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Forest Policy and Economics 5 (2003) 407–419

Forest Policy and Economics

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Innovation and forest industry: domesticating the pine forests of the southern United States, 1920–1999

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Received 10 April 2002; received in revised form 22 November 2002; accepted 7 March 2003

Abstract

The history of forest management in the southern United States has been a process of intensification and the pine forests of the Coastal Plain can be regarded as in the early stage of crop domestication. Silviculture research into tree improvement and other aspects of plantation establishment and management has been critical to the domestication process, which began in the early 1950s with the paradigm shift from natural stand management to plantation forestry. Advances were incremental innovations that relied heavily on basic knowledge gained in other disciplines and from formal university–industry silviculture research cooperatives. These cooperatives played a critical role in the domestication process, especially as they disseminated technological innovations. Sixteen major pulp and paper companies were examined in terms of participation in research cooperatives, expenditures on research and implementation of innovations. Despite a lack of relationship between company size (gross sales) and expenditures on forestry research, implementation of innovations was significantly related to research expenditures, timberland owned and total sales. Adjusting for timberland ownership or annual sales, the companies that spent the most on forestry research did the best job implementing research results. Emerging trends in industry structure and support for research may indicate a new role for public research institutions in the South, and call into question the need for silviculture research cooperatives.

Keywords: Innovation; Technology transfer; Research policy; Forest industry; Plantations; Research cooperatives; Forest productivity

1. Introduction

The forested landscape of the southern United States (the South) is bewilderingly complex to visitors: highly productive, ecologically diverse and virtually unregulated as compared to the western states (Roussopoulos, 1998). Of the 87 million ha of forestland, only 11% is under public management and 67% is managed by non-industrial private landowners, in small parcels of less than one to several hundred hectares (Birch, 1996;

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doi:10.1016/S1389-9341(03)00039-X

Table 1
Chronology of the domestication of the southern pine forest

Characteristic	Original forest	Naturally regenerated forest	1st plantation forest	2nd plantation forest	3rd plantation forest
Initiation	Pre-columbian	Post-agriculture, 1920	1950	1980	2000
Dominant species	Longleaf pine	Slash and loblolly pines	Slash and loblolly pines	Loblolly pine	Loblolly pine
Material	Natural seedlings	Natural seedlings	Aerial seeding followed by bareroot, unimproved stock	Improved bareroot seedlings (1st and 2nd generation half-sib)	Improved bareroot seedlings (3rd generation half-sib or full-sib)
Fire suppression	No	No	Yes	Yes	Yes
Stocking control	No	No	Yes	Yes	Yes
Site preparation	No	No	Heavy	Lighter	Lighter
Fertilization	No	No	P-deficient	P, some N	N and P
Competition control	No	No	No	Some	Yes

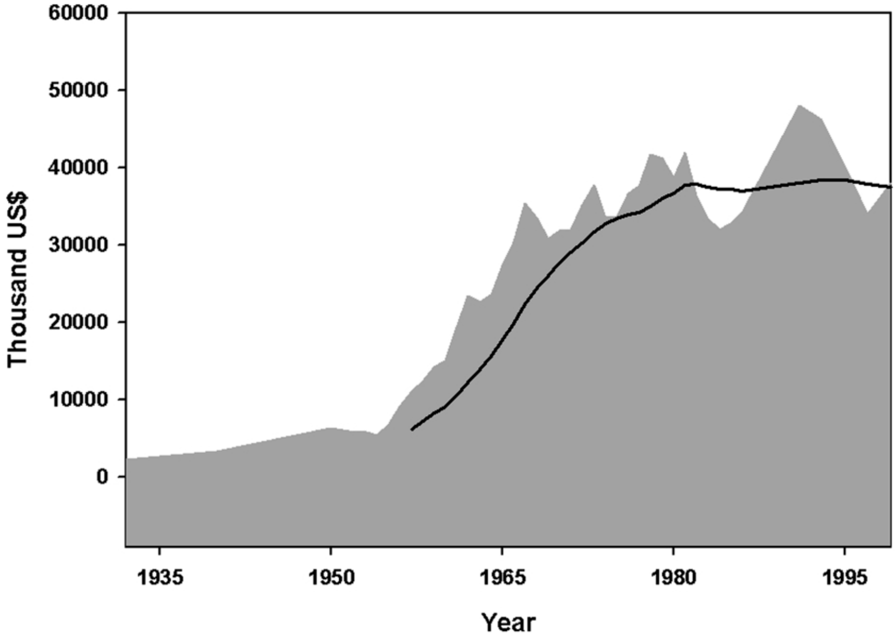

Fig. 1. Federal funding for United States Forest Service Research in the South, 1932–1999. Amounts in constant 1996 dollars; actual values adjusted using the Gross Domestic Product Deflator. Trend line based on 10-year moving average. (*Source:* USDA Forest Service, 1988 for 1932–1989; other years from annual reports of Southern and Southeastern Forest Experiment Stations until they were combined into the Southern Research Station in 1996, then the annual reports of the Southern Research Station.)

Sheffield and Dickson, 1998). Although forest industry owns just 20% of southern forestland, its influence on management of land in other ownerships is substantial (Stanturf et al., 1993). A dominant 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. The productivity and extensiveness of these plantations have placed the South at the forefront of production forestry. In 1997, 57% of the softwood and 52% of the hardwood timber produced in the country came from the region and forecasts predict increases in harvesting over the next three decades (Haynes et al., 2001).

The history of forest management in the South has been a process of intensification, to such an extent that the pine forests of the Coastal Plain can be regarded as in the early stage of crop domestication. Silvicultural research into tree improvement and other aspects of plantation establishment and management has been critical to the domestication process. Surprisingly, forest management in the South is just six decades old, and formal forestry research began only in 1921 (Josephson, 1989). The rapid development and diffusion of new technology were critical to the South recovering from the early days of exploitive logging and rampant wildfire (Williams, 1992) and becoming the ‘wood basket’ of the nation. Coinciding factors created a demand for ways to increase productivity and led to the shift from natural to planted forests. Private landowners sought greater financial return and forest industry wanted to protect its investment in new manufacturing facilities. The need for information was met by a long-standing federal forestry research presence allied with vigorous state universities. In this open environment, new ideas diffused rapidly. Our objectives in this article are to (1) present an historical context for the innovation process in southern pine management, (2) apply a diffusion model to describe the innovation process and (3) test whether the size of forest industry firms or the amount expended on silvicultural research was related to their adoption of innovations.

2. Methodology and theoretical approach

2.1. Methodology

Assessing the contribution of scientific knowledge to technological development is a difficult form of research evaluation (Hodges et al., 1988; Hodges and Cubbage, 1990). We drew on our collective experience in industrial, academic and public agency forestry research to present a qualitative analysis of the role of silvicultural research in evolving forest management practice. In our role as participant observers, we developed a chronology for the domestication process (Table 1). Within this historical framework, we focused on the shift from reliance on natural stands to plantations and subsequent innovations. Our intent was to assess implementation of innovation by major forest industry firms, and to examine this in the context of a diffusion model of the innovation process.

Anecdotal and published information was assembled to construct a picture of the forestry research structure in the South, the resources available for producing innovation, and the dominant means of disseminating technology innovation. To examine the implementation of new technology, we gathered data on 16 pulp and paper companies operating in the South in 1997. These included some of the largest paper companies in the world (WWF, 2001) as well as some primarily regional companies. Information on sales, timberland area owned and total research expenditures were taken from corporate annual reports. We estimated expenditures on forestry research, based on membership in university–industry cooperatives, costs of implementing regional studies as part of those cooperatives, size of the research staff, their disciplines, and whether they were known to conduct in-house studies. From these data, we calculated two ratios, the expenditure on forestry research to either timberland area or sales.

We estimated how the companies compared in terms of implementing research results. The implementation ranking primarily was based on how well a company implemented fertilizer and herbicide technology, as all companies had tree improvement programs. The implementation ranking was based on professional judgment and discussions with knowledgeable colleagues. One limitation of the ranking, which was assigned on data available in 1997–1998, derives from the numerous mergers and acquisitions since then. The results still have meaning because the surviving companies are thought to have a similar strategy to that of the merged companies.

We used nonparametric statistics to test for independence (Hoeffding's measure of dependence) between attributes (Lehman, 1975; SAS Institute, 1988) at the 0.05 level of significance.

2.2. Theoretical approach

The basic structure of the innovation process consists of three steps: research to produce an innovation, dissemination of that innovation to firms or individuals, and implementation of the innovation within an industrial sector. Much of the literature on technology innovation characterizes a pattern of a major technological shift followed by a long period of incremental innovation within an established technological framework (Nelson and Winter, 1977; Abernathy and Utterback, 1978; Rogers, 1983; Saviotti, 1995).

The dissemination and implementation stages are connected by the decision to implement a new technology. Rogers (1983) described five stages in the decision process: (1) becoming aware of the existence of the innovation; (2) persuasion by external sources; (3) the decision to adopt or reject; (4) implementation of the decision and (5) confirming the adoption decision by seeking information from other sources. Baldwin and Haymond (1994) confirmed the importance in the South of key individuals as facilitators of technology dissemination. Researchers in the South have focused on non-industrial private forestland owners, particularly on their decision whether to reforest following harvest (e.g. Royer, 1987; Bliss and Martin, 1990). Surveys have been used to examine landowner characteristics (Doolittle and Straka, 1987; Birch, 1996), communication styles (Baldwin and

Haymond, 1994), use of technology transfer agents (Royer and Kaiser, 1985), management objectives (Kluender and Walkingstick, 2000), and the effects of incentive payments on landowner behavior (Brooks, 1985; Lee et al., 1992). Hodges and Cubbage (1990) examined the factors associated with the adoption of innovation by technology transfer agents, i.e. foresters advising landowners.

Most studies found that adoption of innovation was influenced by size of the forestland unit, personal characteristics of the potential adopter, communication channels and management situations (Hodges and Cubbage, 1990). Although these studies seldom considered the industrial landowner, we hypothesized that companies would behave similarly as individuals. Specifically, we hypothesized that company size and amount of timberland owned would positively affect the amount expended on forestry research. In turn, these factors would influence company participation in university–industry cooperatives and implementation of innovations. Implementation is not within the control of the researcher, however, and often depends on factors outside the control of even the land manager. Market and non-market influences such as prices for stumpage and finished products, interest rates and environmental regulations can determine how quickly or extensively a technology innovation is practiced on the ground.

3. Results

3.1. Production of innovation

The introduction of plantation management was a paradigm shift in the South (Table 1). While there were initially many ways to establish plantations, especially in the varying intensities of site preparation methods, companies converged on a dominant silvicultural system. New technologies, such as fertilizer and herbicides, were incremental innovations that were implemented within the existing technological framework of plantation management.

The complex structure of research organizations in the South has been responsible for developing the knowledge leading to the paradigm shift from natural stands to plantation management and for the subsequent incremental technology innovations. The major sources of research have been the federally funded Forest Service Research and Development organization; universities, mostly publicly supported state schools; and forest industry. Other agencies, such as the Department of Energy (DOE), supported forestry-related research in some areas such as biofuels. Estimated total expenditures by all entities for forestry research in the South was $86.8 million in 1995 (SIFRC, 1996). Beginning in 1996, DOE expanded into genetics, biotechnology, site productivity, GIS/remote sensing and wood products, with estimated annual investments of $5 million.

3.1.1. Research organizations

3.1.1.1. Forest Service research and development. The research arm of the Forest Service has been administratively independent of the land management arm, the National Forest System, since 1915 (Josephson, 1989). The mission of Forest Service Research and Development is to develop the best scientific information available to deliver technical assistance to support ecological, economic and social sustainability (USDA Forest Service, 2000) on forestland of all ownerships. The Southern Research Station headquartered in Asheville, NC, allocates approximately 29% of its total budget to grants and cooperative research agreements to fund research with university scientists through direct financial support, mostly outside of the university–industry cooperatives (N. Herbert, personal communication, 2001).

The general public benefits in two ways from this federal role: consumers benefit from lower costs of products made from wood because of the critical role of non-industrial private forestland in fiber supply, and from the environmental benefits of good land management on all private land. In recent years, internal pressure has been exerted to place higher priority on servicing National Forest System needs, but the process for decision-making on public lands has been stymied through legal challenges.

3.1.1.2. Forest industry. Forest industry in the United States has traditionally taken a conservative approach to research funding. Where the average expenditure on research for all industry in the United States is 3.5% of sales, the pulp and paper industry average is 1% of sales for all aspects of research, including manufacturing. The pulp and paper industry spends significantly less than other comparable major industries such as automotive (3.8%), chemical (3.7%), or healthcare (9.8%). Motivation for industrial research includes maintaining competitive leadership, increased productivity and efficiency, presentation of a positive image and environmental compliance.

Forest industry research expenditures contracted by 30–50% in the late 1970s in response to recession (Hodges et al., 1988). The role of the remaining industry scientists is a curious one; unless engaged in proprietary research such as biotechnology, they facilitate research conducted by university researchers and replicate field studies to test results under their company's specific conditions. Although their role varies between companies, and is subject to radical change within a company over time, industry scientists function as technology mavens (Spivey et al., 1994): they find, broker, or request research conducted by university or federal researchers, and evaluate the appropriateness of the results for their company. Often the most valuable contribution of an industry scientist is to synthesize results from disparate sources and recommend a course of action to managers. Even those who may conduct in-house research seldom are allowed or supported in publishing the results.

3.1.1.3. Universities. University faculty members have difficulty relying on long-term internal funding to install large-scale field trials and maintain the integrity of research. University faculty, however, have access to a steady flow of intellectual resources of graduate students and faculty, and access to funding sources in basic biology not usually available to Forest Service or industry researchers, including National Science Foundation, DOE and Environmental Protection Agency.

3.1.1.4. University–industry research cooperatives. An innovation that developed in the South was the university–industry research cooperative. The cooperatives were organized to overcome shortcomings of both industry and university research, and to capitalize on the assets of each. Cooperatives enabled significant gains in productivity over the last 50 years. Most modern practices of intensive plantation forestry were either pioneered or refined through these cooperatives (SIFRC, 2000). Funding from cooperatives adds significantly to the support of faculty in universities. In 1999–2000, it provided approximately 42 full-time equivalent senior scientific positions and numerous graduate students in nine southern universities.

Today, the most significant asset of cooperatives is the installed base of region-wide experiments. This field trial base available to university researchers is a unique resource (SIFRC, 2000), increasingly useful to address questions other than the ones for which the trials were designed. Industry benefits from the common experimental design installed at multiple locations by having a large inference base for management decisions. In addition to the direct financial payback (leverage is often more than a factor of ten for a company), cooperative membership benefits a company by providing a legal means to interact with counterparts from other companies on technical matters, without violating antitrust laws.

3.1.2. Research support

Despite periodic calls for increased funding for natural resources research (National Research Council, 1998), overall funding for forestry research has declined in real terms. For example, support for the Southern Research Station was declining for most of the 1990s (Fig. 1). Over the longer term, the number of Forest Service scientists nationally eroded steadily (Fig. 2). Industry correctly perceived (SIFRC, 2000) that as productivity-oriented scientists such as silviculturists retired or left, their position either went unfilled or they were replaced with other specialists (Fig. 2).

In the South, the investment in productivity research by the Forest Service is significant, although not necessarily all results are applicable to intensively managed plantations. In 1999, approximately $16 million or 38% of the appropriation to the Southern Research Station was spent

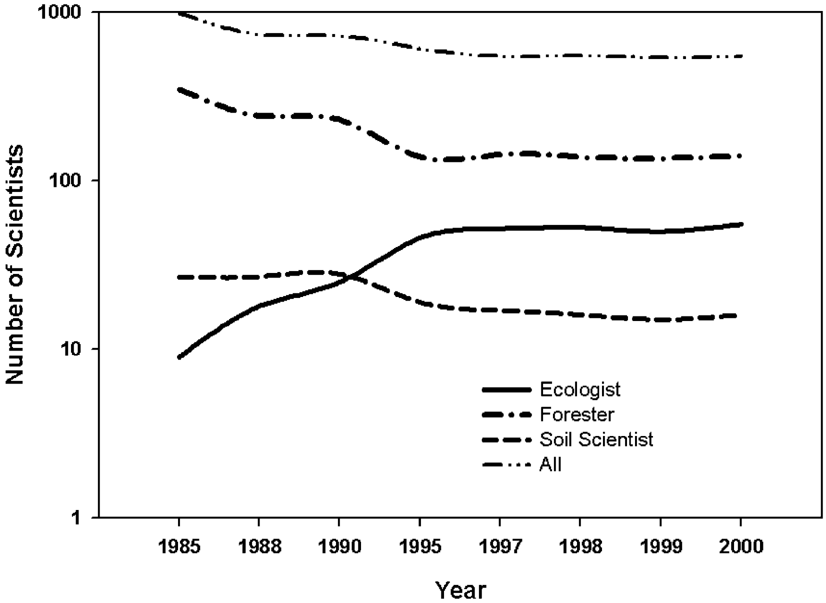

Fig. 2. Declining number of Forest Service scientists nationwide, 1985–1999. Numbers of foresters and soil scientists declined but ecologists increased over the period. Data are displayed on a logarithmic scale (*Y*-axis) to overcome the wide range in values and better illustrate trends. (*Source:* Forest Service Research Advisory Committee, personal communication from Ted Leininger, 2000.)

on productivity research (David Loftis, personal communication, 2000). Productivity research was a stable proportion of the total budget for the Southern Research Station, averaging approximately 40% of annual appropriations during the last decade (Fig. 3). This level of expenditure went against the declining trend in total appropriations over the rest of the 1990s (Fig. 1).

Funding for productivity research conducted in university–industry cooperatives was of a similar magnitude, close to $15 million in 1999 (Table 2). Member contributions accounted for over $4 million, and other direct funding from outside grants and direct support from the university or government agencies provided over $4 million (over $1.6 million of this was an NSF grant to the North Carolina State Forest Biotechnology Group for genomic mapping of loblolly pine; SIFRC, 2000). University supported 'hard money' salaries are not included in this category. University direct funding of over $4 million (Table 2) is an estimate of the salary support provided to the 42.7 faculty and staff positions allocated to the cooperatives. Many of these positions are senior faculty; a conservative estimate of $100 000 for each position was used to arrive at the amount for university direct support (SIFRC, 2000). Industry in-kind contributions were estimated as 50% of the annual member contribution. This contribution comes in the form of costs associated with installing, measuring and maintaining the field trials and probably underestimates real costs. In addition, the overhead foregone in cooperative funding usually assessed against other grants secured by university faculty, could amount to more than $1 million at the standard charge of 25% or greater of the total direct costs of the cooperatives (i.e. of the funds coming into the schools as member dues).

We estimate that industry research in the South in 1997 totaled $54 million for forest productivity and forest environmental research. Estimates (Table 3; ranks in Table 4) are based on membership in cooperatives and the size of in-house research staff and their specialties. There was a positive, significant relationship between gross sales and timberland ownership ($D = 0.19, N = 16$).

Four of the largest companies in sales were in the top five of timberland ownership (International Paper, Georgia-Pacific, Weyerhaeuser and Champion). Three of the smallest companies in sales owned the least amount of timberlands (Rayonier, Potlatch and Westvaco). Kimberly-Clark stands out as a company in the top five of sales that owned little timberland. There was no apparent relationship between company sales and the amount spent on forestry research (Table 4); the top five companies in terms of expenditures included three of the top five in sales (Weyerhaeuser, Champion, Georgia-Pacific), one of the smallest companies (Westvaco), and one middle-sized company (Union Camp). There also was no relationship between research expenditures and the amount of timberland a company owned; one of the top five companies in timberland area owned was in the bottom five of research expenditures (Bowater) and the top company in terms of research expenditure was 14th in timberland owned (Westvaco).

It is difficult to cleanly separate the amount spent by industry on productivity research (in-house plus cooperatives) from environmental research conducted to satisfy regulatory requirements. Nevertheless, most pulp and paper companies contribute to special programs of the National Council for Air and Stream Improvement aimed at environmental research. In 1997, this amounted to $2.121 million (A. Lucier, personal communication, 2001).

Table 2
Estimated cooperative research funding, 1999

Source	Amount ($)
Member contributions	4 243 832
Other direct funding	4 273 316
University direct funding	4 270 000
Industry in-kind	2 123 916
Total	14 911 064

Source: SIFRC (2000).

3.2. Diffusion

The dominant mechanism for disseminating new technology has been by ‘Looking Over the Fence’ and seeing what others in the industry were doing.

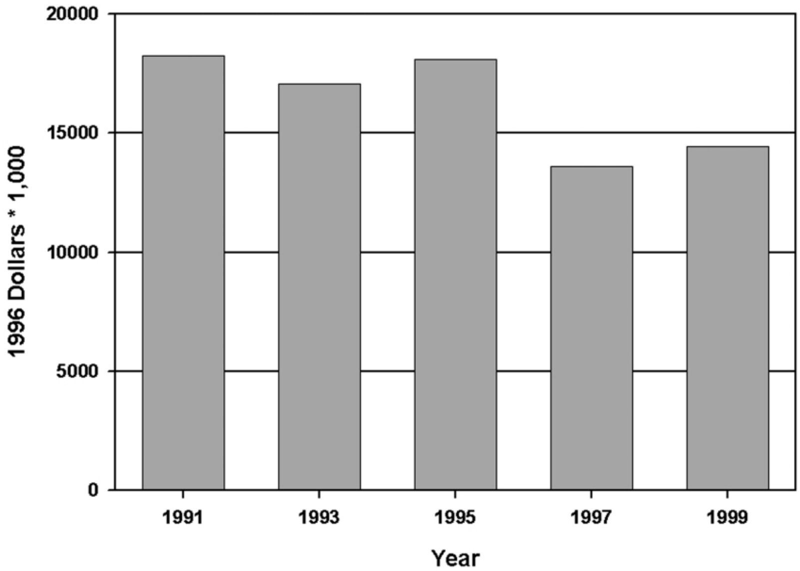

Fig. 3. Expenditures on productivity research by the Southern Research Station, 1991–1999, in constant 1996 dollars (actual values adjusted by the GDP Deflator). Our estimate of Forest Service expenditures on productivity research is based on annual appropriated funding through the Southern Research Station to individual Research Work Units. Project Leaders of the RWUs judged how much annually was spent on conducting productivity research (David Loftis, personal communication, 2000) over time.

Table 3
Sales, timberland area and expenditures for research by major pulp and paper companies in the South

Company	Sales (million $)	Timberland area (million ha)	Total research expenditures ($1000)	Forestry research expenditures ($1000)	Forestry research per timberland area	Forestry research per $1000 sales
International Paper	20 143	2.59	112 000	5000	1.93	0.25
Kimberly-Clark[a]	13 149	0.36	208 000	1000	2.75	0.08
Georgia-Pacific[b]	13 024	2.31	na	3000	1.30	0.23
Weyerhaeuser	11 114	2.14	54 000	12 000	5.59	1.08
Champion[c]	5880	1.94	na	3500	1.80	0.6
Boise Cascade	5108	0.85	11 000	500	0.59	0.1
Mead[d]	4706	0.77	40 000	1500	1.95	0.32
Union Camp[e]	4013	0.65	56 000	5000	7.72	1.25
Temple-Inland	3460	0.89	na	1000	1.12	0.29
Willamette[f]	3425	0.73	na	500	0.69	0.15
Jefferson-Smurfit	3410	0.40	na	1500	3.71	0.44
Westvaco[d]	3046	0.57	38 000	15 000	26.47	4.92
Louisiana Pacific	2486	0.65	na	500	0.77	0.2
Bowater	1718	1.09	na	500	0.46	0.29
Potlatch	1554	0.61	na	1000	1.65	0.64
Rayonier	1178	0.61	11 000	2500	4.12	2.12
Total	97 414	17.16		54 000		
Average	6088	1.07		3375	3.91	0.81

Data for 1997.
[a] During the period under study, Kimberly-Clark divested its southern timberlands.
[b] Following the period under study, Georgia-Pacific divested its southern timberlands.
[c] Following the period under study, Champion was acquired by International Paper.
[d] Following the period under study, Westvaco and Mead merged into MeadWestvaco.
[e] Following the period under study, Union Camp was acquired by International Paper.
[f] Following the period under study, Willamette was acquired by Weyerhaeuser.

Some companies have been early adopters of technology, while others have waited to adopt technology until it was somewhat proven. An example is the use of herbaceous weed control early in the rotation of pine plantations. Weyerhaeuser experimented in the 1960s with herbaceous weed control in hand-hoed plots. Other companies, apprised of Weyerhaeuser's results, began evaluating chemicals for woody and herbaceous weed control. After a few companies established treatments that were effective, chemical company representatives spread the news to other companies, and the practice became operational.

Cooperative-university scientists have played a key role in disseminating technology through publications, annual meetings, short-courses and on-site visits. Likewise, the technical representative from each member organization is tasked with disseminating cooperative research results to his or her company and obtaining advanced genetic materials or data from region-wide trials. In short, the scientist functions as the technology gatekeeper (opinion leader, Doolittle and Straka, 1987; information-intensive individual, Baldwin and Haymond, 1994; technology maven, Spivey et al., 1994).

Another mechanism for diffusing technology has been through service providers. For industry, the suppliers and applicators of fertilizer and herbicides have proven effective technology diffusers. The major chemical companies have supported not only the cooperatives, but herbicide companies in

Table 4
Major pulp and paper companies in the South ranked on the basis of sales, timberland area, expenditures on research and implementation of research results

Company	Ranking					
	Sales	Timberland area	Forestry research expenditures	Research per timberland area	Research per $ sales	Implementation of silvicultural technology
International Paper	1	1	3	8	11	9
Kimberly-Clark	2	16	10	6	16	10
Georgia-Pacific	3	2	6	11	12	8
Weyerhaeuser	4	3	2	3	4	3
Champion	5	4	5	9	6	6
Boise Cascade	6	7	13	15	15	11
Mead	7	8	8	7	8	7
Union Camp	8	10	3	2	3	1
Temple-Inland	9	6	10	12	9	12
Willamette	10	9	13	14	14	15
Jefferson-Smurfit	11	15	8	5	7	4
Westvaco	12	14	1	1	1	5
Louisiana Pacific	13	10	13	13	13	16
Bowater	14	5	13	16	9	14
Potlatch	15	12	10	10	5	13
Rayonier	16	12	7	4	2	2

Data for 1997.

particular have supported individual faculty in state universities to conduct small-scale herbicide trials (efficacy screening and dose–response experiments) and local demonstrations.

Knowledge diffusion to the general public is gained from short-courses, continuing education programs, applied research conferences and field tours. Many innovations developed by the research cooperatives readily became available to non-members such as the larger non-industrial private forestland owners. The results were non-proprietary and rapidly distributed through cooperative extension, state agencies, forest industry programs assisting landowners, or consultants and service providers such as chemical companies and fertilizer distributors (SIFRC, 2000).

3.3. Implementation

We attempted to account for a company's need for research (possession of a company timberland base) and ability to pay for research (gross sales) by calculating ratios of research expenditures to sales and to timberland area (Table 3). In both ratios, Westvaco stands out as greatly exceeding the average of all companies. Implementation rank (Table 4) was significantly related to research expenditures ($D=0.63$, $N=16$) and its ratio with timberland owned ($D=0.65$, $N=16$) and total sales ($D=0.52$, $N=16$). Adjusting for timberland ownership or annual sales, the companies that spent the most on forestry research did the best job implementing research results (implementation rank). The top five companies in terms of forestry research spending per unit area of timberland were the same five companies at the top of the implementation ranking (Union Camp, Rayonier, Weyerhaeuser, Jefferson-Smurfit and Westvaco). With the exception of Weyerhaeuser and Union Camp, these were some of the smallest companies in sales, with the least timberland area.

4. Conclusions

Domestication of pine forests in the South has followed the classic innovation process. The paradigm shift from natural stand management to plantation forestry occurred in the early 1950s.

Further advances were incremental innovations that relied heavily on basic knowledge of genetic improvement, soil fertility management and the technology of competition control using chemicals. Of particular note, southern forestry research has experienced few ‘Eureka!’ moments. Progress has been incremental and predictable. Importantly, an applied research feedback loop, provided through university–industry cooperatives, has proven essential. Scholarly advances with practical payoffs have emerged from across the process continuum, extending from basic discovery, through integration with related disciplines, to dissemination to practitioners, to trial and operational application. Each step added value to knowledge generated by research.

Silviculture research in the South has progressed as a societal initiative, embraced collectively by private and public interests, with results available to all sectors. Advances have directly benefited the landowner applying the innovation, but more broadly have contributed toward public interests in forest stewardship by focusing accelerated domestication on sites and ownerships best suited to fiber production. Open exchange among private sector players and public agencies has contributed positively to the intensification of forestry in the South. Because of the public nature of these benefits, and the difficulty of generating private sector returns from investments in silviculture research, the rationale in the past for public intervention in production-related research has been compelling. The most effective method for innovation in the south has been the university–industry cooperative and the non-proprietary research they conduct. Cooperatives have dominated innovation production and dissemination. They have created the tight social structure required for effective communication of results (Baldwin and Haymond, 1994). Implementation has been rapid due to the efficiency of the diffusion process within the cooperative structure.

Cooperatives are undergoing review and will probably change, although just how is open to debate (SIFRC, 2000). Pressure to change is coming from three directions: demands for proprietary research, eroding cooperative membership base (SIFRC, 2000), and the changing nature of the research questions being asked. Anticipated advances in biotechnology are spurring companies to adopt a more competitive research paradigm, one involving patents, licenses and other exclusive rights to intellectual property (K. Munson, personal communication, 2001).

Acquisitions and mergers have reduced the number of forest industry companies and concentrated industrial timberlands in fewer hands. The costs of corporate restructuring have at times been funded outright by liquidation of timber assets, or fueled divestiture of the timber and land. Of the 16 companies in our study, three were acquired by other companies within our sample (International Paper acquired Union Camp Corporation and Champion International; Weyerhaeuser acquired Willamette) and two merged (Mead and Westvaco). Georgia-Pacific Corporation, the second largest processing company globally, formed the Timber Company with their timberlands and then sold that company to Plum Creek Resources, a Real-Estate Investment Trust (REIT). The impacts of these changes in ownership of forestland are being felt in the declining membership base for research cooperatives.

A problem encountered by cooperatives from the outset was that some companies do not contribute to the cost of conducting research but benefit when results are published. The problem is more acute today with the growth of other corporate owners of forestland such as banks, insurance companies and investment organizations, some of whom are indifferent toward research. Financial institutions such as Timber Investment Management Organizations (TIMOs) and REITs have acquired large areas of timberland. Plum Creek Resources, a REIT, is second only to International Paper in forestland ownership in the United States. John Hancock Timber Resource Group, a TIMO, owns over 1 million ha (SIFRC, 2000). A new ownership class, corporate forestland, is now used in periodic forest inventory to capture this development. Typically these private landowners own very limited manufacturing facilities and in some cases are legally prohibited from doing so. The timberland is owned as part of an investment portfolio for clients and presumably they will sell timber and land at some economically optimum rotation age (Caulfield, 1998).

The research agenda is shifting from empirical, stand-level field trials to process-level understanding of productivity and the interactions among genetics, physiology and silvicultural treatments. This requires more multidisciplinary approaches and is not conducive to large-scale field experimentation. In response, cooperatives are recasting themselves and using their field experiments to examine questions in addition to the ones the experiments were designed to answer. The scientists leading the cooperatives are placing greater emphasis on seeking external funding from granting agencies to fund this research, especially to provide expensive instrumentation.

The anticipated trend toward proprietary treatment of intellectual property will add a market element to sharing and disseminating information and restrict adoption to those willing and able to pay. Because private firms will be able to capture returns from investments made in biotechnology research, there is less need for public intervention. Taken together, these emerging trends in silvicultural research may indicate a new role for public research institutions in the South, and call into question the need for silvicultural research cooperatives. Nevertheless, forestry is a very public activity covering vast area. Innovations are not easy to cloak, even if the tendency were for innovators to restrict dissemination of knowledge. Each partner in forestry research (public universities, government agencies, forest industry, corporate timberland owners) has now to examine its respective past and potential future role and determine how to respond.

Acknowledgments

We would like to acknowledge the people who furnished data from files and internal reports, including Margaret Crabtree, Ted Leininger, David Loftis and Michael Bowker of the Southern Research Station. We would also like to thank those in the private sector who helped but who wish to remain anonymous. Al Lucier, David Wear, James Finley and an anonymous reviewer made helpful suggestions that greatly improved the manuscript.

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