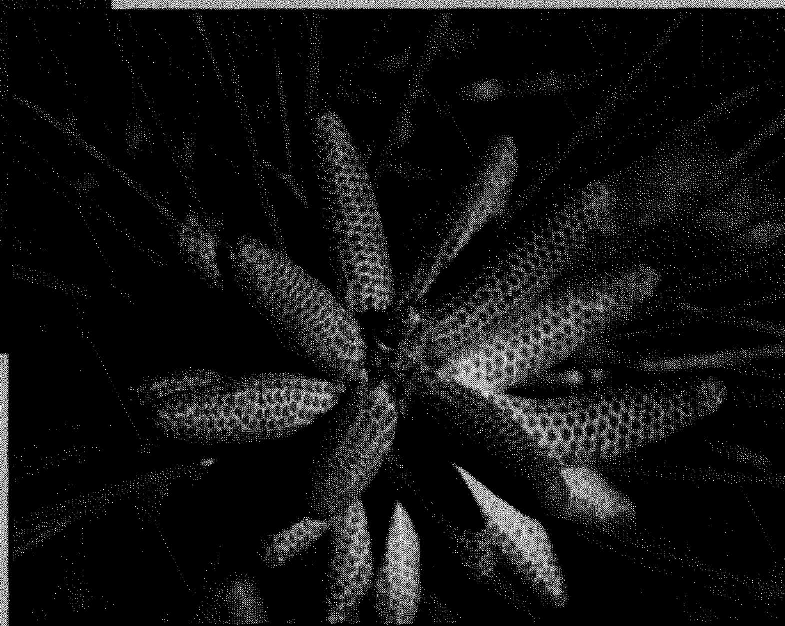
Productivity of Southern Pine Plantations

Where Are We and How Did We Get Here?



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Above: Female cones (left) and male flowers (right) of loblolly pine (*Pinus taeda* L.).

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ABSTRACT

The productivity and extensiveness of southern forests in general, and pine plantations in particular, has placed the South at the forefront of production forestry in the United States. That industrial loblolly pine plantationsarevery productive is a result of researchersand managers developing and applying increasingly intensive silvicultural practices. Our estimatesofthe percentage of productivity gains attributable to improvements made in individual management practices are based on our collective experience, anecdotal information, and discussionswith knowledgeable colleagues. Such informed judgments are based on potential productivity revealed by designed experiments coupled with estimates of how well technology has been implemented.

Keywords: economics; plantations; silviculture; timber markets

A distinctive feature of forestry in the South is the extensive area of intensively managed loblolly pine (*Pinus taeda* L.) plantations along the Atlantic and Gulf coasts. Plantations of all types occupy 17 percent of southern timberland (Guldin and Wigley 1998; Conner and Hartsell 2002) and most are privately owned by forest industry or other corporations (Guldin and Wigley 1998). Nonindustrial private forestland (NIPF) owners hold only 10 percent of their land in plantations, although that amounts to 13.8 million acres (Guldin and Wigley 1998; Conner and Hartsell 2002). The scope of plantation management in the South was summarized by Guldin and Wigley:

- One of six acres of timberland is a plantation.
- Of every 100 acres of plantations in the South, 94 are privately owned (54 acres by industry, 40 acres by NIPF owners).
- Of the six acres out of 100 acres that are publicly owned, four are in national forests and two are owned by

other public entities such as state forestry or wildlife agencies.

The productivity and extensiveness of southern forests in general, and pine plantations in particular, has placed the South at the forefront of production forestry in the United States. The southern region today produces more timber than any other country in the world (Prestemon and Abt 2002). In 1997, 61 percent of the softwood and 53 percent of the hardwood timber harvested in the United States came from this region (Haynes 2002) and increases are forecast for the next three decades (Haynes et al. 1995; Adams 2002). Of the 43 top wood-using companies in the world, 16 operate in the South (World Wide Fund for Nature [WWF] 2001); of the top five companies, together using more than 20 percent of the world's industrial roundwood, four-International Paper, Georgia-Pacific, Weyerhaeuser, and Smurfit-Stone-have manufacturing facilities in the South (WWF 2001).

Although pine plantations dominate the southern landscape, significant changes are predicted over the next decades (Wear and Greis 2002). New plantations are expected in the mid-South to replace forestland converted to urban use in the Piedmont and along the coasts (Prestemon and Abt 2002). Already there are major shifts in commercial timberland ownership as industry consolidates into fewer larger companies and timberland is sold to financial institutions, real estate investment trusts (REIT), and timber investment management organizations (TIMO). Ownership by these "other corporate owners" increased 20 percent between 1982 and 1999, rising to 20 million acres (Conner and Hartsell 2002; Siry 2002).

Because we appear to be on the brink of major change in timberland ownership and how plantations are managed, we think it appropriate to take stock of where we are and how we got here. We will try to answer two questions: How productive are intensively managed pine plantations? How did they get so productive? Our thesis is that industrial loblolly pine plantations are very productive as a result of researchers and managers developing and applying increasingly intensive silvicultural practices.

Just how productive are intensively managed plantations! According to current productivity estimates, 10 tons per acre per year or higher are achievable with the very latest technology. Internally, companies have projected productivity of 12 to 16 tons/acre/yr. We think the current average is closer to eight tons/acre/yr on intensively managed industry land. How did such highly productive plantations occur? Productivity has increased through a combination of three strategies: (1) increase total biomass production, (2) increase the proportion of total biomass production that is useable under current standards, or (3) use a greater portion of the total (i.e., redefine what is usable).

The New Owners of Southern Timberlands

A hybrid category of private timberland owner has emerged in the past 20 years: not quite forest industry because mostly they are not manufacturers, but because they are large corporations they do not fit the notion of an NIPF owner. These "other corporate owners" typically are financial institutions such as Timber Investment Management Organizations (TIMO) or Real Estate Investment Trusts (REIT). They own timberland as part of an investment portfolio for clients and presumably will sell timber and land at some economically optimum rotation age (Caulfield 1998). A TIMO has an economic advantage over industrial timberland ownership in that the income at time of sale is taxed only once, whereas industrial income is taxed twice—at the corporate level and again at the shareholder level. An REIT pays no tax on income, but is required to distribute 90 percent of its net proceeds.

Mergers of forest industry companies and land sales by forest industry to financial institutions have resulted in transfers of more than 15 million acres in the past four years, with a further 12 to 15 million acres expected to transfer out of industry ownership over the next 10 years (Weber 2002). Hancock Natural Resources Group, the largest TIMO, was formed in 1985 and owns more than 2.5 million acres in the United States (SIFRC 2000). Georgia-Pacific Corporation, the second largest wood-processing company globally, formed The Timber Company with their corporate timberlands, which included large holdings in the South. By purchasing The Timber Company in October 2001, Plum Creek Forest Resources, an REIT headquartered in Portland, Oregon, became the second largest private forestland owner in the country, surpassed only by International Paper.

The full impact of this structural change in timberland ownership has yet to be estimated, but the big questions can be anticipated: How intensively will other corporate owners manage their plantations? What will happen to the land after the present stands are harvested in seven to 15 years; will it be held by the other corporate owners and regenerated or sold? If the land is sold, will it be developed for urban uses, converted to agriculture, or kept in forest? The answers to these questions have far-reaching ramifications for the forestry profession.

Advances through Research

The history of forest management in the South has been a process of intensification, and silvicultural research has been critical to this process. Yet forest management in the South is just six decades old, and formal forestry research began only in 1921, with the establishment of the Southern Forest Experiment Station in New Orleans (Josephson 1989). An institutional innovation in the South was the development of university-industry research cooperatives. Cooperatives enabled significant gains in productivity over the past 50 years, and most modern prac-

Table 1. Estimates of productivity gained as management intensified in southern pine plantations.

	Second Forest (naturally regenerated)[1]	Third Forest (unimproved plantation)[2]	Fourth Forest (improved plantation)[3]	Fifth Forest (intensively managed plantation)[4]	Increase over base
Average productivity	1 ton/acre/yr	3 tons/acre/yr	5 tons/acre/yr	8 tons/acre/yr	
	Percentage increase in productivity attributable to each factor				
Stocking control	None	40	0	0	11
Tree improvement	None	0	40	20	20
Nutrition	None	0	10	35	18
Vegetation management	None	0	5	35	16
Seedling quality	None	10	5	0	4
Biotechnology	None	0	0	0	0
Pest management	None	0	5	0	1
Soil-site classification	None	0	10	10	7
Site preparation	None	50	25	0	21
Intermediate treatments	None	0	0	0	0

[1] The naturally regenerated forest, beginning in the 1920s, followed exclusion of wildfire and grazing animals. We set this as our base, and estimated productivity averaged 1 ton/acre/yr. Tons per acre pine roundwood can be converted to cubic meters per hectare solid roundwood by multiplying by 2.09.
[2] Unimproved plantations beginning in the 1950s with aerial seeding, later some planting; typically, this was on old fields and burned areas, and conversion of understocked natural stands. The increase in productivity over the naturally regenerated forest was 2 tons/acre/yr.
[3] Improved plantations with increased productivity of 2 tons/acre/yr over unimproved plantations.
[4] Intensively managed plantations of today; productivity increased another 3 tons/acre/yr.

tices of intensive plantation forestry were either pioneered or refined through them (SIFRC 2000), beginning with the Texas A&M University Tree Improvement Cooperative in 1951 (SIFRC 2000). In 1999, there were 23 cooperatives at nine southern universities with an annual budget of $15 million (SIFRC 2000). The results of cooperative research were nonproprietary, and many innovations readily became available to nonmembers such as the larger NIPF owners (SIFRC 2000; Stanturf et al., in press).

If asked to identify the important advances in productivity research, most researchers and managers would provide a list that included tree improvement, nutrition management, and vegetation management (e.g., SIFRC 1996). A more comprehensive list would also include seedling quality and nursery practices, soil-site classification, site preparation, and pest management. Some would add intermediate treatments and the very optimistic would include biotechnology. All items would relate to increases in biological productivity.

Important advances in other areas have made plantation management more efficient and more profitable but have not increased biological productivity as such. Growth-and-yield and economic decision models have aided management decisions and realized gains from research through cost-effective deployment of genetically improved growing stock and concentrating intensive treatments on the most responsive sites. As wood from fast-growing plantations has begun to reach mills, information on wood quality has increased in importance.

Productivity Increases

Such lists certainly capture' the major areas of research activity over the past 80 years, but how much have advances in any of these areas actually produced more wood or increased profitability? We attempted to answer that question by estimating the overall increase in productivity due to intensive management and how much specific practices contributed to the increase. Although we present our estimates at discrete time steps-as a sequence of coastal plain pine forests from the naturally regenerated forest of about 1920 to the intensively managed forest of today-the process in fact was continuous. Our estimates of the percentage of productivity gains attributable to improvements made in individual management practices are based on our collective experience, anecdotal information, and discussions with knowledgeable colleagues. Such informed judgments are based on potential productivity revealed by designed experiments (e.g., Shiver and Martin 2002) coupled with estimates of how well technology has been implemented (Stanturf et al., in press). We should point out that not every acre could be managed as intensively as discussed here, due to economic and regulatory constraints.

Productivity of the original First Forest is unknown, but probably was lower than the naturally regenerated Second Forest because of periodic fires. Fire, whether wildfire or from Native American burning (Wade et al. 2000; Stanturf et al. 2002), would have wholly consumed some stands, but its greater impact was to generally keep stocking low. Fire effects were exacerbated during the period following exploitive logging of the native forest and before effective fire suppression. The naturally regenerated Second Forest, beginning in the 1920s, followed exclusion of wildfire and grazing animals. We estimate productivity averaged 1 ton/acre/yr and set this as our base level.

Unimproved plantations, the Third Forest, began in the 1950s with aerial seeding, but quickly changed to planting on industry land. Most planting

Productivity and Sustainability

Plantations often are more productive than natural forests, at least in yield of usable biomass. Nevertheless, sustainability of plantations is frequently questioned (Powers 1999). There is no consensus on how to measure sustainability at the stand level where most management occurs, but at least one criterion-maintenance of productive capacity of forest ecosystems-should be easily evaluated (Smith et al. 2001).

Unfortunately, there is no accepted way to define and measure productive capacity. "Productivity" as used in this article is a narrower concept than "productive capacity." Productivity can be defined in the commonly understood sense of biomass or timber production per unit area and evaluated at the stand and landscape levels. We think, however, that this utilitarian notion of productivity should be fixed within a concept of sustainable productivity (*fig. 1*). Thus, we see productivity as nested within several levels of broader concerns, which at the most inclusive level is sustainability in the sense of productive capacity. The utilitarian concept of productivity we used could be called "bioeconomic productivity," to emphasize that it is determined biologically and technologically. On the biological side, productivity can be viewed narrowly or broadly. Narrow-sense productivity includes those tree-environment interactions that contribute to inherent site productivity, primarily nutrients, moisture relationships, and aeration. Broad-sense productivity refers to tree-vegetation interactions. the inter- and intraspecific, density-dependent competition effects manipulated by managers initially through choices of stocking, species, and genotype. Technological determinants of bioeconomic productivity are yield qualifiers imposed by technology and consumer preferences that introduce size and quality differentials.

Factors that reduce or enhance bioeconomic yield may be controlled or avoided by intervention. A manager may have biologically effective and technically feasible techniques to enhance yields or avoid losses, but the decision to intervene is determined at the next higher level of integration, "socioeconomic productivity."

In the socioeconomic domain, a company must manage financial resources within the social context of a regulatory environment. Management requires investment (capital and labor certainly, but also managerial ability) of scarce resources. The goal is to maintain or enhance site resources, avoid yield-reducing interactions, control crop density, and increase competitive ability or yield enhancement through genetic manipulation. Simply put, this means finding the economic optimum yield level. Government regulation attempts to internalize within industry the social costs of producing wood fiber. Because a company must be a good corporate citizen and meet legal and social norms for protecting other resources (water quality and quantity, aesthetics, air quality, human health and safety, wildlife, endangered plants and animals, and rare plant communities), the costs of complying with regulation are treated as costs of doing business.

Sustainability is the matrix in which cultural values and other societal concerns (e.g.. intergenerational equity, biodiversity maintenance, and long-term site productivity) are embedded. Companies with plantations have begun to address these issues through certification, but potential social benefit must be balanced against fiduciary responsibility to stockholders. Does research to address regulatory or sustainability questions qualify as productivity research? Probably not. But productivity research that ignores sustainability concerns likely is irrelevant.

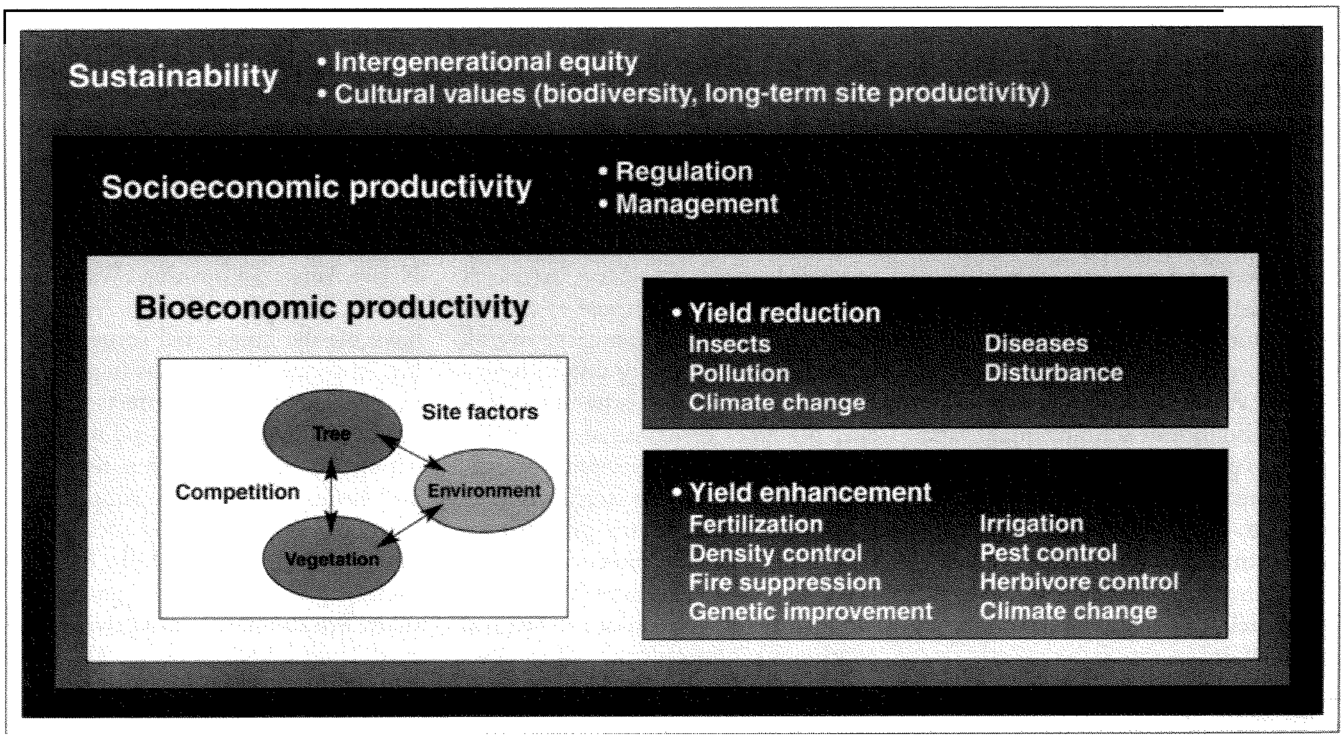

figure *1.* Productivity is commonly understood as biomass production per unit area but should be understood as nested within several levels of sustainable productivii.

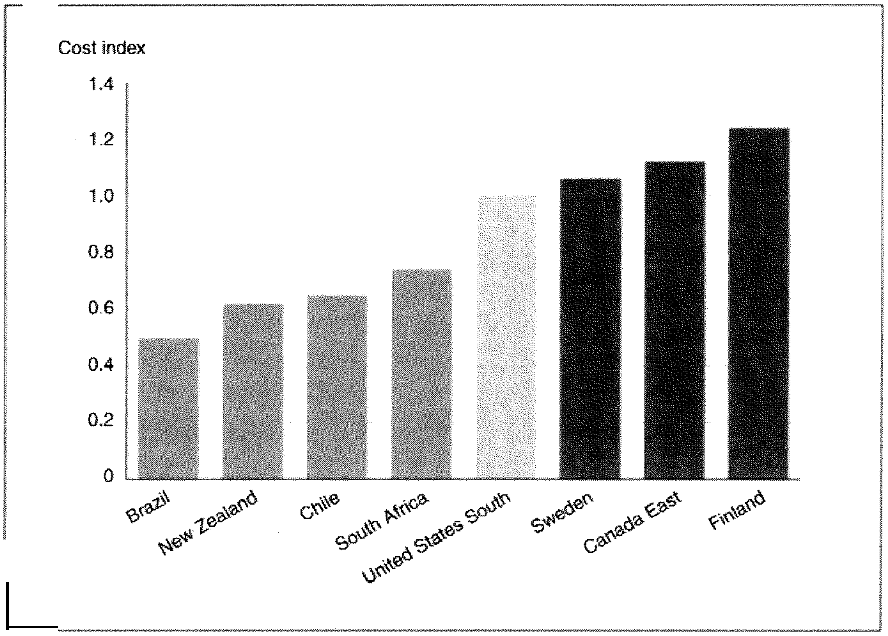

figure 2. Delivered cost of softwood roundwood in major pulpwood-producing countries, indexed to average cost in the southern United States of $34 per cubic meter (solid wood, mill-delivered). Data are for the third quarter of 1999. *Source:* Hytonen and Pihlajamaki (2000).

was of old fields and burned areas or resulted from converting understocked natural stands. The increase in productivity over the naturally regenerated forest was 2 tonslacrelyr. Increased productivity at this stage resulted from advances in site preparation (50 percent, mostly from bedding), better stocking control from planting (40 percent), and more vigorous seedlings (10 percent)

Productivity increased in the improved plantations of the Fourth Forest by 2 tons/acre/yr over unimproved plantations. This increase resulted from tree improvement (40 percent), further advances in site preparation (25 percent), fertilization of phosphorus-deficient sites (10 percent), soil-site classification and treatments matched to site (10 percent), pest management (5 percent, use of Bayleton on seedlings to prevent transfer of rust spores from the nursery to the woods), early gains from vegetation management (5 percent), and seedling quality (5 percent).

Productivity jumped another 3 tons/acre/yr in the intensively managed plantations of today-the Fifth Forest. Increases resulted from advances in nutrition (35 percent) and vegetation management (35 percent), with further increases due to tree improvement (20 percent) and matching treatments to site (10 percent). In the early 1990s, management was even more intensive by some companies. Nantucket pine tip moth was controlled operationally, for example, and provided a further productivity gain of 1 ton/acre/yr.

The largest increases in productivity realized today over the naturally regenerated forest of 1920 came from site preparation (21 percent). In fact, the increased productivity from site preparation was already realized in the establishment of the Fourth Forest ***(table 1).*** Bedding applied to sites with impeded soil drainage increased the productivity of the Third Forest. The gain in productivity due to site preparation between the Third and Fourth Forests (0.5 tons/acre/yr) is the result of less intensive mechanical treatments. Foresters found that root raking and windrowing to facilitate planting caused a loss of productivity because nutrients and organic matter were moved with the topsoil into the windrows. Bedding sandy soils, even those with impeded internal drainage, also caused a loss of productivity. Chemical site preparation avoids the potentially site degrading aspects of mechanical methods and more effectively kills the root systems of competing woody vegetation, thereby avoiding sprouting (Lowery and Gjerstad 199 1).

We have described the development of the Fifth Forest as resulting from more intensive management, but greater intensity of mechanical treatments was not the cause. Rather, the gains have come from more intensive tree improvement. Not surprisingly, gains from tree improvement have been substantial, accounting for 20 percent of the increase over base level of productivity ***(table 1).*** No doubt there will be further gains from tree breeding, a tribute mostly to the genetic diversity of loblolly pine. As compared to cereal grains such as wheat, which have been subjected to breeding for 5,000 to 10,000 generations, we are just beginning to domesticate loblolly pine as a crop (R. Sederoff 200 1, pers. commun.).

The Future?

What will the future bring? We did not set out to examine our crystal ball, only to take a look back. Nevertheless, we cannot resist looking-forward a bit. From a researcher's perspective the future is bright. Clonal forestry and improved understanding of nutrition could greatly enhance productivity of pine plantations. We are uncertain, however, whether the level of management described for the Fifth Forest will be maintained. Despite these levels of productivity, southern pine plantations are not the most productive sources of fiber, nor are they the lowest cost fiber produced (*fig.* 2). Consolidation of the vertically integrated forest products industry and devolution of industrial timberlands to other corporate owners (REITs and TIMOs) suggests a retreat from the capital-intensive Fifth Forest plantations, although some of these other corporate owners have shown an interest in fertilization (H.L. Allen 200 1, pers. commun.).

We should soon see more clearly what the future holds for southern plantation forestry. If the projections of the Southern Forest Resource Assessment (Wear and Greis 2002) and timber supply projections made for the Resources Planning Act (Haynes in press) come to pass, new pine plantations will be established in response to market forces along the northwestern border of the South. Management intensity is predicted to increase by all private landowners, including NIPF owners (Alig et al. 2002; Siry 2002). The technology used to establish new plantations will provide an early indication of the intensity of future loblolly pine plantation management.

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