productivity. Other factors such as non-forest land uses and stream channel and bank sediment sources further complicate the link between forest management practices and the sediment loads of larger streams and rivers.

Nevertheless, the direct sediment loads which result from forest management have been summarized and reported for a number of specific silvicultural practices over a broad range of soils and topography (Yoho. 1980). These data do give a relative measure of the impact of forest management on water quality. Normally, average sediment concentrations are calculated for individual storms or for streamflow on an annual basis as a measure of water quality impact. Erosion and sediment loading varies within storms and therefore the suspended sediment concentration in streamflow changes with stage (discharge) and through time. We have all casually observed these phenomia in streams and rivers.

For the Arkansas and Oklahoma studies reported above we examined the concentration of sediment at discrete points through time during stormflow runoff. Analysis of individual samples allowed an examination of the percent of time total suspended sediment (TSS) levels exceeded some predetermined levels (Miller, 1984). A summary of the Oklahoma, Ouachita Mountain results showed that only small differences in the time of elevation of TSS occurred between treatments at the 10, 20, 50, and 100 mg/l levels for the four years following clearcutting and intensive site preparation treatments (figure 1). Similar results were obtained in the Arkansas, Ouachita Mountain study (Miller et al. 1986). This method of summarizing suspended sediment data may be more useful than average annual or storm TSS concentration calculations, to those evaluating the impact of suspended sediment on aquatic organisms.

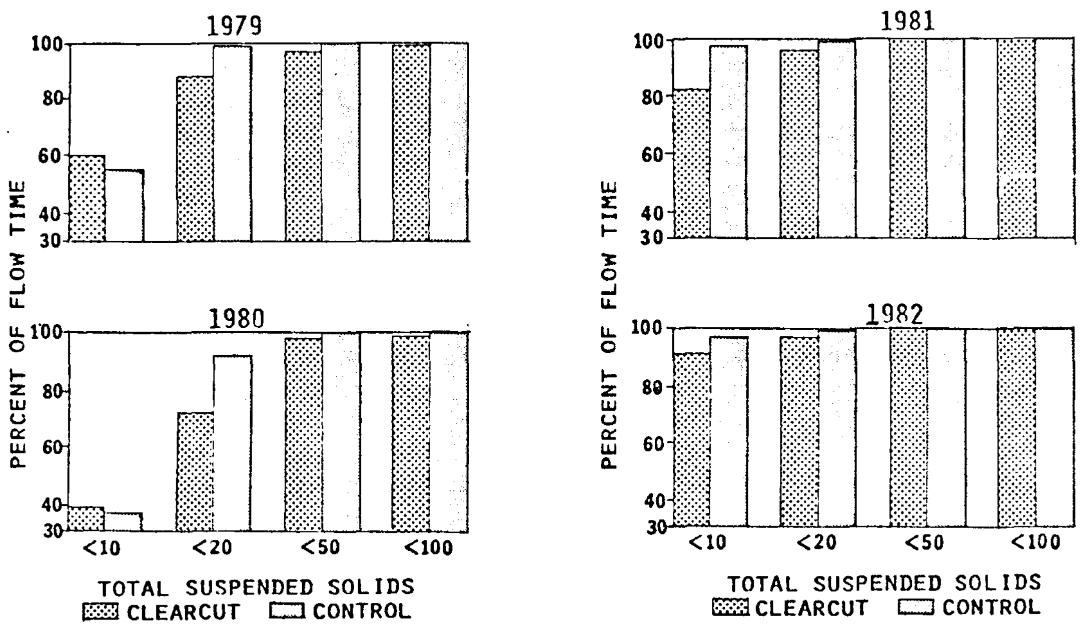

Figure 1. Percent of stormflow time that total suspended solids (TSS) in stormflow were less than 10, 20, 50 and 100 mg/l.

Road Sediments

Unfortunately a thorough review of forest road erosion studies in the southern U.S. is not available and research has been conducted in only a few southern physiographic regions. However, it is generally accepted that among forest management activities, the construction and maintenance of a road system presents the greatest single potential source of sediment (Patric, 1978 and Ursic and Douglas, 1979). Roads are a necessary part of any forest management scheme and since forest road erosion is largely a function of physiographic conditions, general principles apply in forest road erosion control (Trimble and Sartz, 1957, Kochenderfer, 1970, Groves et al. 1979 and Swift, 1984).

Two studies of erosion from forest roads in the Ouachita Mountains are reported by Beasley et al. 1984, Miller et al. 1985 and Vowell, 1985. The primary objectives of these studies were to evaluate the sediment production rates from two contrasting road types, a 15 year old USFS primary access road and a recently constructed state of the art industrial primary access road, and to determine the nature and extent of sediment routing and delivery to stream courses. In the Arkansas study on the older established road erosion rates averaged about 60 T/mi/yr from monitored road sections, about 10% of the 692 T/mi/yr estimated in the Arkansas statewide nonpoint source assessment (Arkansas Department of Pollution Control and Ecology, 1980). Sediment delivery to streams was projected to be 7.9 T/mi/yr, about 10% of total production and only 1% of the Arkansas assessment estimate. A large portion (90%) of the total sediment production was entrapped before entering a stream course. The delivered sediment equated to about 0.038T/ac/yr over the entire basin, roads and forested acres combined, a relatively low level of sediment loading. erosion from roads was related to soils, slopes, area of exposed backslopes, and the timing and intensity of rainfall. Sediment delivery to streams was more a function of road location and/or the direct discharge of road runoff into ephemeral and flowing streams. Single poorly constructed and designed stream crossings where road ditch sediments were delivered directly to the stream had an overriding influence on suspended sediment levels in streams. When roads are properly located and drainage structures are well designed and maintained, excellent opportunities exist to trap sediments on vegetated slopes before they reach streams. Results of the Oklahoma study showed similar results indicating sediment yields and delivery can be controlled on newly constructed roads, as well as older established systems.

Streamside Management

The idea that management near the stream should be different in order to protect the stream environment is not new. However, the concept of the streamside management zone (SMZ) was developed during the formulation of Best Management Practices (BMP's) for forestry and to many it is in contrast to the older concept embodied in the terms buffer, leave or filter strip. There are two basic differences in the old and newer concepts. First, under the old concept, the streamside zone was expected to mitigate the effects of activities or practices outside and upslope of the streamside zone. For example, erosion on the hillslope might be acceptable so long as a "filter strip" (usually the wider the better) was provided to stop all sediment from entering the stream. Unfortunately, due to the physical processes involved, SMZ's do not usually act to filter out sediments from upland erosion. And second, that all forestry practices should be restricted from the streamside zone and that only in this way could the value of the streamside zone be maintained. For example the removal of any trees from the streamside zone would reduce it's ability to function as a wildlife corridor or in erosion control.

In contrast the SMZ concept involved identifying specific objectives to be met in the riparian area and subsequently devising a management scheme to meet those objectives. Forestry or other management activities could be allowed within the zone if the objectives were met and in some cases forestry activities within the SMZ might enhance the opportunity to meet SMZ objectives.

Given this concept what are some key objectives to be met through wise use of the SMZ? The primary watershed oriented objectives of streamside management are, 1. Stability of the stream bed and bank, 2. protection of the floodway from erosion and scour and 3. maintenance of stream temperature. Other non-watershed objectives may be appropriate and compatible with these watershed objectives.

Stability of the stream bed and bank means prevention of the short or long term destabilization of the bed and bank by mechanical equipment or the removal of streambank vegetation. The SMZ may be used as a barrier for stream crossing except at designated areas. The width of the SMZ and acceptable mechanical and harvest guidelines must be determined on a site specific basis and will be a function of factors such as stream size, bed and bank soils (natural), bed and bank configuration (steepness and stability), timber type and size, and the importance of vegetation in maintaining stream bank and bed stability.

Where overbank flooding occurs forest vegetation can provide important erosion protection for the alluvial soils of the flood plain. The soil materials and the nature and timing of flood events largely determining the erosion risk and would be a key in determining a reasonable level of harvest from the SMZ. Flood plain vegetation can be both a source of and a trap for large and small organic debris. Large debris can form substantial check dams within the SMZ or in stream channels during floods and can consequently cause serious flood plain erosion and in some cases stream rechannelization. Large debris must therefore be carefully managed. The stability of overflow channels should also be given special attention if rechannilization is to be avoided.

The shade provided by streamside vegetation is often critical for maintaining favorable stream temperatures necessary for aquatic organisms. Studies have shown that maximum stream temperatures increase and minimums may decrease when stream shade is removed (Greene, 1950, Swift and Messer, 1971, Lynch et al. 1975 and Kochenderfer and Aubertin, 1975). Temperatures may return to normal upon reentry to shaded stream segments depending largely on the amount of shade and groundwater flux or other cool water inflow. Even when stream temperatures are increased, thermal refuges or zones where stream water remains cool may exist which provide relief for aquatic organisms during stressfull periods.

Specific temperature requirements depend on the species present. Temperature sensitive streams and stream segments are normally designated in state water quality standards. The effectiveness of streamside shade in moderating stream temperatures is a function of season, the height, and type and density of vegetation, stream orientation, topography, stream size and groundwater flux among others. Reviews of the literature and principles involved in determining stream temperatures are readily available (Brown, 1974, Woolridge and Stern, 1979 and USFS 1980). Some of this information is applicable in the southeastern U.S. or can be modified as the general principles apply.

Summary

In this paper some key watershed management concerns within the shortleaf pine ecosystem have been briefly discussed. For most concerns the principles are well understood and forest management alternatives for the protection of watershed values are available and attractive. We have good opportunities to sustain the quality of our soil and water resources in the process of managing for timber.

There is nothing particular about shortleaf pine that enhances or detracts from our ability to practice good watershed management. There is a wide physiographic diversity across the range of shortleaf and the watershed management objectives and requirements will vary accordingly. Even within a narrow range of silvicultural practices applied on a particular site there is room for error or success as the abilities of individual managers and operators to apply watershed management principles in the field will vary.

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WILDLIFE AND SHORTLEAF PINE MANAGEMENT

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ABSTRACT

Shortleaf pine forests (Pinus echinata) are used for multiple purposes. This paper discusses the effects that timber management, livestock grazing, and recreational uses of the shortleaf forest may have on its wildlife resources.

The shortleaf pine (Pinus echinata) forest, whether in its pure state or mixed with hardwoods or other pines, is of immense value to wildlife and to people. Because its range is larger than that of any other pine in the southeastern United States (Lawson 1986), management of shortleaf forests potentially affects our environment more than management of most other pine species. This management is a matter of concern among the human residents of the shortleaf range who are keenly interested in the wildlife resources that inhabit the forest. Many of the residents of the southeastern United States actively participate in wildlife-related recreation. For example, 12% of citizens older than 16 years of age in the Southeast participated in hunting during 1980 and 46% made some nonconsumptive use of the wildlife resource (U. S. Dept. of Interior 1982). Recent studies in Mississippi (Nabi et al. 1983) and Arkansas (Owen et al. 1985) indicate that wildlife-related goals are the second most important reason that many landowners own forestland. Therefore, it is only natural that concerns should arise over management of shortleaf and the effects that such management might have on wildlife communities.

There have been a number of compendiums prepared that describe the effects of southern pine management on wildlife communities (Dickson 1982, Buckner 1982, Owen 1984). This author will not attempt to duplicate these efforts. Rather, a brief summary of these results will be provided along with a discussion of how other uses of the shortleaf forest affect wildlife resources. This paper will also emphasize wildlife communities rather than game species. At least 90% of vertebrate species in the continental United States are found in forest ecosystems (Shaw 1981). Although many of these species are not considered "game" and are present only seasonally, their needs must also be met and should be of concern to resource managers (Robbins 1984).

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SHORTLEAF MANAGEMENT AND WILDLIFE RELATIONSHIPS

There are a number of forest characteristics that influence the density and composition of wildlife communities. Habitat diversity is one of the most important of these characteristics because most wildlife species require more than one habitat or forest type to fulfill their life requisites. For example, eastern wild turkeys (*Meleagris gallopavo silvestris*) need a number of plant communities for such functions as hiding, escaping, roosting, brood rearing, resting, nesting, and breeding (Hurst 1981). Forest types used by turkeys include most seral stages from openings to climax. The need by wildlife species for among-stand diversity can be met in the shortleaf forest by providing stands of different ages and species composition, including sufficient numbers of natural stands (Harris and Marion 1982).

In addition to among-stand diversity, within-stand diversity is important to wildlife species. Within-stand diversity includes such characteristics as the number of horizontal strata, "patchiness" or spacing of trees, and species composition. Each of these influence the diversity and density of wildlife species present within a forest. For example, the number of horizontal strata is positively correlated with bird species diversity (Myers and Johnson 1978) but negatively correlated with development of the ground-level vegetation that benefits browsers, grazers, and breedings birds (Blair and Feduccia 1977). Irregular spacing of trees within a stand exposes open areas to full sunlight permitting increased growth of ground-level and understory vegetation. Roth (1976) suggested that uniformity in tree spacing reduces bird species diversity.

Although the hardwood component is often an economically undesirable component of the shortleaf forest, it does contribute to the welfare of numerous wildlife species. These trees produce seeds that are eaten by both birds and mammals, their bark harbors invertebrates that are also a food resource, and they provide cavities for nesting and roosting. Shortleaf pine is most valuable for birds when mixed with hardwoods (Myers and Johnson 1978, Briggs et al. 1982). Perhaps this is fortunate considering the difficulty of eradicating hardwoods from the shortleaf forest. Cain and Yaussy (1984) concluded that short of soil sterilization, complete eradication of hardwoods is unachievable.

EVENAGED MANAGEMENT OF SHORTLEAF

Evenaged management of pine forests has probably caused more furor among the public and profession than any other silvicultural option. In particular, clearcutting operations followed by intensive site preparation have received close attention. The rapid and highly visible change from existing forest communities to the first seral stages has probably been most responsible for this reaction. Wildlife-oriented organizations located in areas where shortleaf is intensively managed have felt so strongly about clearcutting that they have brought stockholder pressure on timber companies to change management practices.

If intensive site preparation follows the clearcutting operation, most of the ground-level plant community may be removed and mineral soil exposed. Within one year, however, about one half of the harvested area will be revegetated and vegetation will average approximately 1 m in height (Beasley and Granillo 1985). These young clearcuts are attractive to many small mammals, mourning doves (Zenaida macroura), bobwhite quail (Colinus virginianus), and meadowlarks (Sturnella magna) (Dickson 1982). In addition, the predators that often feed on these species are attracted to these sites.

For the next two to four years, production of browse, forbs, and soft mast recovers from site preparation and is much greater than in native stands (Stransky and Halls 1978, Stransky and Roese 1984). From two years after clearcutting until crown closure, sites are dominated by perennial grasses, woody shrubs, hardwood sprouts, and a number of annual and perennial forbs (Beasley and Granillo 1985). It is in this stage of stand development that white-tailed deer (Odocoileus virginianus), rabbits (Sylvilagus floridanus), Peromyscus spp. and other small mammals are most benefited. In addition, possibly 30 to 40% of breeding bird species benefit from these shrubland communities until crown closure occurs (Johnston and Odum 1956). Because shortleaf generally grows more slowly than loblolly pine (Pinus taeda) (Chapman 1942), this shrubland community can persist longer in shortleaf plantations.

As crown closure occurs, habitat characteristics and wildlife communities also change. The intense shade from the pine canopy and the developing hardwood mid-story discourages the growth of ground-level vegetation and inhibits soft mast production (Halls and Alcaniz 1968, Blair and Enghardt 1976, Blair and Feduccia 1977). This results in loss of habitat for a number of species, that flourished in earlier seral stages, until thinnings or other cultural practices open the canopy once again. Thinning greatly enhances the habitat quality in shortleaf plantations through increased forage quality and quantity (Wolters et al. 1982, Blair et al. 1983), and increased soft mast production (Campo and Hurst 1980). Increased mid-story growth as a result of thinning greatly enhances habitat for songbirds (Kroodsma 1984).

After thinnings begin, a variety of management practices may alter the quality of habitat in shortleaf stands. Prescribed burning is a management practice that has both favorable and adverse effects on wildlife communities in the shortleaf forest. The effects of prescribed burning vary with the frequency, time of year, and intensity of fires, and with stand structure. Burning favors browsers and grazers by temporarily increasing the nutrient content of forage plants, increasing the amount of light reaching herbaceous plants, and by causing sprouting of woody plants so the succulent growing portions are once again within reach of browsing animals (Lay 1956, Lay 1957, Dills 956). Burning encourages patchiness in the understory that may increase the number of species and density of birds associted with ground-level vegetation (Myers and Johnson 1978). Burning can also create snags, attract large numbers of wood-dwelling insects, scarify leguminous seeds, and make available seeds previously hidden in the duff (Conner 1981, Dickson 1981). Conversley, fires can also destroy snags and temporarily lower hardwood mid-story and soft mast production, thus reducing the number of birds that are dependent on this habitat component (Dickson 1982).

The effects of evenaged management on wildlife communities can also be modified by such practices as providing streamside management zones, leaving snags wherever feasible, limiting stand size, providing a mosaic of stand ages within compartments, and shaping stands to provide a high amount of edge to area. Streamside management zones are often recommended for riparian areas that are inherently more productive for shortleaf than dryer sites. Yet, these zones are a wildlife management practice that potentially have great impact on most wildlife species in the evenaged shortleaf forest. By providing hard mast, snags, cavities, travel corridors, shade for the aquatic system, stabilization for stream banks, and an aesthetic buffer, streamside management zones can greatly diversify evenaged shortleaf pine systems. Abundant edges between stands that differ in age and structure, improves habitat quality for most species requiring more than one habitat type. For example, Strelke and Dickson (1980) found about three times the number and diversity of birds in stand edges as in stand interiors. However, predation rates may also be higher in these edges (Robbins 1984). Some large stands (> 1000 ha) are necessary for species dependent on forest interiors (Dickson 1982).

UNEVENAGED MANAGEMENT OF SHORTLEAF

Although many shortleaf forests are managed under an evenaged regime, numerous shortleaf stands are of an unevenaged structure, a management option particularly viable for private nonindustrial landowners (Reynolds et al. 1984). Yet, there are little data describing the quality of wildlife habitat in unevenaged shortleaf stands. These stands have characteristics that make them good habitat for wildlife species. Unevenaged stands of shortleaf generally carry between 45 and 75 ft^2/ac basal area (Farrar 1984), which is less basal area than stands of an evenaged structure. In addition, these stands have an irregular canopy profile, a highly developed mid-story, abundant ground-level vegetation, and an irregular spacing of trees (Farrar 1984). This diversity in habitat characteristics favors most members of the wildlife community.

OTHER MULTIPLE USES AFFECTING WILDLIFE

The shortleaf pine forest is a multiple-use forest. Although only pulic lands are mandatorilly managed for multiple uses (Multiple Use-Sustained Yield Act 16 U.S.C. 528-531), most shortleaf forests serve more than one purpose. Two uses of the shortleaf forest that affect wildlife resources are livestock grazing and public recreation.

Grazing and wildlife communities

Grazing of livestock, particularly cattle, in shortleaf forests has been a practice of homesteaders and livestock producers for decades (Grelen 1978). Because of the low cost of producing forage, this practice is an especially attractive alternative to improved pasture (Pearson 1974). Yet, there have been concerns raised about the potential effects that grazing might have on the quality of wildlife habitat in the shortleaf forest.

Of particular concern has been the effects of cattle grazing on white-tailed deer populations. A number of preferred deer foods are also eaten by cattle (Thill 1984). Both deer and cattle utilize hard and soft mast, grasses, woody browse, and forbs. Recent studies in the Louisiana shortleaf-loblolly forest, however, suggest that these two interests are not necessarily mutually exclusive. Grasses and grasslike plants are preferred by cattle while deer depend heavily upon woody browse (Thill 1984, Thill and Martin 1979, Moore and Terry 1979). Thill (1984) found that woody browse provided an average of 89% of the forage eaten by white-tailed deer and an average of 32% of cattle diets. Hard and soft masts usually comprised less than 1% of deer diets except during fall when these food items made up as much as 10% of the diet. Less than 0.1% of cattle diets was composed of hard and soft masts and peak use during fall did not exceed 4%. Grasses and grasslike plants made up an average of 66% of the diet of cattle but less than 2% of deer diets. Forbs were used most heavily by deer, and greatest competition between deer and cattle occurred during spring when forb resources are abundant.

Thill (1984) also suggested that on young clearcuts deer and cattle diets are especially complementary. The abundant supply of grasses produced on young clearcuts provides excellent grazing opportunities and an inexpensive means of improving accessibility to these sites. Deer and cattle are frequently observed feeding in the same clearcut, but use patterns differ temporally and spatially. Nelson and Shalaway (1985) found that cattle preferred to feed in young clearcuts during daylight while deer used them mostly at night. McKee

(1979), however, recommended that cattle be excluded from clearcuts during at least the first growing season to improve pine survival.

The greatest period of diet overlap for deer and cattle is during winter and early spring when deer and cattle are sharing hard mast and evergreen or tardily deciduous woody plants such as water oak (Quercus nigra), red maple (Acer rubrum), yellow jessamine (Gelsemium), Japenese honeysuckle (Lonicera japonica), blackberries (Rubus spp.), and greenbriars (Similax spp.) (Thill 1984). Apparently, little competition occurs during other seasons. Management of the grass resource seems to be the key to resolving the conflict between cattle and deer. Because grasses are so important to the diet of cattle, stocking levels should be based on production estimates of grasses (Thill 1984).

Grazing by cattle also modifies habitat quality for other wildlife species. Moore and Terry (1979) suggested that in Florida, cattle grazing actually improves habitat quality for other species by reducing the abundance of plants that are of relatively low quality. In addition, moderate trampling by cattle breaks up dense ground-level vegetation, stimulates the development of other ground-level plants, exposes seeds, prepares a seedbed, and provides access for ground-feeding wildlife.

The influence of grazing other livestock species, such as hogs (Sus scrofa), in the shortleaf pine ecosystem are less well understood. Sweeney and Sweeney (1982) have compiled a thorough review of the food habits and habitat use of wild or "released" hogs. Hogs are opportunistic feeders, eating whatever foods are available. Like cattle, hogs also seem to prefer succulent young grasses during spring (Springer 1977, Roark 1977), but do not use them so heavily during other times of the year (10% to 36% of the diet). Acorns are used heavily during fall and winter, comprising as much as 50 to 84% of the diet. Roots are used year-round. Also used are soft mast, mushrooms, carrion, invertebrates, bulbs, and pine seeds. Their preference for acorns and pine seeds have at times inhibited forest regeneration (Wahlenberg 1946, Wakely 1954, Lucas 1977). Most wildlife species do not benefit from the presence of feral hogs because of their heavy use of hard and soft masts and their destructive feeding habits. However, the degree of competition depends upon the relative abundance of mast crops, alternative food supplies, and the hog population (Sweeney and Sweeney 1982).

Often, owners of forestlands are not in complete control of grazing practices on their lands. This is particularly true of large industrial or federal forestland owners and landowners in that portion of the shortleaf range where the "common lands" attitude remains prevalent. These landowners are sometimes trapped between those interests that demand access for grazing and those interests that demand regulations on grazing (Rochelle and Melchiors 1985). Improved relations between these user-groups may be achieved by fostering more ethical behavior and an awareness of fiscal responsibility among livestock owners, and by informing sportsmen and conservationists of the positive aspects of regulated grazing practices.

Public use of shortleaf forests

Recreational use of the shortleaf forest is another factor that affects both timber and wildlife resources. Many forestland owners have management objectives that are adversely affected by public use. In turn, recreational users of forestland may perceive the management practices of the landowner as detrimental to their recreational pursuits. These problems are particularly acute on privately owned forestland.

Hunting is the most important recreational use of privately owned forestlands in the southeastern United States (Kluender 1978, Owen et al. 1985). Use of forestland by hunters, however, can lead to problems such as litter, road damage, timber damage, trespass, and interference with landowner activities (Owen et al. 1985). Unregulated access for hunting can also result in undesirable impacts on wildlife populations. Careful regulation of game harvests cannot be achieved without access control. In addition, landowners are less likely to encourage wildlife populations if these populations only attract problems. Liability of landowners for recreationists is also a disincentive to wildlife management. Often used programs for achieving access control are posting, road closings, and leasing. Quite often, however, landowners simply ignore the problem (Owen et al. 1985).

Other important public uses of the shortleaf forest include trash dumping, firewood gathering, fishing, three and four wheel vehicle use, sightseeing, and trapping (Owen et al. 1985). Many of these uses, if unregulated, can also lead to serious problems for both timber and wildlife resources. For example, illegal trash dumps are often the source of wild fires that can occur during any time of year. In addition, the individual, corporation, or agency on whose land the dump is located can be held legally responsible for adverse consequences of the dump. Landowners are often fined for a dump that they did not start, that they have vigorously discouraged, and that they have even attempted to clean up. Illegal firewood cutting is also a major problem for timber and wildlife resources. In the shortleaf forest, this cutting often occurs in streamside management zones or other areas left specifically for the benefit of wildlife populations and results in a reduction of habitat quality.

As the human population increases in the southeastern United States, demand for recreational access in the shortleaf forest will increase. Ways must be found to promote harmony among user-groups and between users and landowners. Programs designed to raise the level of ethics among recreationists are one means of addressing this problem. Recognizing that the forestland owner is the producer of our wildlife resource and properly compensating him or her for this effort would also be beneficial (Leopold et al. 1930, Lewis 1983).

CONCLUSIONS

Timber management in shortleaf stands should be modified to accomodate the needs of as many wildlife species as possible. In particular, we should be aware that our forests are home to numerous neotropical migratory species that depend heavily upon shortleaf forests for their life requisites. Use and awareness of this nongame resource is increasing. For example, 28.8 million Americans took trips during 1980 primarily to participate in "nonconsumptive" wildlife-related activities (U. S. Dept. Interior 1982). An additional 9.4 million citizens enjoyed wildlife "nonconsumptively" during that year while on trips for other purposes. During 1980, 10% of Americans over 16 years old were hunters but 55% of Americans made nonconsumptive use of wildlife resources. These citizens are also rapidly learning how to encourage public agencies and privately owned corporations to manage for wildlife species they enjoy.

Management practices that should be encouraged include routine prescribed burning, leaving snags, and retaining hardwoods in areas such as streamside management zones. Regulating other uses of the shortleaf forest such as recreational use and grazing will also be benificial to wildlife communities. The implementation of these practices on private lands have costs that the public often expects the landowner to bear. However, the public must learn that conservation of our forest and wildlife resources is a matter of concern for all citizens. The private landowner should be reimbursed for implementing management practices that are favorable to wildlife resources that belong to all Americans. Users of timber, wildlife, and grazing resources on public and private lands must also understand that resource use carries with it fiscal and ethical responsibility. Collectively, these steps can benefit landowners, timber resources, wildlife resources, and all users of the shortleaf forest.

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PROTECTION OF SHORTLEAF PINE FROM INSECTS AND DISEASE

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ABSTRACT

All major and potentially serious insect and disease pests of shortleaf pine are briefly presented and discussed. Major emphasis of discussion is that losses can be minimized by selection and application of appropriate pest management systems. With some pests, integrated control can be supplemented with an economic analysis to further assist selection of management options.

INTRODUCTION

As a major commercial timber species, shortleaf pine is relatively free of destructive disease and insect pests. Potentially serious growth losses and mortality, however, can be caused by several normally insignificant pests which increase following certain management activities. The two most serious pests, the southern pine beetle and littleleaf disease, are discussed in some detail. Currently available integrated pest management systems which can be easily incorporated into the management plan are introduced and discussed.

DISEASES

Nursery problems

Nursery seedlings of shortleaf pine are subject to damping off caused by *Rhizoctonia solani* Kuehn, *Fusarium oxysporum* (Schl.) em. Snyd. & Han., and *Sclerotium bataticola* (Taub.) (Hodges 1962) in soils with pH above 6 and under moist weather conditions.

Needle diseases

Foliage diseases include the needle rusts (*Coleosporium* spp.), needle casts [*Ploioderma* (*Hypoderma*) *lethale* (Dearn.) Dark. and *P. hedgcockii* (Dearn.) Dark.], and brown spot [*Scirrhia acicola* (Dearn.) Sigg.] (Hepting 1971). *Lophodermium pinastri* (Schrad. ex Hook.) Chev. is commonly observed on dead needles but is not believed to be parasitic (Boyce 1951). Witches' brooms, of apparent genetic origin, are occasionally encountered.

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Cankers

There are many stem and twig diseases but none are very damaging. Atropellis tingens Lohm. & Cash (Diller 1943) sometimes kills twigs and small branches but only produces a characteristic elongate perennial canker on larger stems and branches (Lightle and Thompson 1973). The wood beneath the canker will have a blue-black discoloration. A few trees of all ages and sizes are affected in any given stand.

Pitch canker (Fusarium moniliforme Sheld. var. subglutinans Wr. & Reink) is increasing in incidence, especially on stressed trees, and can be locally serious following insect injury. Infection results in copious resin flow and a resin-soaking of the wood under the canker face extending to the pith (Dwinell 1978). Cankers on small shoots result in dieback of the shoot. Dead needles may persist for more than a year and fade to a dull, grayish-brown color (Blakeslee et al. 1980). Cankers on large branches or on the upper portion of the main stem often do not kill the shoot until the following year, whereas cankers on larger stems usually live longer and produce copious resin flow (Blakeslee et al. 1980). These cankers, though, eventually girdle the stem.

Rust

Stem and branch infections of gall rust [Cronartium quercuum (Berk.) Miyabe ex Shirai f. sp. echinatae (Cumm.) Burds. et Snow] are occasionally encountered. Infections are usually scattered but sometimes there are extremely heavy infections on both pines and oaks, reflecting a previously favorable microenvironment for spore production and infection. In any case, this rust is not damaging except to seedlings.

Comandra blister rust (Cronartium comandrae Pk.) is a potentially serious threat that can be devastating wherever the alternate host is abundant. Shortleaf pine is quite susceptible (Berry et al. 1961). The natural range of the alternate host, Comandra umbellata subsp. umbellata Piehl, extends as far south as northern South Carolina and northern Georgia, Alabama, Mississippi and Arkansas (Piehl 1965). The rust is most destructive in plantations in the Ouachita and Ozark Plateaus of Arkansas and Missouri and in the Cumberland Plateau of eastern Tennessee. Although there is some indication that the Arkansas strain has adapted to the higher mean temperatures of the southern states (Eppstein and Tainter 1976), phenological and epidemiological studies (Dolezal and Tainter 1979) indicate that occurrence of comandra rust on shortleaf pine is dependent on close proximity of pines to infected alternate host plants and the passage of weather frontal systems which disseminate and disperse spores. Since the alternate host is an early colonizer of disturbed or mechanically prepared sites its presence is a reliable predictor of potential damage. The comandra plant also tends to maintain itself well and will even flourish if livestock grazing is allowed in older plantations.

Heart rot

The only trunk rot, Phellinus (Fomes) pini (Thore ex Fr.) A. Ames (red heart), is seldom a problem in trees less than 80 years of age (Hepting 1971). It is presently a problem only in parks, urban areas, or other areas where older trees are maintained.

Root rot

Root rot caused by Heterobasidion annosum (Fr.) Bref. (Fomes annosus) is common throughout the range of shortleaf pine and some other southern pines wherever there are deep, well-drained sandy soils (Wilson 1963). Because of their high clay contents, most piedmont soils are of low hazard to annosum root rot. However, one can expect losses from annosum root rot to increase as the sand content of the surface layer of soil increases. It is not unusual to find sites with from 10-12 inches of sandy clay in the upper horizon. Stands on these sites may not exhibit appreciable mortality, but diameter and height growth of infected trees may suffer, similar to growth losses in loblolly pine (Bradford et al. 1978). The colonization of shortleaf pine stumps by H. annosum was demonstrated by Kuhlman et al. (1962). Stump colonization following thinning is the means by which H. annosum enters the stand. Subsequent thinnings on high risk sites can result in a greatly increased incidence of root rot due to this pathogen. On some sites, annosum affected stands can be confused with littleleaf disease unless root excavations are made and positive root isolations are obtained. Annosum root rot mortality on high risk sites and growth loss on low risk sites can largely be avoided if guidelines for prevention are heeded (Froelich et al. 1977). Prevention depends largely on recognizing the degree of risk, then selecting appropriate controls.

Old growth shortleaf can be found to be infected with Phaeolus (Polyporus) schweinitzii (Fr.) Pat. but this is a practical problem only in recreation areas or with some urban trees.

The most important disease of shortleaf pine is littleleaf disease (Campbell and Copeland 1954). Littleleaf disease was first recognized in 1934 in Alabama. Although the common name of the disease suggests shortleaf pine as the only host, loblolly pine is also affected when it occurs on unfavorable sites for the tree species and where the fungus involved can develop (Oak and Tainter 1985). The fungus, Phytophthora cinnamomi Rands, associated with littleleaf is an important root pathogen on many hosts, including conifers and hardwood species. It has been reported on over 100 different hosts.

Since the original report of littleleaf, the disease has been found only east of the Mississippi River in piedmont and certain contiguous mountain and upper coastal plain areas from Virginia to Mississippi. P. cinnamomi is more widely distributed than the disease, occurring in southern and western United States as well as other temperate and many tropical and subtropical regions of the world.

At one time, shortleaf pine occupied 41 million acres in southeastern United States. Although shortleaf pine is presently of less importance on federal lands, this species is still prevalent on private lands, especially on those managed by the small, nonindustrial owner. The fact that littleleaf affects trees over 20 years of age, and especially trees 30-50 years old, makes this an especially serious problem.

As is typical of many root diseases, the symptoms consist of sparse foliage, short needles, tufted upturned groups of needles and yellow foliage. Affected trees die within 3-10 years and once affected grow very little in height and diameter. Normal growth rings may be 0.5 inch in width per year and in affected trees only hundredths of an inch. Cones from infected trees are smaller and the seed less viable. Necrotic brown lesions form on large roots and many of the small roots die.

P. cinnamomi has been known as a root parasite on such hosts as chestnut, avocado, azalea, cinnamon, oak, pineapple, and chincona. At first, P. cinnamomi was difficult to obtain from diseased trees, but by using the apple as a selective medium, a correlation was found between incidence of fungus and the disease (in healthy stands, P. cinnamomi was isolated from 5% of the root samples but was recovered from 42% of the samples from littleleaf trees). When shortleaf and loblolly pine seedlings were inoculated with the fungus, reduced root and top growth resulted. P. cinnamomi apparently restricts its activities to the root system and scions from littleleaf infected trees grafted onto healthy root stock will recover completely. The fungus is present in soil to a depth of 12 inches and is most abundant in the upper 2-3 inches. There is not necessarily a positive correlation between relative abundance of P. cinnamomi and disease incidence.

Apparently the fungus is widespread throughout the South, but the disease develops primarily in clay soils where internal soil drainage is poor. Infection of the host occurs when roots are most active, probably in spring and fall with very little infection during the summer. Throughout the year, roots of diseased trees contain less than one half of the starch and sugar found in healthy roots. Soils that are poorly drained, severely eroded, shallow in depth, highly variable as to porosity, permeability, compactness, or plasticity and usually low in fertility are likely littleleaf sites.

Diseased foliage contains approximately 1/3 to 1/2 the normal amount of nitrogen. If the trees are in the early or intermediate stages of littleleaf, the addition of nitrogen reduces symptoms. The addition of large quantities of organic matter low in nitrogen and mechanical injury of the roots will result in increased symptoms. These facts indicate that littleleaf is the result of the failure of the roots to absorb nitrogen even though this nutrient is present in adequate amounts in the soil.

The fungus is able to spread for short distances through the soil by means of swimming zoospores. Another kind of spore, the thick-walled oospore, enables the fungus to survive unfavorable conditions, such as when the soil is dry. P. cinnamomi also produces chlamydospores in soil and root exudates stimulate their germination. The fungus penetrates epidermal cells directly and also invades the host roots through wounds.

For management of existing stands that have some littleleaf symptoms, the following cutting practices have been recommended to minimize overall losses (Campbell et al. 1953):

1. If only an occasional tree is diseased, cut lightly at 10-year intervals.

2. If 10-25% of the stand is diseased, cut at 6-year intervals, removing all diseased trees.

3. If over 25% of the trees are diseased, clear cut as soon as the stand is merchantable.

Predicting littleleaf risk can be done for existing or future stands using two methods. In the first rating system, on-site evaluations are made of erosion class and internal drainage characteristics of the soil, and a 100-point system used to classify risk (Campbell and Copeland 1954). The second rating system utilizes the identified associations of some soil series with different amounts of littleleaf (Campbell and Copeland 1954). Internal drainage characteristics for these soils were summarized from published Soil Conservation Service (SCS) descriptions and extended to previously unrated piedmont soils (Oak 1985). Though more general than the point system, the soil system does not require on-site evaluation but can be applied using existing SCS county survey maps. Soil types which are high hazard for littleleaf disease are characterized by the SCS as having mostly clay subsoils with moderately slow to slow permeability about 12 inches below the surface.

Using this information hazard maps may be prepared identifying high hazard sites which the forest manager can use to provide treatments before actual growth losses occur. On U.S. Forest Service lands in the piedmont, stand hazard ratings and other important stand information are maintained and updated using a computerized data management system and are used for short- and long-range planning purposes. Hazard ratings are used in the compartment prescription process when priorities are established for harvesting, thinning, regeneration planning, stand conversions, timber stand improvement, and possible fertilization. They are also valuable for setting priorities in reconnaisance and salvage activities during attacks by southern pine beetle. An overview of the interrelationship in the piedmont between littleleaf disease and the southern pine beetle is provided by Belanger et al. (1986).

INSECTS

Sawflies

Several species of spring- and summer-feeding pine sawflies (*Neodiprion* spp.) can cause locally serious damage to shortleaf pine. Sawflies receive their name from the saw-toothed ovipositor which the female uses for cutting slits in the needles in which to lay eggs. The damage is done by the larvae as they feed on the foliage. Some sawfly larvae are gregarious and as they consume all of the foliage tissues, the defoliation can be impressive. Attack is usually restricted to trees less than about 15 feet tall.

Reproduction weevils

First year plantings of shortleaf pine may be seriously attacked by two reproduction weevils, *Hylobius pales* (Herbst) and *Pachylobius picivorus* (Germ.), the pales and pitch eating weevils. Only the adults cause tree injury. They eat areas of bark and phloem and may girdle the twig or seedling or weaken the seedling, predisposing it to drought.

Damage only occurs where pines were present in previous stands. Reproduction weevils are not a problem in old-fields or in aerially-seeded plantations. Nor are they a problem in stands harvested and site-prepared before July since overwintering adults and their broods will have migrated from the areas before fall or winter planting. High hazard sites are those which were previously in pine and have been harvested after June 30 or have been site-prepared in late summer or early fall. Weevils are attracted to volatiles released from pines damaged during these operations. Adults initially feed on the inner bark of fresh stumps or coniferous logging debris. When this material is no longer available, the weevils feed on pine seedlings or the inner bark of twigs of larger trees.

If the weevils are attracted into an area early in the spring or summer year, they will lay eggs and disperse to other areas before fall. If attracted into an area in fall, they will lay eggs but will stay on the site until the next spring. It is this combination of overwintering parent adults and emerging brood adults that accounts for the heavy damage in newly regenerated plantations.

Management of reproduction weevil populations consists of three alternatives: (1) harvest before June 30, (2) delay regeneration one year, or (3) the use of insecticides. If planting is delayed one year, all weevils will have migrated from the area and no damage will occur. The economic loss associated with the loss of one year of growth, however, may be unacceptable. A variety of insecticides and treatments are available and are effective against a given anticipated level of attack. Under extremely heavy weevil populations, however, even insecticide-treated seedlings may be killed (Cade et al. 1981).

Tip moth

The Nantucket pine tip moth [*Rhyacionia frustrana* (Comst.)] is a serious pest of young plantation-grown shortleaf pines. Tip moths infest developing shoots and buds. Adults emerge in spring and females lay eggs for the first generation. Larvae tunnel in the twig and eventually into the base of the bud. There are 2 to 4 generations per year, 5 to 6 in the extreme south.

Attacks are concentrated in the upper portion of trees less than 15 feet in height. Preferential attack of the leading terminal shoot leads to growth response by the host as either a whorl of adventitious buds forming just below the killed bud, or a lateral branch assuming dominance and becoming the new leader. Damage may result as a severe stem deformity, more knots in the wood, more compression wood, and some amount of growth loss. The net effect is to delay crown closure.

In unthinned stands, growth of tip moth attacked trees nearly catches up in volume growth by rotation age. In thinned stands, however, the growth differences are carried throughout the rotation.

High hazard sites for tip moth are those that have been mechanically site prepared, and they are even higher in hazard if they have had herbaceous weed control. Pine tip moths are attracted to the higher nutritional value of more vigorous trees and, thus, high populations result. There also appears to be a relationship between high populations of tip moth and incidence of pitch canker fungus. Several insecticides and correct timing of their application are effective but may not be cost-effective.

Bark beetles

The southern pine beetle (SPB) (*Dendroctonus frontalis* Zimm.) is the most destructive insect pest of shortleaf pine. It is greatly feared because great epidemics may develop with concurrent heavy mortality. Attacked trees are colonized with blue stain fungi, followed by wood decay fungi and the wood rapidly deteriorates. Beetle attack may shift management expectations significantly for the stand and incur actual control and salvage costs. In addition, substantial degrade may occur in the salvaged logs.

In general, SPB infestations are associated with adverse conditions, such as lightning or other injury, moisture extremes, excessive stand density or stocking levels, slow growth rate, and diseases such as annosum root rot and littleleaf.

Stand risk rating is one of the first steps toward minimizing losses to this pest. Different systems are available for different geographic areas (the mountains, piedmont, and coastal plain) and for different landowners (USDA Forest Service, private industry, and the small private landowner).

Information necessary to apply the system may come from a variety of sources. Risk rating may employ data obtained from aerial photographs (Mason et al. 1981) including basal area/acre, total stand height, species composition, crown closure, average tree diameter, and topographic position; or utilize readily available resource data (Lorio and Sommers 1981) such as forest type, tree size and age, stand density, and site index from continuous inventory of stand conditions. These are subjected to a sequential evaluation to determine stand risk for SPB.

Another system (Ku et al. 1980) uses field data collected in SPB attacked stands to identify unique factors that predisposed those stands to attack and includes variables of total basal area, hardwood basal area, stand age, and radial growth in last 10 years. Since the data were collected from undisturbed natural stands on upland flats, application of this system is best suited to these sites.

A system for predicting potential loss from SPB in the Gulf coastal plain of Georgia (Karpinski et al. 1984) uses the variables of landform, total basal area, and percent pine. These variables can be collected in the field in conjunction with a simple prism cruise or in the office if suitable stand records exist. This system determines risk of spot occurrence and then determines hazard of spot spread. These two can be combined to determine potential loss which is then used to determine the need for cultural treatment. A similar system is used for SPB hazard rating in the mountains of Georgia (Karpinski et al. 1984).

Two systems have been developed for the piedmont (Karpinski et al. 1984 and Belanger et al. 1981). Risk in the former is evaluated from the percentage shortleaf pine component, percent slope, and percent clay content. For the latter system, variables included proportion of shortleaf pine, radial growth, amount of clay and depth of surface soil. A land manager's model was also developed which included four variables that are easily measured or are contained in existing inventories.

The significant variables in both of these systems strongly suggest the contributing role of littleleaf disease in predisposing trees to attack by SPB, and stand treatment to reduce SPB risk may actually preempt recommended controls for littleleaf-related injury. Recent control efforts for SPB in shortleaf pine stands are aimed at minimizing initial attack of the beetle and reducing its chances of spread if a spot is initiated. This is done by identifying high risk stands and then using thinning, harvesting, or other stand manipulations to reduce the amount of wood lost. Almost no direct or chemical controls are used to reduce beetle populations.

INTEGRATING PEST MANAGEMENT INTO OVERALL FOREST MANAGEMENT

A demonstration project conducted on USDA Forest Service lands carries pest management one step further along toward integrating pest control into the overall forest management plan and, if successful, will provide a strong impetus to expanding the concept to other land management groups. This represents a natural evaluation from an early approach toward integrating the available management strategies for control of major diseases of southern pines, including shortleaf, provided by Anderson and Mistretta (1982) and later updated (Anderson et al. 1985). This latest development is outlined by Hoffard and Oak (1985) and represents the closest practical refinement yet of the integrated forest pest management concept for this tree species.

In this project major tree pests were identified on national forest districts in the piedmont of Georgia and South Carolina. These included fusiform rust, annosum root rot, pales weevil, littleleaf disease, and SPB. Best available risk rating systems were selected from those mentioned previously. Where appropriate, economic analysis of control options was provided through the IPM Decision Key (Anderson et al. 1985).

This technology was communicated to federal land managers at the district level and district personnel assisted in production of hazard maps in a form compatible with their current management methods. All appropriate data were computerized for the mapping process and to assist in long-term storage and retrieval of the data. This was accomplished by using a computerized Geographic Information System developed by Beveridge and Knapp (1984). This system allows overlaying of different data files (e.g. such as overlaying soil hazard with forest type, or age) and it can be done on the same scale as maps currently in use in ranger districts.

The hazard maps and pest related recommendations will be placed in compartment prescription files for continuing reference. Ready access of this information will ensure that pest management information will be considered in the future in formulating silvicultural strategies.

This project has thus far met with great success at the district level. District personnel recognize that some pests are causing severe losses and that preventative measures must be addressed if losses are to be minimized. Consideration of major pests and control strategies in the prescription file each 10 years ensures that potential problems will be addressed before they actually occur. Even more benefits will accrue when this concept is expanded and employed by other forest landowners.

CONCLUSION

Current and potentially serious pests of shortleaf pine can be successfully managed to minimize losses if available pest management information is considered within the overall forest management plan.

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ESTHETIC CONSIDERATIONS IN MANAGEMENT OF SHORTLEAF PINE

Robert H. Stignani[1]

ABSTRACT

Application of esthetic concerns in the management of Shortleaf Pine or any species should be predicated on a systematic approach. Many mitigation techniques are available, but those selected will need to be carefully tailored to the specific situation and to the unique characteristics of plant communities and landforms involved. Some additional costs should be anticipated by forest managers who are commited to manage all natural resources. The growing use of computer technology will lead to increasingly sophisticated application of computer graphics to resolve resource conflicts.

INTRODUCTION

Historically, esthetics in forestry has not been a very relevant factor. Undoubtedly, many of those who pioneered in the early days of the timber industry in this country had an underlying recognition of and a concern for the natural beauty in which they labored. While this concern has only attained a status approaching that established for commodity forest resources in recent years, there is evidence that forest esthetics easily qualifies as an octogenarion.

Our earliest reference dates from 1903, in which the following is quoted from the Bureau of Forestry Departmental Reports - Report of the Forester:

> Southern Appalachian Hardwoods - "The tract of the Linville Improvement Company, comprising 16,000 acres in Mitchell, Caldwell, and Watauga counties in North Carolina, offered a somewhat unusual problem in the preparation of a working plan. . . . The present owners desire to cut the mature trees in such a way that the beauty of the forest will not be impaired, while its condition will be improved. . . . The problem of lumbering at a profit in such a way as to improve the condition of

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the forest without impairing its beauty was carefully studied. . . . The working plan contains detailed instructions for the location and execution of the cuttings, so planned as not to injure standing trees and young growth, and to provide for reproduction."

Thirteen years later, an early textbook authored by Yale University Professor James W. Toumey included the following paragraph under a section entitled "Species Selected for Their Esthetic Qualities":

> "When the object in establishing a forest by seeding or planting is its pleasing appearance in the landscape, the choice of species is less restricted. It depends upon the personal taste of the owner and the esthetic qualities of the species. The effect produced is governed primarily by the grouping of the species and how well they fit into the general landscape. For instance, the form and foliar effects of species that are effective along water courses are usually inappropriate on high ridges. In most instances, a mixed uneven-aged forest in which the stand is not too dense is more pleasing to the eye and affords greater variety in form, color, and foliage than an even-aged stand of a single species. In the selection of species for esthetic purposes, therefore, special attention should be given to their form, color, foliage, and grouping. As a rule, the native species should be the basis of all planting for esthetic purposes, as they fit better into the general landscape. Exotic species and indigenous species from more or less remote regions, if adapted to the site, can be used in order to give variety or attain some particular effect."

Over 70 years later, we have finally turned the corner in accepting visual resource values as something that can be measured and evaluated and is worthy of management, along with timber and other more tangible forest resources. Yet it has been a most painful process. Consider the following House Resolution which was introduced in March 1985, by State Representative Ode Maddox and was passed by a large majority of the State of Arkansas General Assembly:

HOUSE RESOLUTION

> REQUESTING THE UNITED STATES FOREST SERVICE AND THE SEVERAL TIMBER COMPANIES TO LEAVE BUFFER ZONES ALONG U.S. HIGHWAYS, ARKANSAS SCENIC HIGHWAYS AND ALONG THE SHORES OF LAKES IN THIS STATE WHEN THEY CLEARCUT THE TIMBER ON LAND ADJOINING THE HIGHWAYS AND LAKES.
>
> WHEREAS, the clearcutting of timber is an unsightly operation; and WHEREAS, the majority of tourists coming into and passing through this State travel upon the U.S. highways and Arkansas scenic highways within this State and visit the beautiful lakes in the State; and
>
> WHEREAS, the General Assembly exercises its best efforts to promote tourism in Arkansas; and
>
> WHEREAS, in keeping with this goal it is necessary that buffer zones be maintained along the U.S. highways and Arkansas' scenic

highways and along the shores of lakes in the State when the timber is being clearcut on the land adjoining those highways,

NOW THERFORE, BE IT RESOLVED BY THE HOUSE OF REPRESENTATIVES OF THE SEVENTY-FIFTH GENERAL ASSEMBLY OF THE STATE OF ARKANSAS:

That the United States Forest Service and the timber companies within this State are requested to leave buffer zones along U.S. highways and Arkansas' scenic highways and along the shores of lakes in the State when they clearcut the timber from lands adjoining these highways and lakes.

BE IT FUTHER RESOLVED that upon the adoption of this Resolution the Chief Clerk of the House shall forward a copy hereof to the United States Forest Service at Hot Springs and various timber companies in this State.

U.S. Forest Service recognition of such a plea is supported by a number of acts, regulations, objectives, and policies, with the National Forest Management Act of 1976 perhaps being one of the most significant. However, continuing diligence is necessary to realize the essence and the spirit of such concern. Thus, once an agency, company, or individual has established a commitment to acknowledge and manage the visual resource, the question tends to be reduced to "how," and "at what cost?"

SYSTEMATIC APPROACH

Time will not permit us to address the point in depth; there is, however, a need to discuss, at least briefly, the basis for much of the systematic analysis of scenic quality used both in this country and abroad today--the Forest Service Visual Management System (VMS). In a nutshell, the Forest Service-VMS, developed primarily in the early 1970's, identifies: basic concepts (characteristic landscape, variety, and deviations); dominance elements (form, line, color, texture); dominance principles (contrast, sequence, axis, conver- gence, codominance, and enframement); and a range of variable environmental factors (motion, light, atmospheric conditions, season, distance, observer position, scale and time).

Interestingly enough, several key factors such as variety, form, color, and foliar texture can be traced directly to the early text reference of Professor Toumey.

These factors interact with each other and three primary evaluation criteria:

1) Distance Zones, or divisions of a particular landscape being viewed;
2) Sensitivity Levels, or a measure of the number of viewers and their concern for scenic quality;
3) Variety Class, a stratification of scenery, or inherent scenic quality based on the degree of variety or diversity when related to a "local" physiographic frame of reference.

These criteria are in turn combined to establish a hierarchy of achievable management objectives called Visual Quality Objectives (VQO's):

Preservation - A VQO that allows for natural changes only.

Retention - A VQO which, in general, means man's activities are not evident to the casual forest visitor.

Partial Retention - A VQO which, in general, means man's activities may be evident but must remain subordinate to the characteristic landscape.

Modification - A VQO which, in general, means man's activity may dominate the characteristic landscape, but, must, at the same time, utilize naturally established form, line, color, and texture, so that its visual characteristics are those of natural occurrence with the surrounding landscape.

Maximum Modification - A VQO, which, in general, means man's activity may dominate the characteristic landscape. However, when viewed as background, the visual characteristics must be those of natural occurrences within the surrounding area.

Once a visual objective has been determined for an area, silvicultural practices can be modified to achieve the desired visual result. However, it should be pointed out that not all standard silvicultural practices are automatically detrimental to forest esthetics. In fact, the visual values we enjoy today may not persist in many, if not most, timber types without some degree of management. For example, thinning in some areas may be necessary to even see into the forest. In many parts of the Eastern United States, travelers by both road and trail are denied outstanding views of the distant countryside because of the vegetative enclosure that characterizes the landscape. Increased variety of vegetative pattern or rehabilitation of visually disastrous earlier impacts may often be tempered by increased cutting rather than reduced cutting.

Still another facet of the art and science of visual resource management deals with the relative ability of land to withstand management manipulation without a significant effect on its visual character. This Visual Absorption Capability addresses certain environmental factors such as complexity of the landscape, slope, vegetative screening potential, soil or rock color contrasts, and vegetative regeneration potential, together with observer position factors of relation to focal points, visual magnitude or aspect relative to distance, and the frequency an activity may be seen. These factors should be considered when coordinating silvicultural practices to meet esthetic objectives.

As is often the case, the ounce-of-prevention vs. the-pound-of-cure adage is valid in visual resource management also. The better the early planning and analysis, the less remedial mitigation that may be required. However, the best overall approach generally is the result of adequate advance planning, effective implementation of prescribed mitigation, and follow-up monitoring to assure compliance.

One additional observation emerges with the acceptance of a systematic analysis of scenic values: the need for schools of forestry to include forest esthetics in their curriculum. While this concern is not based on any specific research, it is apparent that most forestry graduates in recent years have had little or no academic exposure to such concepts. In an era where social concerns are having an increasing influence on commodity-oriented management decisions, young foresters should be better equiped to deal with this added dimension of professional forestry.

PRIVATE SECTOR APPLICATION

Although this systematic evaluation and analysis was pioneered by the U.S. Forest Service and subsequently was adopted in various forms by others, the private sector generally has not seen the need to embrace systematic consideration of visual resource management. An early exception, however, was the Georgia Kraft Company. Their Woodlands Division, headquartered in Rome, Georgia, developed a Forest Landscape Management Plan in 1975 that was essentially based on the Forest Service Visual Management System. The stated objective for their plan was: "to apply the concepts of Forest Landscape Management on Georgia Kraft Company forest lands to the extent necessary and compatible with the basic objective of maximum wood fiber production by recognizing visually vulnerable landscapes and treating these areas with alternate management options to reduce the undesirable visual impacts of some standard management practices." Today, over 10 years later, although their plan receives somewhat less emphasis than when it was first established, Georgia Kraft has not abandoned the plan but still follows its procedures and standards.

Although the private sector has not been particularly enthusiastic about visual resource management, there are indications of a high level of concern for esthetics. In a paper presented by William D. Ticknor at the National Meeting of the American Forestry Association in Traverse City, Michigan last October, he reported the findings of a recent survey of private timberland owners published in the September 1985 Northern Journal of Applied Forestry. Land owners, asked to characterize the importance of nine ownership objectives, responded with the following priority and percentage of those indicating the factors were "very" or "somewhat" important ownership considerations:

Provide shelter for Wildlife	87.2%
Preserve natural beauty	81.1%
Heritage for future generations	80.3%
Provide own firewood and timber needs	65.6%
Family recreation	60.3%
A place to hunt	55.4%
Future investment	51.1%
Homesite	43.6%
Produce income from sale of wood products	16.2%

While such findings are in no way conclusive or universally applicable, they do reflect an often latent but real concern for esthetics.

VISUAL FACTORS OF SHORTLEAF PINE

This general overview of systematic visual resource analysis is relevant to management of any forest species anywhere, as has been proven many times in recent years where the principles, theory, and implementation of visual resource management have been applied not only throughout the U.S. but in several foreign countries. Thus, this discussion is equally applicable to Shortleaf Pine (SLP).

The adaptability of SLP has made it the most widespread of any pine species in the southeastern United States (Lawson and Kitchen, 1983). The inherent diversity resulting from its inclination to occur naturally in mixed stands of many forest cover types, constitutes a significant esthetic factor. This characteristic becomes a substantial plus when the forest manager is faced with designing a pleasing shaped clearcut in a highly sensitive visual area.

SLP growth throughout the interior highlands of the southeast in both pure and mixed stands is another major visually significant characteristic of the species. Because visibility of harvested stands increases considerably with terrain change, particularly in the most vulnerable middleground distance, forest managers need to include visual objective considerations that might otherwise be unnecessary in the flatlands of the Coastal Plains. Thus, the irregular boundary of a naturally occuring SLP stand lends itself to the build-in mitigation technique of an undulating and irregular edge that blends well with the terrain and adjacent stands of hardwoods.

In considering foreground views, the characteristics of individual trees becomes a more significant factor. Since some of the best SLP growth sites include the fine sandy loams or siltloams characteristic of flood plains of small streams (Fowells, Et al, 1965), the more spectacular sized trees could be expected to thrive here. Such locations similarly often lie in proximity to roads and highways from which examples of exceptional SLP individuals can be easily seen and appreciated. A forest manager's awareness of this phenomenon, whether based on either casual observation or a more detailed inventory, could lead to at least an interim protection of selected groups of SLP whose visual value to the traveling public may well exceed their commodity value.

Another aspect of foreground management along visually sensitive road corridors relates to the contrived, unnatural appearance often evident in pine plantations where mechnical tree planting was done at right angles to the observer. With a little forethought, this negative effect can be avoided by planting the first several rows adjacent to the travel corridor parallel to the observer, or, preferably, in small random groups. Subsequent management to encourage these naturalized margins, enhanced perhaps with hardwood inclusions, all contribute to an uneven-age appearance along these roads which will improve the esthetics considerably.

Because SLP is generally fire resistant (Fowells, Et al, 1965), use of prescribed burns can often expand visible depth into the stand; however, associated species, especially understory hardwoods, if not protected may be eliminated, thus leading to a loss of stand diversity.

One major problem that should be of concern to forest managers attempting to deal with visual values as well as commodity production, is SLP regeneration competition from hardwoods or other pines (Barrett, 1980). The characteristic slow start of SLP seedlings results in a protractive period of visual impact for a harvest clearcut that may be located in a highly sensitive view area. While a range of mitigation techniques such as block shaping and slash reduction may have already been planned, recognition of this extended residual impact, particularly on poor sites, is also essential. One obvious solution, which in fact is already applied by some forest managers for economic rather than esthetic reasons, is to replant to faster regenerating species such as Loblolly Pine. But where the management objective is to perpetuate a SLP stand, this solution may be unacceptable. Research has shown that with adequate seedbed treatment, some overhead shade is desirable until seedlings become established. However, prolonged overstory competition can be highly detrimental to young reproduction (Fowells, Et al, 1965). This combination of factors suggest that the application of a seedtree or modified seedtree cut may be appropriate to best meet both silvicultural as well as visual objectives. Experience indicates that seedtree or shelterwood cuts, especially those viewed from middleground distances of about one-half to three miles, substantially reduces the visual contrast, the essence of negative impact on the landscape.

On small tracts, uneven-age management of SLP using single tree or group selection and natural regeneration is a viable alternative that would particularly favor stand esthetics.

SPECIFIC MITIGATION TECHNIQUES

In reference to the House Resolution passed by the Arkansas Legislature cited earlier, their recommended solution regarding visual impacts of clearcutting along senic highways and lakeshores was to retain (uncut) buffer zones. It should be understood that buffering or screening of an unpleasant appearing clearcut is only one of many visual mitigation techniques. When used as the sole mitigation tool, it may be construed by some as an attempt to hide impacts and thus appear as a deception. On the contrary, when a well-designed clearcut is brought up to a road and unsightly slash and residue has been reduced, the new opening may often be perceived as a positive element, permitting views into the middleground distance which otherwise would have only been a visually impenetrable wall of trees along the traveler's foreground view.

As with any forest species or stand mix, there are a number of techniques that can be applied as circumstances dictate. Time and space preclude more than the partial listing included here, but these examples will serve as a point of interest and departure for those forest managers searching for an appropriate technique:

- Retain selected flowering trees/shrubs.
- Introduce small scale openings along travel routes.
- Maintain old growth characteristics.
- Utilize natural-appearing shapes for clearcut units rather than geometric configurations.

- Develop natural-appearing clearcut edges by: locating harvest boundaries at existing biological edges; tying several clearcuts together over time; locating unit boundaries below the ridge tops; and feathering, through retention of the existing understory just inside the cutting unit boundary, progressively increasing the height of uncut vegetation away from the unit boundary, or thinning along the unit boundary.

- Consider scale or the relative size of a harvest cut in relation to the surrounding landscape or to the human figure.
- Distribute harvest cuts over time and space relative to critical viewpoints.
- Employ modified silvicultural practices: (standard clearcuts, seedtree cuts, or shelterwood cuts that have the general appearance of the standard silvicultural practice but have been changed to favor esthetics and thus do not conform to the true definition).
- Apply residue and slash reduction.
- Retain residual "leave islands," including understory, to benefit both visual and wildlife values.
- Use seasonal logging restrictions.
- Use logging equipment restrictions.
- Consider road and landing location and design.

The forest manager might also consolidate a range of possible visual impact mitigation techniques into a simple matrix which relates the silvicultural practice to the particular visual quality objective identified for a given stand or area. The specific mitigation techniques coded in the sample matrix (Figure 1) are defined in the listing on the following page. These techniques are not applicable in every area; the intent here is only to convey the utility and convenience of such a reference. Of course, the pitfalls associated with any cookbook interpretation of such a tool should also be readily apparent.

Figure 1. Typical Mitigation Techniques to Meet Established Visual Quality Objectives

Coded Matrix

CULTURAL PRACTICES	MOST CONSTRAINED <——————> LEAST CONSTRAINED VISUAL QUALITY OBJECTIVES (VQO's)			
	RETENTION	PARTIAL RETENTION	MODIFICATION	MAX MODIFICATION
CLEARCUT	ABDFIMU	ABDGJLNU	ADHKLO	AD
SEEDTREE	ABCDFIMTU	ABCDGJLNU	ACDHKLO	AD
SHELTERWOOD	ABCDEFIMTU	ABCDEGJLNUV	ACDHKLO	AD
SALVAGE SANITATION CUT	IMU	JLNU	KLO	
COMMERCIAL THIN	EIMU	EJLNU	KLO	
PRE-COMMERICAL THIN	JU	KLN	KL	
SHEAR SITE PREP	I	J	K	
CHOP SITE PREP				
CHAIN SAW SITE PREP	J	J	K	
PRESCRIBED BURN	Q	Q	R	R
INJECTION SITE PREP	NOT APPROPRIATE	NOT APPROPRIATE		
WINDROW	NOT APPROPRIATE	NOT APPROPRIATE		
CHEMICAL SITE PREP		S	S	
SPECIAL USES	P			
ACCESS ROADS	T			

Figure 1. Typical Mitigation Techniques to Meet Established Visual Quality Objectives (continued)

Matrix Code Definitions

A. Establish irregular stand shape avoiding straight lines or geometric forms except as necessary along land lines (follow natural land features).
B. Feather the edge of cut or adjacent stand by retaining (if present) mid and understory trees in a 25' - 100' zone.
C. Leave flowering and ornamental forms of vegetation where practical to enhance vegetative variety.
D. Reduce openings along road to as narrow as possible (1/4 mile preferred maximum).
E. Vary densities of thinnings.
F. No opening exceeding 10 acres (preferred maximum) will be viewed from any location on a travelway or lake.
G. No opening exceeding 15 acres (preferred maximum) will be viewed from any location on a travelway or lake.
H. No opening exceeding 25 acres (preferred maximum) will be viewed from any location on a travelway or lake.
I. Slash removal 150' from edge of travelway in seen area with slash in remaining seen area lopped and scattered to within 2' of ground.
J. Lop and scatter slash to within 2' of ground within 100' zone beyond ROW edge (in seen area).
K. Lop and scatter slash to within 2' of ground within 50' zone beyond ROW edge (in seen area).
L. Direct felling cuts away from travelway or lake within lop and scatter zone and adjacent trees that may fall into lop and scatter zone.
M. Log landings excluded, unless they can be screened from view and completely restored except where terrain or other resources dictate.
N. Log landings no closer than 300' from edge of travelway except where terrain or other resources dictate.
O. Log landings no closer than 200' from edge of travelway except where terrain or other resources dictate.
P. Exclude all special uses, borrow pits, transmission lines, mining, or oil and gas developments in seen area.
Q. Only late winter burns.
R. Burns carefully controlled in pine types permitted year-round.
S. Vegetative control by spraying permitted with environmental analysis approved by Forest Supervisor.
T. Access roads a minimum of one-fourth mile apart, intersect existing roads at right angles. 150' from edge or existing road, curve alignment right or left to prevent continuous view of new road.
U. Apply marking paint on leave trees so it's not visible from travelway.

BENEFITS AND COSTS

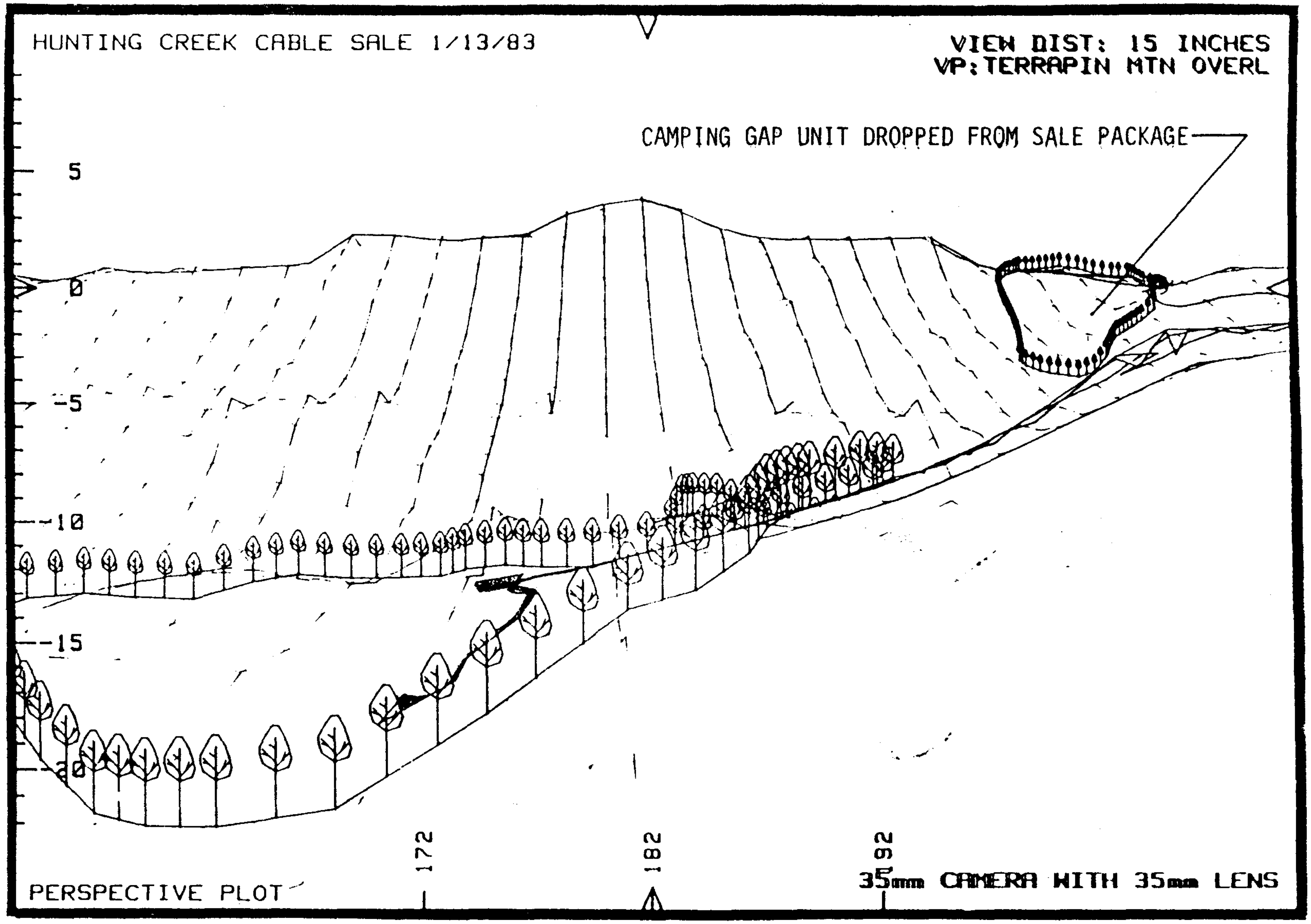
We need to also address, at least briefly, factors of cost. Unfortunately, as with many non-timber outputs, there is not a lot of information available. Generally, increased costs can be tied directly to actions done or not done to favor esthetics, or to reduced timber production, or some combination of both.

Land managers employed by state or federal agencies today almost universally must consider scenic values as a part of their mandate to manage the total forest resource. Agency costs for maintaining a program of non-market resource management are often difficult to isolate for many organizations utilizing an integrated resource management approach. While several efforts have been made by researchers and managers alike to gain a better understanding of how such costs can be determined, the subject remains a high priority for further study. As elusive as the costs have been over the years, so too have been the tracking of the tangible benefits. For a private sector operation, the public relations benefits may be substantial, and the value of political good will benefits is evidently an added dimension which although difficult to measure, still obviously exists. Unquestionably, it must be acknowledged that recognition of visual resource values and its management requirements comes with some added costs, including, in effect, a sub-optimization of the timber resource in certain areas. Yet, an acceptance of this resource, along with the other more tangible commodity resources by private and government land managers alike, must ultimately be considered as a part of the basic land ethic necessary for comprehensive land management and stewardship.

ADVANCE TECHNOLOGY APPLICATIONS

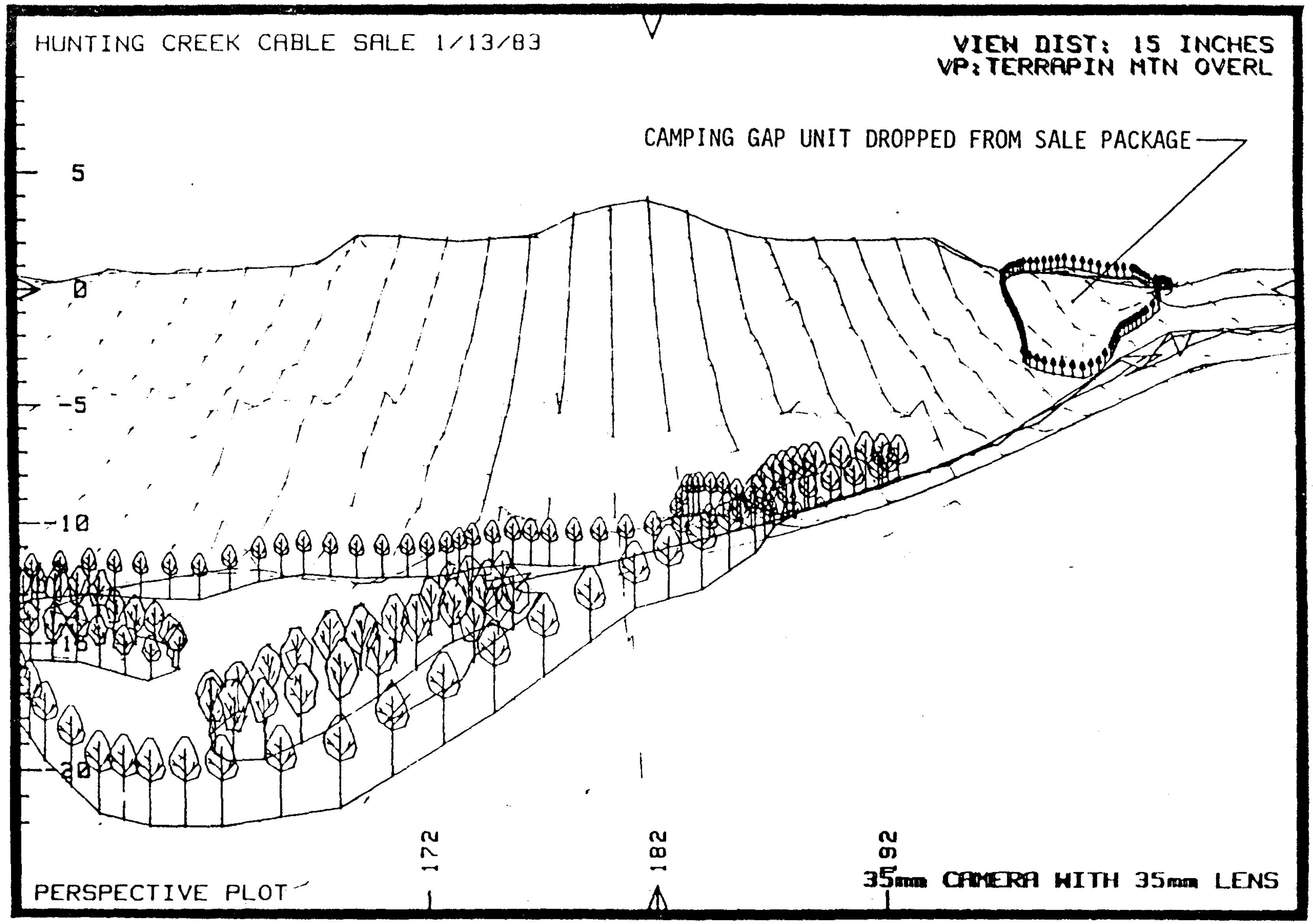
Finally, where is visual resource management heading and what can we expect in the future? Although management of the visual resource is still in its infancy compared to many of the other forest resources, modern technology has already lead to several innovative tools and techniques. An example of the progress in this area is the computer analysis program known as "Perspective Plot." This program, developed by the U.S. Forest Service, provides the design and perspective graphic visualization of a proposed management activity, such as a clearcut unit on the side of a visually sensitive ridge. Examples described in Figures 2 and 3 show the computer printout from an actual sale on the Jefferson National Forest in Virginia. These accurate, simulated three-dimensional oblique views from the critical observer position on the Blue Ridge Parkway helped the Forest analyze the impacts and meet it's restrictive Retention visual quality objectives when seen from this visually sensitive corridor.

The Perspective Plot Program software, designed for the Hewlett-Packard 9020 computer, is currently being upgraded and promises many new features and capabilities. Similar programs are being developed or improved by others in this rapidly expanding technological field. If you or your organization are seriously considering expanding your management of visual values on your forest lands, it would be advantageous to investigate the possible application of computer graphics.



PERSPECTIVE PLOT COMPUTER DEPICTION
OF PROPOSED SALE UNITS
WITHOUT VEGETATIVE INCLUSIONS
TERRAPIN MTN. OVERLOOK-BRP

FIGURE 2



PERSPECTIVE PLOT COMPUTER DEPICTION
OF PROPOSED SALE UNITS
WITH VEGETATIVE INCLUSIONS
TERRAPIN MTN. OVERLOOK-BRP

FIGURE 3

SUMMARY

This paper traces some of the earliest historical references to management of scenic values, up through major state-of-the-art contributions in recent times by the U. S. Forest Service. This background established a basis to discuss the need for a systematic approach to visual resource management, with emphasis on application in the private sector. Esthetics of Shortleaf Pine management was addressed, including a wide range of specific mitigation techniques available to land managers. Problems inherent in the tracking of costs of non-market resources due to their intangible nature were discussed, followed by a brief look at current and future applications in computer graphics technology.

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SHORTLEAF IN PERSPECTIVE: OUTLOOK FOR THE STATES

Edwin E. Waddell[1]

First, I want to express my appreciation to all the attendees of this Shortleaf Pine Symposium for taking time away from busy schedules to come to Little Rock and learn more about the management of shortleaf pine. Second, I want to thank the many speakers who have prepared and presented fine papers on shortleaf pine management these past two days. These presentations should give many foresters new ideas and criteria with which they can better evaluate and manage shortleaf pine stands.

I would now like to give you a brief summary of the Arkansas Forestry Commission's position on the management of shortleaf pine. However, before I do this, there are some pertinent facts that I wish to point out.

1. The Arkansas Forestry Commission works mostly with small private non-industrial landowners scattered all over Arkansas. They own lands on many different and varied sites.

2. Their timber stands generally are in very poor condition initially.

3. These landowners usually have very little capital to invest in their timber stands.

4. By far, the biggest percentage of these landowners will want and need to reforest by natural regeneration.

5. They will, as a matter of economic necessity, have to rely on natural stand management.

6. Sites in Arkansas vary drastically as any you will find in the southeastern United States. From the Coastal Plain to the Quachita and Ozark mountains, to the Flatlands of eastern Arkansas, you will find a variety of site conditions.

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Our foresters and technicians are trained and instructed to consider the landowner's objective for his woodland, to evaluate existing stand conditions, and to build a forest management plan suited to the landowner's goals and financial ability. We have to be extremely careful and practical with our recommendations. If the practice fails, the landowner may not have the means to repeat a practice. Even if he does, he will have lost at least one year's growth plus all costs of the practice installation. If management practices fail for whatever reasons, small landowners are most likely to let their land remain unmanaged or convert it to open land. This, we want to avoid.

With these things in mind, we must be extremely careful to recommend the correct tree species for management on appropriate sites. We know that in the past loblolly pine has been planted outside its natural range on sites adversely suited to its survival and growth. Loblolly is not as drought hardy as shortleaf, nor is it as fire or ice resistant (shortleaf has the ability to sprout back after fire). Also when managed properly, shortleaf has unequaled quality. In the near future this characteristic will mean more dollars to landowners. Finally, shortleaf occurs naturally over all the state and seed is produced in abundance so that natural regeneration can be counted on where adequate seed trees are present. This cannot be said of loblolly, when planted far north of its natural range. For example, if site preparation is required for stand establishment and you don't get adequate flowering and seed production due to species being off site and too far north, you will have failed to establish a stand. You will also have lost the cost of site prep, a year's growth, and in all probability, the landowner's interest.

In conclusion, let me say that we are fortunate in Arkansas to have sites that are suited to both loblolly and shortleaf pine. We must take advantage of this opportunity and recommend the correct species for appropriate sites. We must also remember that results of incorrect management prescriptions will be with us for many years. Although it may take many years for these mistakes to become evident, surely they will. It is my hope that this symposium has stimulated thoughts and that we can continue this informative mode in the management of shortleaf pine. This information is timely and badly needed.

In conclusion, the policy of the Arkansas Forestry Commission is to prescribe the species of tree best suited for a given site, taking into consideration site conditions and the natural ranges of the species. Also, we must consider the long range advantages and disadvantages and not limit ourselves to just the immediate future. Therefore, shortleaf pine has an important niche in the future of Arkansas forests.

SHORTLEAF PINE IN PERSPECTIVE: OUTLOOK FOR THE NATIONAL FORESTS

James R. Crouch[1]

ABSTRACT

Shortleaf pine occupies more acreage on Southern National Forests than does any other softwood species but major concentrations on National Forest lands occur only in Arkansas, Texas and Missouri. National Forests in these states intend to continue to regenerate most shortleaf stands to shortleaf.

INTRODUCTION

I appreciate the opportunity to participate in this panel discussion today. For the past three days you have heard the foremost experts in the field discuss the silviculture and management of shortleaf pine. I will not attempt to add to that, but will try to give you an overview of the occurrence and use of shortleaf on the National Forests.

Shortleaf pine occurs naturally on all the National Forests in the Southern Region except the Delta in Mississippi, the St. Francis in Arkansas and the Ocala in Florida. In fact, the shortleaf pine type occupies a larger acreage (about 2.4 million acres) on Southern National Forests than does any other pine type. Significant acreages, however, occur mainly on the Ozark and Ouachita Forests here in Arkansas and on the National Forests in Texas. The Ouachita has 1,070,000 acres in shortleaf pine type, the Ozark has 332,000 acres and Texas has 165,000 acres. Taken together, these three National Forests contain 65 percent of Region 8's shortleaf acreage. Another significant concentration of shortleaf is found on the Mark Twain National Forest in Missouri where the shortleaf pine and shortleaf pine/oak types occupy some 324,000 acres.

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POLICY

Because of the threat of Littleleaf disease, most National Forests located east of the Mississippi River are not replanting shortleaf after harvest, but are replacing it with other species. The Chattahoochee in Georgia and the Daniel Boone in Kentucky are exceptions. The Kisatchie in Louisiana also has about 10,000 acres of shortleaf which they plan to maintain in this forest type.

In Texas, shortleaf mostly occurs on dry, sandy soils. The policy there is to regenerate these sites to shortleaf because it is considered to be the best species for the droughty conditions.

In Arkansas, shortleaf pine occupies a wide range of sites on the National Forests from the dry cherty soils of the Ozark Plateau to deep alluvial soils along stream bottoms in the Boston and Ouachita Mountains. Although some loblolly pine is being planted on the better soils and at lower elevations, it is the policy on both the Ozark and the Ouachita that the majority of shortleaf sites be maintained in shortleaf. In this respect, the Forest Service differs from most managers of large shortleaf acreage, many of whom routinely plant loblolly behind shortleaf.

Why do we plan to continue to feature shortleaf pine in our management when the early growth of loblolly appears better almost anywhere it is planted throughout the shortleaf range? There are several reasons.

1. Shortleaf is the native pine species on both the Ouachita and the Ozark National Forests. Although there is some native loblolly on the south edge of the Ouachita, it soon fades out as one moves north and there is no native loblolly on the Ozark. The National Forest Management Act of 1976 clarified and formalized long standing Forest Service policy to "maintain the diversity of tree species similar to that existing in the region". We understand this to mean continued use of native species. Inherent in this policy is the notion that native species are generally better adapted to an area and are less susceptible to failure due to insect and disease attack or catastropic weather occurrences. Because maximum fiber production is not the primary purpose of the National Forests, we are willing to sacrifice some early volume production for the greater ecological security of using a native species.

2. The timber product objective on the National Forests is to grow quality sawtimber size trees on all sites that are capable of producing them. For this reason, rotations are generally longer on National Forest lands than on private holdings. Rotations for shortleaf pine

are generally 70 to 80 years in current Timber Management Plans. Existing yield data for shortleaf seems to indicate that on rotations of this length, the mean annual board foot growth increment for shortleaf will equal or exceed that of loblolly.

3. Shortleaf pine from National Forests here in Arkansas has developed a reputation for producing high grade lumber which is sometimes referred to in the trade as "Mountain Pine". We feel that there will continue to be a demand for this type of lumber and that the National Forests should be responsive to this demand.

In conclusion, shortleaf pine will continue to be the major softwood species used on the National Forests here in Arkansas and in Missouri. One indication of our commitment to continued use of shortleaf is the seed orchard which has been established on the Ouachita National Forest. In this orchard are separate seed sources for the Ouachita, the Ozark and the Mark Twain National Forests that will produce sufficient seed for all their shortleaf regeneration needs. A progeny testing and second generation orchard establishment program are also well underway.

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