Chapter 6.

Productivity

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The South is blessed with abundant and diverse forest resources. Today, forests cover approximately 215 million acres in the South, which represents 29 percent of the forest land in the United States (Conner and Hartsell 2002). Maintaining the productivity of these forests is essential to the economic, environmental, and social well being of the South and the Nation. The forest products industry ranks among the top industries in most Southern States and is the largest industry in several. The wood products sector contributed 770,000 direct jobs and over $120 billion in total industry output in 1997 (Abt and others 2002).

The diversity of forest ecosystems in the South is also large, ranging from mixed, mesophytic hardwood forests of the Southern Appalachians, to the planted pine forests of the Coastal Plain and Piedmont, to the bottomland hardwood forests along major rivers throughout the region. In 1999 there were 65 million acres of upland hardwood forests, 30 million acres of lowland hardwoods, 29 million acres of mixed pine-hardwood forests, 33 million acres of natural pine, and 30 million acres of pine plantations in the South excluding Kentucky (Conner and Hartsell 2002). These forests provide a wide variety of goods and services other than timber, including a diverse range of habitat for wildlife, recreational opportunities, and clean air and water. These goods and services contribute to an improved quality of life for an increasing population that has become more urbanized. Modern forest management regimes must provide these noncommodity benefits.

Management practices have been developed and refined for each of the major forest types in the South since the advent of scientific forestry at the Biltmore Estate led by the work of Olmstead, Pinchot, and Schenck in the 1890s. Although tremendous strides have been made in the management of most forest types, progress has been uneven. Economic factors associated with the development of southern pine-based pulp and paper industry, which started in the 1920s and 1930s, fostered the development of pine plantation management using an agronomic approach. The work of research scientists and practicing foresters in the U.S. Department of Agriculture Forest Service (Forest Service), southern forestry schools and universities, State forestry agencies, and private industry in pine tree improvement and intensive silvicultural practices has greatly improved the productivity of southern pine plantations. Similar but less sustained efforts were periodically directed toward intensive management of plantation hardwoods, generally with mixed results. The research efforts directed toward the management of natural hardwood, pine, and mixed hardwood-pine stands have been less concerted than that associated with intensive pine plantation silviculture. However, individual research programs within the Forest Service and at several southern forestry schools have maintained a strong and consistent focus on these forest types. Most notable are the Forest Service research units at Bent Creek and Coweeta focused on upland hardwoods, the program at Mississippi State University on silviculture of bottomland hardwoods, the industry-sponsored Hardwood Research Cooperative at North Carolina State University, which has strong programs in both upland and bottomland hardwoods, and the Forest Service Research Work Unit at Crossett, AR, that has developed uneven-aged silvicultural systems for southern pines.

Six chapters are included in this section on productivity. Three of these chapters review and highlight the progress made on silviculture of the major forest types in the South. This is followed by a chapter on the history and accomplishments of tree improvement programs in both southern pine and hardwoods. The final chapter discusses the links that exist between silviculture and remote sensing, specifically focusing on the use of remote sensing as a mensurational technique.

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The second chapter of this section "Silviculture and Management Strategies Applicable to Southern Hardwoods" by Ray R. Hicks, Jr., William H. Conner, Robert C. Kellison, and David Van Lear addresses the management of upland and bottomland hardwood forests in the South. Hardwoods comprise a significant component of the southern landscape. Some southern forests are dominated by hardwoods, such as the mesophytic forests of the Southern Appalachians and the bottomland stands that border all the major river systems of the South. In addition, hardwoods form a significant component of many southern pine stands. Hardwoods play an important ecological and economic role in southern forests. They provide ecological and habitat diversity, valuable lumber and veneer, and fiber for pulp and paper.

The authors first summarize the physiographic, edaphic, and climatic factors that characterize the various types of hardwood forests in the South. They then address the land use history and ownership patterns and the role these forces play in determining the type of hardwood stands that exist and their influence on objectives of ownership. Emphasis is placed on our improved understanding of the role of fire in hardwood forests and how the extent and frequency of fires, both historical and current, influence the composition and structure of hardwood forests. A detailed description of the silvicultural techniques for regenerating and culturing the commercially valuable species of hardwoods is then presented. The authors also discuss how silvicultural practices in hardwood stands are complicated because many hardwood stands occur on sites that are difficult to operate equipment and contain a diversity of species that vary greatly in stumpage value. These factors, along with the fact that most hardwood stands occur on small, privately owned tracts, contribute to the fact that most hardwood stands are not actively managed and have historically been exploited and high-graded.

The third chapter in this section "The Evolution of Pine Plantation Silviculture in the Southern United States" by Thomas R. Fox, Eric J. Jokela, and H. Lee Allen reviews the historical development of intensive southern pine silviculture. The acreage in pine plantations has increased significantly over the last 50 years from < 2 million acres in 1952 to 32 million acres in 1999 (Wear and Greis 2002). More remarkable is the significant increase in per-acre productivity that has accompanied the rapid expansion of pine plantations. Mean annual increment of pine plantations has more than doubled, and rotation lengths have been cut by more than 50 percent. Although planted pine accounts for only 15 percent of the total forest land base in the South, it accounts for 35 percent of the annual harvest volume (Wear and Greis 2002).

The authors of this chapter highlight the changes in pine plantation silviculture that have occurred since 1950. The contributions to improved plantation yields of tree improvement, improved nursery practices, site preparation, competition control, fertilization, growth-and-yield modeling, and land classification are presented on a decade-by-decade basis. Current state-of-the-art silvicultural practices involving integrated, site-specific, rotation-long silvicultural manipulations are discussed. A vision of the future presented by the authors includes clonal deployment of elite genotypes produced through somatic embryogenesis and managed on a site-specific basis to optimize growth rates and financial returns in an environmentally sustainable manner. Precision silviculture of pine plantations in the 21st century in the South will embrace the advances coming out of precision agriculture. The role that cooperative research and technology transfer had in the successful development of intensive pine plantation silviculture is emphasized throughout the chapter. The take-home message from the authors is that no one single organization had the financial or intellectual resources required to develop the needed silvicultural technology in the past. As the level of complexity of pine plantation silviculture increases in the future, concerted, cooperative research efforts will continue to be needed.

The fourth chapter in this section "Reproduction Cutting Methods for Naturally Regenerated Pine Stands in the South" by James M. Guldin, discusses management practices in natural pine and mixed pine-hardwood stands. Although the acreage in pine plantations has increased significantly over the last 50 years, the author correctly points out that a large percentage of forest land in the South will remain in natural stands. There are currently 62 million acres of natural pine or mixed pine-hardwood forests in the South (Wear and Greis 2002). These stands must be managed using classical silvicultural practices that establish and maintain productive, healthy forests that provide a variety of goods and services required by society. Natural regeneration is frequently the only option financially available

to nonindustrial landowners. Longer rotations required to produce large-diameter pine trees and other multiple-use benefits associated with them, such as aesthetics and wildlife habitat, may not be feasible in plantation systems. Certain landowners and segments of the general public may reject the clearcut and plant approach required in plantation silviculture. Regulatory requirements, including best management practices in all Southern States, prohibit clearcutting in streamside management zones. Management prescriptions involving natural regeneration that avoids high-grading and protects water quality must be developed for these sensitive, high-quality sites.

The author reviews silvicultural practices that establish and maintain naturally regenerated pine and pine-hardwood mixtures. He discusses both even-aged and uneven-aged reproduction cutting methods, including seed tree and shelterwood systems and group and single-tree selection. He illustrates how both even-aged and uneven-aged systems can be effective in southern pine stands depending upon which species are present, the site preparation practices, and the manner that required intermediate treatments, such as release, are employed to assure adequate seedling establishment and rapid stand development. The importance of residual overstory basal area, timing of harvests to take advantage of cone crops and seed production, appropriate site preparation to create suitable seed beds, control of competing vegetation, and control of stand density are emphasized as key components of a successful natural regeneration system in southern pine.

The fifth chapter in this section "The Role of Genetics and Tree Improvement in Southern Forest Productivity" by R.C. Schmidtling, T.L. Robison, S.E. McKeand, R.J. Rousseau, H.L. Allen, and B. Goldfarb documents the impacts that tree improvement activities have had in the South over the last 50 years. The contributions of applied tree improvement to the increased productivity of southern pine stands are recognized throughout the world as one of the major success stories of modern forestry. Beginning with the pioneering work of Wakeley on seed source variation in southern pine in the 1920s, research on tree improvement in southern pines has progressed to the point where loblolly pine (*Pinus taeda* L.) is today probably the most domesticated and best understood conifer in the world. Again, hardwood species have received less attention in the South than have pines. However, interest in hardwoods has recently increased because of work in the developing field of forest biotechnology. Hardwood species, most notably those in the genera *Populus* and *Eucalyptus*, are proving to be much easier to study and manipulate through tissue culture, genetic mapping, and genetic engineering techniques than conifers. Hardwoods will probably serve as model systems where the gains in biotechnology are first realized in forestry.

The authors of this chapter provide a thorough review of the history of forest tree improvement in the South from its infancy in the 1920s. They include a discussion of both southern pine and hardwood tree improvement programs. They illustrate how the observations and efforts of practicing foresters played an important role during the early phases of tree improvement. These initial efforts were superseded by well-coordinated, sophisticated, cooperative research programs involving Federal and State Governments, universities, and private industry. Today approximately 1 billion southern pine seedlings are planted annually, nearly all of them the product of tree improvement programs. The authors discuss the productivity gains made using first-generation slash (*Pinus elliottii* Engelm.) and loblolly pine. Gains are estimated to be 15 to 20 percent over unimproved, natural populations. Additional gains will be made from the deployment of advanced generation material from elite populations through techniques such as open-pollinated single-family block plantings, and full-sib deployment using control mass pollination. Clonal forestry looms on the horizon as an opportunity to exploit the full genetic potential of various commercial species through the development of tissue culture techniques, such as rooted cuttings and somatic embryogenesis. The science of genomics will provide improved tools such as marker-aided selection that will increase the efficiency of tree improvement programs. The authors conclude with a cautionary note on the need to conserve long-term genetic diversity while managing for short-term productivity gains.

The final chapter in this section, "Forest Mensuration with Remote Sensing: A Retrospective with a Vision for the Future," by Randolph H. Wynne, discusses the role of remote sensing as a tool that practicing foresters can use to improve forest productivity. As management practices intensify, foresters require more detailed information upon which to base their decisions. Forestry is moving toward the agricultural model of intensive, site-specific management that can be broadly characterized as precision forestry. Information from digital remote sensing can be quickly integrated into a forester's decision process to develop sophisticated, fully integrated rotation-long management regimes that best meet landowner objectives. Although forest management at this level of intensity is often associated with the desire to optimize financial returns, sophisticated management scenarios are needed by any forester attempting to meet the competing demands placed on forest resources today. For example, meeting the needs for aesthetics, recreation, wildlife habitat, water quality, endangered species, wilderness, and timber production is a much more complicated task than simply optimizing growth and associated financial returns from timber management.

The chapter begins with a retrospective discussion of remote sensing, which reviews the long use of aerial photos to improve forest management. A section on timber volume estimation using aerial photos is then presented. This section explains how tree and stand properties such as stand density, tree height, crown dimensions, and crown cover can be obtained from conventional aerial photos and used to create photo volume tables. Historically, the variation in stand-volume estimates based on aerial photos was too high (often exceeding 25 percent) to be of great value for many uses. The most widespread use of remotely sensed data in forestry has been, and continues to be, to stratify and map stands, calculate land area, and simplify navigation. The value of aerial photos as a navigation tool used by foresters to increase the efficiency of their day-to-day activities in the woods should not be overlooked. The author then discusses new developments in remote sensing and computer technologies, and explains how they are being used to improve volume estimates of stands. The developing tool of lidar (light detecting and ranging), which uses an airborne laser to accurately estimate canopy height, crown density, and stand density is discussed. Lidar-based measurements are proving to be more accurate and less biased than conventional photo-based estimates of tree and stand parameters. The author is optimistic that the high cost of cost data acquired with these new techniques will decrease and that the combination of decreasing cost and increasing efficiency will improve the cost/benefit ratio of this technology. The chapter concludes with a discussion of how remote sensing utilizing these new techniques and tools will be an integral component of the new precision forestry paradigm.

LITERATURE CITED

Abt, K.L.; Winter, S.A.; Huggett, R.J., Jr. 2002. Local economic impacts of forests. In: Wear, David N.; Greis, John G., eds. Southern forest resource assessment. Gen. Tech. Rep. SRS–53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 239–267.

Conner, R.C.; Hartsell, A.J. 2002. Forest area and conditions. In: Wear, David N.; Greis, John G., eds. Southern forest resource assessment. Gen. Tech. Rep. SRS–53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 357–401.

Wear, David N.; Greis, John G., eds. 2002. Southern forest resource assessment. Gen. Tech. Rep. SRS–53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 635 p.