Chapter 4.

Southern Forest Resource Conditions and Management Practices from 1950–2000: Benefits of Research

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Abstract—*Over the past five decades, research progress and implementation have been the leading factors supporting the rapid development of southern forestry. The South has become the leading timber-supplying region in the United States, taking advantage of a large accumulation of growing stock and a substantial investment in intensive, research-based management treatments. This chapter focuses primarily on intensive management of planted pine forests. Plantations commonly receive high levels of all inputs and are major beneficiaries of research advances. High plantation growth rates are essential if our increasing demand for wood is to be met and if harvest pressure on the remaining natural forests is to be reduced.*

INTRODUCTION

During the first half of the 20th century, forest researchers established the basic management guidelines for forest management in the South. They developed reforestation techniques, learned how to control forest fires, carried out surveys of southern forest resources, learned how to protect forests from insects and diseases, developed soil protection techniques, and introduced new technologies that greatly increased the efficiency of wood products manufacturing. These achievements were essential not only for restoring southern forests but also for making possible their future expansion.

During the second half of the 20th century, these basic forest management guidelines were refined on the basis of new knowledge, and more importantly, many of them were implemented on a very large scale in the South. Although this chapter provides a brief overview of major advances in forestry research, it focuses on research related to management of planted pine (*Pinus* spp.). Research findings have influenced planted pine management in the South in important ways.

Over the past five decades, the South has experienced rapid growth in planted pine area and productivity. These gains were made possible in part by research that paved the way for the development and widespread application of new technologies including genetic improvement and application of fertilizers and herbicides. Today the South is the leading U.S. regional and global supplier of softwood timber. Extensive forest management that emphasized the exploitation of existing resources has been abandoned in the South and has been replaced by an intensive, primarily softwood-producing industry propelled by implementation of research.

OVERVIEW OF SOUTHERN FOREST RESEARCH AND MANAGEMENT: 1950–2000

The contributions to southern forestry made by forest scientists employed by the U.S. Department of Agriculture Forest Service (Forest Service), forestry schools and departments, forest industries, and other forestry organizations during the past half-century were enormous. Scientists developed knowledge and technologies that constituted an essential basis for rapid gains in the production of timber and nontimber goods. Extensive cooperation among scientists at various organizations and the combination of research and implementation made possible by Federal, State, and industrial programs were of great importance in the development of southern forestry. The following brief overview of major research advances in southern forestry is based largely on Johnston's (1989) record of a great history of forestry research in the South.

Growing demand for wood and research in forest products manufacturing were important factors in increasing utilization of southern forests. Research led to the development of technology for producing kraft pulps from the wood of southern pines, and the availability of this technology resulted in the rapid expansion of the southern pulp and paper industry. New technologies

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created new uses for southern pines, increasing their commercial value and leading to the rapid development of wood-manufacturing industries. For example, the development of plywood technology for southern pines in the 1960s was followed by the development of a variety of panel products, such as fiberboard, particleboard, and oriented strand board. Research also improved sawmilling efficiency by developing new equipment and cutting practices that increased lumber yields, especially from small logs. New equipment for logging operations, such as tree harvesters and machines for in-woods chipping, was also developed.

Increasing demand for small wood coincided with the exhaustion of convenient supplies from natural forests and encouraged the development of pine plantation programs at a time when land was abundant. Planting programs required large quantities of good seedlings, effective site-preparation methods, and protection from fires, pests, and diseases. Research provided the knowledge needed to secure seed sources, establish productive tree nurseries, develop effective planting methods, and protect forests. Fire research, for example, helped reduce area burned and damage caused by wildfire while it demonstrated the value of controlled burning. The area burned by wildfire averaged 38 million acres per year from 1931 to 1935; this was reduced to about 2 million acres per year by the mid-1960s (Southern Forest Resources Analysis Committee 1969). This progress permitted large gains in timber growth and encouraged investment in timber growing.

Timber management research has always been important in the South. Forest scientists developed guidelines for the management of all major species and forest types in the region. Research provided better knowledge of silvicultural practices, vegetation control, soils and fertilizers, and nutrient cycling. Scientists developed and used models for analyzing timber growth, yields, and effects of thinning and other management practices. Economic research identified promising investment opportunities and needs, stimulating the development of intensive pine management. By demonstrating that even small owners can benefit from intensified management, economic research helped establish a number of forest assistance programs. Further, researchers analyzed present and future timber supply conditions. Biometric and economic research combined with advanced forest surveys provided better information about forest inventory, growth, mortality, and utilization, helping guide investments in land acquisition and intensive management to support industrial expansion.

Hardwood forests, which cover more than half of the South's forest land, also attracted substantial research efforts. Research provided guidelines for regeneration and culture of hardwood forests in both natural and planted stands. Plantations of cottonwood (*Populus* spp.), sycamore (*Platanus occidentalis* L.), and yellow-poplar (*Liriodendron tulipifera* L.) have shown much promise of increased productivity. But there has been much less research and investment in hardwood management than in pine management (Hicks and others 2001, Kellison 2001). One reason for this is that hardwoods have been in ample supply, and returns from managing them actively have generally been insufficient to justify widely applied intensive silviculture.

Research produced hardwood pulp technology, however, and the availability of this technology has fostered increased utilization of southern hardwoods and has provided incentives for expanded research in their silviculture and natural regeneration. As available hardwood inventories dwindle and hardwood prices and management returns increase, more research effort and applications can be expected. Trials of early silvicultural interventions in natural hardwood stands show promise of providing substantial and profitable growth increases (North Carolina State Hardwood Research Cooperative 2001).

Finally, growing demand for forest recreation and wildlife stirred considerable research interest in these areas. For example, scientists investigated the impact of intensive forest management practices on recreation opportunities and developed guidelines for use of thinning and prescribed burning to improve the quality and increase the availability of wildlife habitat. Growing environmental concerns led to expanded investigation of the impact of forest management practices on water quality and to the development of best management practices.

Substantial research efforts had a great impact on the character of southern forests. In the 1950s, southern forests were managed primarily with low intensity in natural stands. More than 7 million acres of the region's timberland were nonstocked and in need of regeneration. Only 2 million acres were in planted pine forests. The area planted in pine had expanded to about 30 million

acres by 1997, along with rapidly intensifying management and increasing productivity (Smith and others 2001).

Planted pine management has changed southern forestry dramatically. While the South accounts for only 40 percent of the Nation's forest land area and 22 percent of its softwood growing stock, it supplies 64 percent of all softwood harvested in the United States. Today, the South's pine plantations account for nearly 19 percent of the world's area of fast-grown industrial wood plantations. While the region's planted and natural pine forests represent < 3 percent of global conifer forest cover, they supply nearly 19 percent of global industrial softwood roundwood harvests (Food and Agriculture Organization of the United Nations 2002, Smith and others 2001). No other region or country in the world supplies more softwood timber than the U.S. South.

INTENSIVE PLANTED PINE MANAGEMENT IN THE 1990S

Pine plantations are managed much more intensively now than they were formerly, when management consisted primarily of site preparation and planting. Today's intensive management relies heavily on the widespread application of research-based approaches such as the planting of genetically improved seedlings and the application of fertilizers and herbicides. The management of industrial pine plantations is a particularly good example of the contribution of intensive management technologies to greater growth because such management involves high levels of all inputs and because industrial plantations benefit greatly from research advances.

The results of a forest industry management survey[2] were used to estimate current operational results of intensive management of planted pine. The survey was designed by the American Forest and Paper Association's Resource Planning Act (RPA) Task Group and was used to collect data about industry land and management practices for use in the 2000 RPA Timber Assessment. The survey covered the 13 Southern States and collected data on tree planting, genetic improvement, control of vegetation and stocking, nutrition, thinning, harvest age, and the management of future stands on leased and company-owned forest land. Participating companies accounted for 16.3 million acres of planted pine, or about 90 percent of pine plantation area in forest industry ownership in the region.

The survey provided the basis for the development of five management intensity classes (MIC) for planted pine (Siry and others 2001). MIC 1 represents traditional management consisting only of site preparation and planting. MIC 2 represents low intensity that involves site preparation and planting of genetically improved seedlings. MIC 3 describes moderate intensity with fertilizer application. MIC 4 stands for high intensity in which herbicide use is added to MIC 3 treatments. Finally, MIC 5 represents very high intensity, with multiple applications of fertilizers and herbicides.

Table 4.1 presents total and average annual yields of merchantable wood for planted pine on medium-quality sites at age 25. Total yields range from about 2,700 cubic feet per acre for MIC 1 to nearly 4,600 cubic feet per acre for MIC 5 (Siry and others 2001). These total yields translate into average annual growth rates ranging from 109 cubic feet per acre for MIC 1 to 183 cubic feet per acre for MIC 5. These data show that very intensive management can produce almost 70 percent more volume than traditional management produces.

Table 4.1—Intensively managed planted pine growth and yield data (wood volume) for medium sites and 25-year rotation

Management intensity class	Total wood yield at age 25	Average annual growth rate
	ft^3/ac	*$ft^3/ac/yr$*
MIC 1 - traditional	2,716	109
MIC 2 - genetics	3,135	125
MIC 3 - MIC 2 + F	3,433	137
MIC 4 - MIC 3 + H	4,033	161
MIC 5 - MIC 4 + 2nd F and H	4,587	183

MIC 1 = site preparation and planting; MIC 2 = site preparation and planting of genetically improved seedlings; MIC 3 = moderate intensity with fertilizer application; MIC 4 = high intensity in which herbicide use is added to MIC 3 treatments; MIC 5 = very high intensity with multiple applications of fertilizers and herbicides; F = fertilization; H = herbicide application.

[2] Goetzl, A. 1998. AF&PA southern forest management intensity survey: data summary and survey results. [Number of pages unknown]. On file with: American Forest and Paper Association, 1111 Nineteenth Street, NW, Suite 800, Washington, DC 20036.

INTENSIVE TIMBER GROWING METHODS

Genetic Improvement

The forest industry survey indicates that use of genetically improved growing stock increases wood volume by about 15 percent, or nearly 420 cubic feet per acre at age 25. Such increases were made possible by genetic research and industrial tree improvement programs that began in the South as early as the 1950s.

Genetic improvement of pines was focused on site adaptability, disease tolerance, growth rates, tree form, and wood quality (Zobel 1974). Rapidly expanding planting programs demanded large quantities of pine seed, and this demand stimulated the establishment of seed orchards. Most tree improvement effort was directed at slash (*Pinus elliottii* Engelm.) and loblolly pine (*P. taeda* L.), but some emphasis was also put on longleaf pine (*P. palustris* Mill.). Continued interest in genetic improvement has resulted in the establishment of industry-university cooperative tree improvement programs at Texas Agricultural and Mechanical University, the University of Florida, and North Carolina State University. Hardwood tree improvement work began after the work on pines started and later subsided. Very few hardwood plantations were established.

The 42 years of loblolly pine improvement studies carried out by the North Carolina State University-Industry Cooperative Tree Improvement Program have yielded 7- to 12-percent volume increases in trees grown from first-generation seed orchards (Zobel and Talbert 1984). Second-generation tree breeding produced wood volume gains of 17 to 30 percent over unimproved seeds (Li and others 1998). Genetically improved trees also display improved stem quality and fusiform rust (*Cronartium quercuum* f. sp. *fusiforme*) infection rates that are reduced by as much as 25 percent. The history of tree improvement research in the South is summarized in Zobel and Sprague (1993).

Fertilization

Pine fertilization research trials were established in the South as early as the mid-1940s. Foresters, however, showed little interest in this work until 20 years later, when remedial fertilization of slash pine forests growing on phosphorus-deficient sites produced spectacular responses (Pritchett and Comerford 1982). On such sites, phosphorus fertilization resulted in great volume and value gains, as phosphorus shortages virtually precluded the establishment of viable pine plantations. Volume gains were as high as 50 cubic feet per acre per year for up to 20 years in response to a single phosphorus addition at or near planting.

Growing interest in forest fertilization led in the late 1960s to the establishment of industry-funded research cooperatives at the University of Florida and North Carolina State University. The Florida program focused on slash pine and the North Carolina program on loblolly pine. Both programs researched possibilities of increasing growth by applying fertilizers and developed technologies for operational use of fertilizers in forestry.

Fertilizers are now applied at planting, at young ages, and in midrotation. Two of the most commonly supplied nutrients are phosphorus and nitrogen. Fertilization at planting is frequently aimed at ameliorating phosphorus deficiencies, while applications in established stands usually supply additional nitrogen and phosphorus. Operational data from the forest industry survey indicate that midrotation applications of 25 pounds per acre of phosphorus and 200 pounds per acre of nitrogen increase yield by 400 cubic feet per acre, or 15 percent per application, for a 25-year rotation. To date, fertilizers are applied almost exclusively in intensively managed pine plantations; they have been used very little in hardwood stands.

Scientists have moved to investigate interactions of fertilization with other silvicultural treatments that may influence nutrient availability, the effects of applications of nutrients such as potassium and boron, and interactions between nutrient additions and tree resistance to pests and diseases (Allen 1983, Ballard 1984). Presently, research focuses on developing more integrated approaches to site nutrient management (Allen 2001).

Herbicide Application

The largest problem in intensive pine culture in the South is the difficulty of controlling hardwoods that invade pine sites (Waldstad 1976). Natural succession, when accompanied by reduced fire frequency and increased pine harvesting, favors hardwood development. Hardwood competition can overtop young pines and greatly reduce the availability of moisture, nutrients, and sunlight to pine trees, resulting in higher seedling mortality and slower growth (Clason 1993, Glover and Zutter 1993).

Foresters did not initially consider herbaceous competition a major impediment to pine growth, so early forest herbicide research focused on control of hardwoods in pine stands (Gjerstad and Barber 1987). Research developed rules for herbicide selection, dosage, timing, and application methods. In the 1980s, research trials indicated that herbaceous vegetation does compete with young pine seedlings and that its elimination can increase survival and growth rates of young pines (Creighton and others 1987, Lauer and others 1993, Yeiser and Williams 1996, Zutter and Miller 1998). This has led to the development of approaches for controlling both woody and herbaceous vegetation.

The forest industry survey indicates that control of vegetation has the largest impact on wood volume growth. In MIC 4, woody plant treatment in year 1 increased yield by about 600 cubic feet per acre at age 25. In MIC 5, herbicides were applied twice; herbaceous plant treatment at planting was followed by woody plant treatment in year 3. These applications increased yield by as much as 750 cubic feet per acre at age 25, or by nearly 28 percent over untreated stands.

Herbicides are used for site preparation before stand establishment, release from hardwood and herbaceous competition in young stands, and timber stand improvement in midrotation. Herbicide treatments gain popularity because they are cheaper, more effective, and easier to apply than others. To date, herbicide research and applications have been limited primarily to intensively managed southern pines, but there is growing interest in herbicide applications in hardwood forests. Fitzgerald (1980) provides an historical overview of herbicide research and use in forestry.

RETURNS FROM INTENSIVE MANAGEMENT

While intensive management can greatly increase pine growth and yield, investment returns will largely determine how widely it will be applied and how intensive it will become. The costs of genetically improved seedlings, herbicides, fertilizers, and other treatments increase the total management costs per acre. However, production rates may increase sufficiently to decrease average production costs and justify increased investment in timber management. Real rates of return for planted pine management now vary from nearly 10 percent (MIC 1) to 12 percent (MIC 5) (Siry and others 2001). Net present values and soil expectation values also indicate that intensive management offers attractive returns—values associated with very intensive management (MIC 5) are more than 1.6 times higher than returns associated with traditional management (MIC 1). The increased returns reflect higher production values resulting from increases in timber volume and quality. These returns are sufficient to justify investment in improved timber management practices on a large scale.

EXTENT OF INTENSIVE FOREST MANAGEMENT PRACTICES

Forest Service, Forest Inventory and Analysis (FIA) data spanning from 1982 to 1999 show increases in rates of harvesting, planting and natural regeneration, timber stand improvement, and chemical application in the South (Siry 2002). Intensive management is practiced primarily in planted pine forests, where most planting, site preparation, fertilizer and herbicide use, and thinning occur. The FIA data also indicate that natural pine, oak (*Quercus* spp.)-pine, and upland and bottomland hardwood forests are managed with considerably lower intensity.

Several authors have presented survey information that shows what forest management practices are employed, and how extensively they are employed, by important owner groups in the South (Moffat and others 1998, Siry and Cubbage 2001, Siry and others 2001). Table 4.2 summarizes this information and information provided by other sources that are described subsequently.

Table 4.2—Extent of intensive forest management practices in the South

Forest type	Management treatment	Forest land area
		million acres
Planted pine	Genetic improvement	26
	Fertilization	11
	Herbicide use	11+
Natural pine	Some practices such as fertilization and/or thinning were or will be used	6
Oak-pine		3
Upland hardwood		5
Bottomland hardwood		3

In the South, only about 4 million acres of pine plantations were established under management consisting only of site preparation and planting of seedlings that were not genetically improved. Pine plantations on 26 million acres were established using genetically improved seedlings. Today, virtually all seedlings of pine species planted in the South are genetically improved (Li and others 1998).

Data collected by the North Carolina State Forest Nutrition Cooperative (2001) indicate that almost 1.6 million acres of southern pine stands were fertilized in 2000. Since 1969 slightly more than 11 million acres have been fertilized in the South. This area is estimated to exceed the sum of forest acreage fertilized in the rest of the world. While midrotation fertilization is most common, the area fertilized at planting and at young tree ages is increasing. If current planting trends continue and pine plantations are fertilized at least twice throughout the rotation, then the area on which fertilizers are applied will at least double.

It is difficult to obtain reliable information about the extent of herbicide use. However, herbicides have a long history of use in pine management, and it is clear that they are employed widely in the South. Pesticide-use patterns (Michael 2000) indicate that nearly 1 percent of forest land in the United States is treated annually. If these patterns hold for herbicide use in the South, approximately 2 million acres of southern forest land receive herbicide treatments each year.

Natural pine, oak-pine, and hardwood stands are often managed custodially on an even-aged basis and receive no treatments. Management at higher levels of intensity, which includes the application of treatments such as fertilization or thinning of even-aged stands to promote growth and quality, is limited. Survey results indicate that only about 6 million acres of existing natural pine forests have received or are scheduled to receive such treatments. Following harvesting, natural pine forests are often replanted with pine seedlings and managed more intensively. Growth-promoting treatments have been applied on or are planned for 3 million acres of oak-pine forests and 8 million acres of hardwood forests.

EFFECTS OF INTENSIVE FOREST MANAGEMENT PRACTICES

Table 4.3 compares the growth rate of very intensively managed planted pine (MIC 5) with empirical rates used in the Subregional Timber Supply (SRTS) model, which analyzes and forecasts southern timber supply conditions (Abt and others 2000). The empirical growth-and-yield estimates employed are based on FIA data. Across all sites, management intensities, and owners in the South, growth of planted pine averages 94 cubic feet per acre per year for a 25-year rotation (Abt and others 2000, Siry and others 1999). Industrial yields are from about 15 percent (for MIC 1) to 95 percent (for MIC 5) above current SRTS model values for average sites at age 25. This implies that very intensive planted pine management (MIC 5) has the potential to double recently observed production rates. Very intensively managed pine plantations (MIC 5) can grow more than twice as fast as natural pine stands, which grow at an average rate of 72 cubic feet per acre per year.

An analysis based on FIA data indicates that average annual pine growth in the South (for planted and natural stands combined) increased by 22 percent from the mid-1980s to the mid-1990s (Siry and Bailey 2003). This increase added about 26 million tons per year to the region's softwood production. The analysis also indicates that pine growth increases are positively correlated with the area of intensively managed pine plantations.

Table 4.3—Growth rates (wood volume) for intensively managed planted pine (MIC 5) and SRTS-FIA forest management types

Management type	Average annual growth rate
	$ft^3/ac/yr$
Planted pine (MIC 5)	183
SRTS-FIA[a]	
Planted pine	94
Natural pine	72
Oak-pine	51
Upland hardwood	42
Bottomland hardwood	42

MIC 5 = very high intensity with multiple applications of fertilizers and herbicides; SRTS = Subregional Timber Supply model; FIA = Forest Inventory and Analysis.
[a] SRTS-FIA data are average values for all site indexes.

From the mid-1980s to the mid-1990s, planted pine area increased by 7 million acres to about 30 million acres while natural pine area decreased by 5 million acres to 33.5 million acres.

Growth rates for oak-pine and hardwood forests are substantially lower than those for planted pine. Oak-pine growth rates average about 51 cubic feet per acre per year for 60-year rotations. Growth rates for hardwood forests are still lower, averaging 42 cubic feet per acre per year for 60-year rotations. Growth rates in very intensively managed pine plantations (MIC 5) are nearly 3.6 times as great as average oak-pine growth rates and nearly 4.4 times as great as average upland and bottomland hardwood growth rates. Intensively managed plantations of hybrid poplars and other hardwood species grow rapidly, but their area is very small.

DISCUSSION AND CONCLUSIONS

Planted pine forests account only for about 15 percent of southern timberland but for a much greater share of softwood growth and harvests. The SRTS model indicates that pine plantations now account for about 56 percent of total softwood growth in the South (Prestemon and Abt 2002). The model indicates that pine plantations will overtake natural pine forests in supplying softwood timber between 2000 and 2005 as planted trees mature and reach merchantable size. Within a decade, harvests from pine plantations will amount to nearly a third of total softwood and hardwood timber production in the South.

The ability of pine plantations to supply the majority of softwood harvests is a clear indication of their great relevance for sustainable wood supply and conservation of the remaining natural forests. Since the area of commercial timberland is expected to remain relatively stable, existing forests will have to be utilized more intensively to satisfy timber demand. Intensive management of planted pine makes it possible to grow more wood on less land. Plantation success means that harvesting pressure on natural forests, old-growth forests, and environmentally sensitive areas will be reduced as timber demand is met primarily by wood grown on plantations. This creates new opportunities for conservation of the natural forests.

Ever-increasing demands for wood and other forest products and services imply that the productivity of pine plantations will have to continue to grow. Progress made in recent years indicates that this is entirely possible. Today's challenge is to develop approaches that combine various intensive management treatments in ways that generate the maximum returns in an environmentally responsible manner.

More frequent and more widespread application of fertilizers and herbicides could increase productivity substantially. Nearly half of the South's forest acreage would benefit from timber stand improvement, including herbicide use (Waldstad 1976). Nutrient-deficient sites are also widespread, and even sites previously thought not to be nutrient deficient can benefit from fertilization (Allen 2001). There is also abundant evidence that appropriate repeated fertilizer applications produce additional response from forest stands (Ballard 1984). For example, annual fertilization and multiple applications of herbicides resulting in total control of competing vegetation on loblolly pine research sites in Georgia produced annual growth rates ranging from 325 to 490 cubic feet per acre (Borders and Bailey 2001). Such growth rates are about twice as high as current rates in intensively managed industrial pine plantations (MIC 5).

Genetic improvement of trees appears to hold the greatest long-term promise. Although realized genetic-related gains in wood volume have not averaged more than 30 percent to date, the best second-generation loblolly families have shown volume increases of up to 66 percent and improved stem straightness, wood quality, and resistance to diseases (Li and others 1998). Continuing progress in breeding technologies, including controlled mass pollination and vegetative propagation (rooted cutting and tissue culture), and eventually genetic engineering of trees, promises even greater gains in wood volume and quality. The limits of such gains are today largely unknown.

Over the past five decades, forest research has developed powerful new timber-growing technologies. The use of genetically improved seedlings, fertilizers, and herbicides in intensively managed pine plantations now results in growth rates that are nearly twice as high as those associated with traditional management consisting of site preparation and planting. Wider and more intensive application of growth technologies now in use could double or triple the current production levels for intensively managed pine. Such increases will be essential for sustaining and expanding southern timber harvests while limiting pressures on the remaining natural forests.

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