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Planning and priorities for timber harvesting research in the Southern United States

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PLANNING & PRIORITIES

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T·I·M·B·E·R HARVESTING RESEARCH

in the Southern United States

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Planning and Priorities for Timber Harvesting Research in the Southern United States

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Foreword

In 1983, the Office of Technology Assessment, Congress of the United States, completed an assessment of the role of technology in the U.S. forest products industry and reported the findings of the assessment in a document entitled *Wood Use: U.S. Competitiveness and Technology.*

As a part of the overall assessment, the OTA identified opportunities for improving wood utilization, for improving forest productivity, and for enhancing the competitiveness of the forest products industry through improvements in timber harvesting technologies. To this end, the OTA recommended policy considerations to encourage research, development and transfer of forestry-related technologies, especially for timber harvesting technologies.

Congress subsequently provided special funds to establish centers at three universities to undertake the expanded research program. Mississippi State University, one of the universities selected for this role, was awarded a special research grant administered by the Cooperative State Research Service, U.S. Department of Agriculture, for this purpose.

One characteristic of the general field of forestry research is the relatively low level of funding allocated to timber harvesting research in comparison with other forestry problem areas. This is true nationally and in the southern region. As a consequence, in recent times there has been no comprehensive overview of the significant timber harvesting problems in the South. There has been no conceptual framework developed for a comprehensive southern regional timber harvesting research program, nor has there been a sufficient effort to estimate the resources necessary to support a comprehensive regional research program addressing timber harvesting problems.

An initial goal of the specially funded program at MSU was to develop a planning and priorities statement for timber harvesting research in the southern United States. By design, information to support the planning and priorities statement evolved following considerable dialogue, debate, and brainstorming among logging managers, foresters, and researchers. Three experienced and knowledgeable consultants, C. Ross Silversides, Donald M. Tufts, and Thomas A. Walbridge, were employed to prepare a report on the issues. Thereafter, a scientist from the Mississippi Agricultural and Forestry Experiment Station, Steven H. Bullard, assisted the consultants in preparing a manuscript for publication.

This publication is intended to provide research scientists, research administrators, and public policy advisors with information to assist decision making in timber harvesting research. It is hoped the publication will serve as a catalyst for increasing the awareness of timber harvesting research needs in the South.

Contents

Executive Summary

The U.S. South is one of the most important timber producing and processing regions in the world. The region has many forestry advantages, including extensive timber resources and proximity to major eastern and midwestern U.S. markets for wood and paper products. Timber-based industries employ about 10 percent of all southern U.S. workers, and provide about 10 percent of all income created through manufacturing in the region.

Lumber and wood products companies, furniture manufacturers, and pulp and paper producers vary in the sizes and species of timber they require as raw materials. Each segment of the industry, however, relies on the inventory of standing timber–an inventory that cannot be increased overnight. In some areas of the U.S. South, standing timber inventories are declining; more timber is being cut than is being grown. Forestry production and employment in the South can be sustained and expanded, however, if more timber is grown for future harvest and if existing stands of timber are used more efficiently.

Future timber availability in the U.S. South is closely related to the forestry perceptions of nonindustrial private landowners. The future of forestry in the region depends upon the 122 million acres owned by hundreds of thousands of individuals. Most tracts of timber that are privately owned are eventually harvested, and the economic and environmental results of the harvest have a direct impact on forestry attitudes, reinvestment plans, and future timber availability.

Technologies developed from timber harvesting research can extend *existing* timber inventories, and can also increase *future* timber availability. Research addresses the economic and environmental impediments to harvesting, and increases the proportion of timber stands that can be used commercially. This report describes the importance of timber harvesting and transportation in the U.S. South, and identifies specific research needs in six major categories:

1. Management–This includes research and demonstration needs of independent logging contractors. Efforts are recommended to improve skills and efficiency in selecting, repairing, and replacing timber harvesting equipment, to explore worker incentive systems for safety and production, and to examine potential wood procurement strategies. Estimated manpower and funding for the recommended 10-year program: **13 scientist-years, $1,950,000.**

2. Labor–This addresses research and demonstration needs of woods workers. Recommended efforts include new training program techniques and methods to select, compensate, and retain workers. Research is also recommended in ergonomics. Estimated manpower and funding for the recommended 10-year program: **15 scientist-years, $2,250,000.**

3. Machines and Systems–This category focuses on research needs that are primarily directed toward improved equipment application and maintenance. Research is recommended to define the engineering characteristics of trees, stands, and soils. Research in equipment design is recommended for micro-terrain adapatations and environmental effects, and specific examples of research needs in equipment performance are presented. Estimated manpower and funding for the recommended 10-year program: **21 scientist-years, $3,150,000.**

4. Economics–Research is needed to improve the cost and productivity of timber harvesting operations. Recommended efforts include defining new relationships between tree size, productivity and costs, terrain effects on equipment utilization times, and effects of tract size, timber volumes, and harvest intensity on costs. Studies are also recommended to define the impact of volume quotas, relationships between timber harvesting and stand establishment costs, cost impacts of new wood forms and utilization standards, equipment relifing, and the economics of truck transport. Macroeconomic studies are recommended to examine aggregate improvements in the productivity of timber harvesting. Estimated manpower and funding for the recommended 10-year program: **28 scientist-years, $4,200,000.**

5. Technology Transfer–Research is needed to improve the transfer of new timber harvesting methods and machines to contractors and laborers. Estimated manpower and funding for the recommended 10-year program: **3 scientist-years, $450,000.**

6. New Technologies – Examples of research needs in new technologies include electronic data management, computer software development, new materials from geotextiles and plastics, and Loran for controlling and monitoring equipment. Estimated manpower and funding for the recommended 10-year program: **13 scientist-years, $1,950,000.**

The recommended 10-year program of timber harvesting research requires an estimated **93 scientist years and $13,950,000**. The program would double the research effort in timber harvesting in the South, but would still represent less than 5 percent of total forestry research and development in the region each year. Such efforts scarcely reflect the importance of timber harvesting to southern forestry. Literally half of the value of delivered timber raw materials in the South is attributed to harvesting and transportation. Most of the millions of acres of timberland in the South will be harvested at some time – and the men, methods, and machines used in the harvest will directly impact the economic and environmental success of commercial forestry, today and in the future.

Problems exist in many areas of timber harvesting, from systems that are relatively labor intensive (above) to systems that are highly mechanized and capital intensive (below). Problems are addressed in the areas of: *Management, Labor, Machines and Systems, Economics, Technology Transfer,* and *New Technologies.*

Planning and Priorities for Timber Harvesting Research in the Southern United States

Introduction

In 1982, the United States Senate Committee on Appropriations requested the Office of Technology Assessment (OTA) to undertake on its behalf an inquiry into the technologies related to the growth and use of U.S. timber resources. The results of this inquiry were published in August 1983 as *Wood Use: U.S. Competitiveness and Technology.* OTA identified timber harvesting and associated problems as prime targets for research to improve production cost efficiencies, long term productivity and the Nation's wood supply.

Timber harvesting in the southern U.S. is a $3 billion per year industry. Harvesting research has a direct impact on the industry, and on the timber-growing profits of thousands of private nonindustrial landowners each year, yet most forestry research funds are allocated to other subjects. The OTA (1983), for example, reported that 70 percent of the USDA Forest Service research and development budget is allocated to growing, protecting, and inventorying trees, while less than 3 percent is devoted to improving timber harvesting.

The present report describes problems and constraints to improved timber harvesting and transportation in the southern U.S., and presents priorities for research. The "Background" section of the report describes the importance of timber harvesting and associated problems in the region. The section also summarizes timber harvesting research, and explains why agencies such as OTA have concluded that such research is vital to U.S. interests. The next sections are "Objective" and "Program Description". These sections include topics and priorities for a recommended 10-year timber harvesting research program in the southern U.S. Final sections describe "Program Implementation" and estimated "Manpower and Funding Requirements".

Background

Timber harvesting is an integral part of commercial forest management, yet most textbooks on forest management have little or no discussion of harvesting technologies. Textbooks on timber harvesting, however, clearly describe a close relationship between harvesting and forest management, a relationship that has existed for many years:

"Logging constitutes a very large part of the practice of forestry in our North American forests. It may be good, poor, or indifferent forestry, but logging is the important part of forestry in which our woods are treated and a future supply of timber is assured, or the areas are left in an unproductive condition. Harvesting the woods requires more capital and labor than any other phase of forest work and is, therefore, the principal business of the woods." (Nelson C. Brown, 1934, *Logging*).

"The harvesting of timber crops according to correct forestry methods is the key to most other forestry operations. Timber harvesting may logically be considered the principal operation in forestry in that the culmination of all forestry effort is a merchantable tree for service to mankind. Harvesting, therefore, is one of the most important operations in forestry, entirely aside from the fact that it provides the income necessary to carry on the whole forestry business." (Wackerman, Hagenstein, and Michell, 1966, *Harvesting Timber Crops*).

The relationship between harvesting and forest management is especially important in the U.S. South, where landowner perceptions of the economic and environmental results of commercial forestry are extremely important. As background to establishing research priorities, two important features of timber harvesting and forestry in the southern U.S. are discussed: "Harvesting and Timber Availability" and "Industry Organization, Mechanization, and Training."

Harvesting and Timber Availability

Domestic and world markets for U.S. forest products are expanding, yet annual timber removals are exceeding growth for commercially important species in some regions of the country. Only very recently has the potential timber shortfall in the U.S. South been realized.

The USDA Forest Service released a review draft of *The South's Fourth Forest: Alternatives For the Future* in March 1987. The basic objectives of the southern timber study were to determine the type of forest presently developing in the South, and to determine what type of forest would be of greatest benefit to U.S. society. Although the review draft will be revised before publication, major conclusions are not likely to be changed. The "Highlights" section of the draft contains the following statements:

"Timber removals have been rising steadily because of increased harvests and for softwoods are above net annual growth over large areas in the South.

"The base projections in this study show timber removals rising above net annual growth and declines in inventories—in the 1990's for softwoods and beyond 2000 for hardwoods.

"The base projections of resource change mean that the South is facing a future of rising stumpage and roundwood prices, much lower rates of growth in timber harvests, and declines in employment in the forest industries."

The Forest Service study also shows tremendous opportunities to increase timber production in the South, and to sustain high levels of timber-related employment. The study provides new evidence of the need to harvest and process *existing* stands efficiently, as well as the importance of encouraging timber production for *future* harvest. Timber harvesting research addresses both of these issues.

Increased efficiency in harvesting timber is a direct result of many research efforts. Studies of machine design and application effectively extend existing timber supplies. Greater efficiency means less timber left on the site, and may also allow harvest of areas otherwise economically or physically beyond the logger's reach. Timber harvesting research can also affect future production, however, by encouraging private nonindustrial landowners to reinvest in forestry. Research may result in direct incentives such as higher stumpage values, and may also result in less site and stand damage from logging. The potential influence of harvesting research on future timber availability in the South is demonstrated by forest ownership and size patterns, and the total value of stumpage harvested in the region each year.

Forest Ownership and Size. There are nearly 182 million acres of timberland in the South (U.S. Forest Service 1987), and ownership and size characteristics present challenges to logging practitioners and researchers. In contrast to Canada and the U.S. Pacific Northwest, timberland in the U.S. South is primarily in private ownership. Public agencies administer 10 percent, companies in the forest industries own and lease about 23 percent, leaving more than two-thirds of the region's timberland in nonindustrial private ownership.

There are nearly 2 million nonindustrial private forest (NIPF) landowners in the South, and typical tract sizes are small. Harvesting operations, therefore, encounter smaller average tract sizes and smaller average tree sizes than in many areas of the world. The Office of Technology Assessment (1983) emphasized the need to develop harvesting equipment for use on small forest tracts, targeted to diverse objectives of small landowners.

Timber Harvesting and Stumpage Values. Standing timber provides wildlife habitat, forest recreation, and watershed protection, as well as raw material for producing solid-wood and paper products. Timber may, therefore, have value for different reasons, depending on its location, characteristics, and ownership. The value of stumpage for producing lumber and other wood products is the result of asking "How much can a buyer afford to pay for timber and still cover all costs and make a satisfactory profit?" (Duerr 1985). The answer depends on the value of the wood products processed from the timber, and on the costs of harvesting, transporting, and manufacturing the timber from forest to final product (Figure 1). Lower logging and hauling costs therefore result in higher stumpage values—buyers can afford to pay more for standing timber. When this results in greater returns to timber growers, reinvestment in active forest management is encouraged.

The economic magnitude of timber harvesting and transportation in the U.S. South is illustrated in Figure 2. In 1984 alone, standing timber valued at $3.1 billion was harvested, and the roundwood was valued at more than $6 billion at local points of

Wood Products' Selling Prices
− Manufacturing Costs
− Hauling Costs
− Logging Costs

Stumpage Value– the value of standing timber is the value of wood products, minus the costs of harvesting, hauling, and processing the timber.

Figure 1

delivery. Harvesting and transporting timber to rail sidings, concentration yards, and other delivery points added more than $3 billion to the value of standing timber sold in 1984 (U.S. Forest Service 1987).

Industry Organization, Worker Training, and Mechanization

Organization and Worker Training. The structure and organization of the logging industry in the southern U.S. is an important factor in setting priorities for current and prospective timber harvesting research and development. Some forest products companies in the region maintain their own logging crews, but independent contract loggers with an average of fewer than six employees comprise the largest portion of the South's logging industry. A dominant characteristic of the industry is the very large number of very small firms.

Another important characteristic of contract logging firms in the South is that owners and workers often have not been trained adequately in efficient, safe, and environmentally sound harvesting methods. In Sweden, half of the recent increases in productivity are attributed to machine operator training programs. Worker training would certainly improve the pulpwood logging industry's safety record and reduce Worker's Compensation Insurance rates, which in the state of Mississippi, for example, are a staggering **$76 per $100 of payroll** for unmechanized operations.

Although there are natural differences in employment conditions, worker training, and capital requirements between woods operations and processing facilities, the degree of difference is especially great in the southern U.S. A clear image of the disparity between southern mill and woods operations was presented by Berger (1972):

"When I first arrived in the South and looked at a modern paper mill, it suddenly occurred to me that paper men were either the greatest optimists this world has ever known or the biggest gamblers. Here, men were gambling that the voracious appetites of hundreds of millions of dollars worth of highly automated plants were going to be fed by a "rag tag" assortment of vehicles that looked like refugees from a junk yard. But somehow the armada groped its way out of the woods, dragged itself down the roads and highways and fed the ravenous chippers.

"When we walk inside a paper mill we find a highly

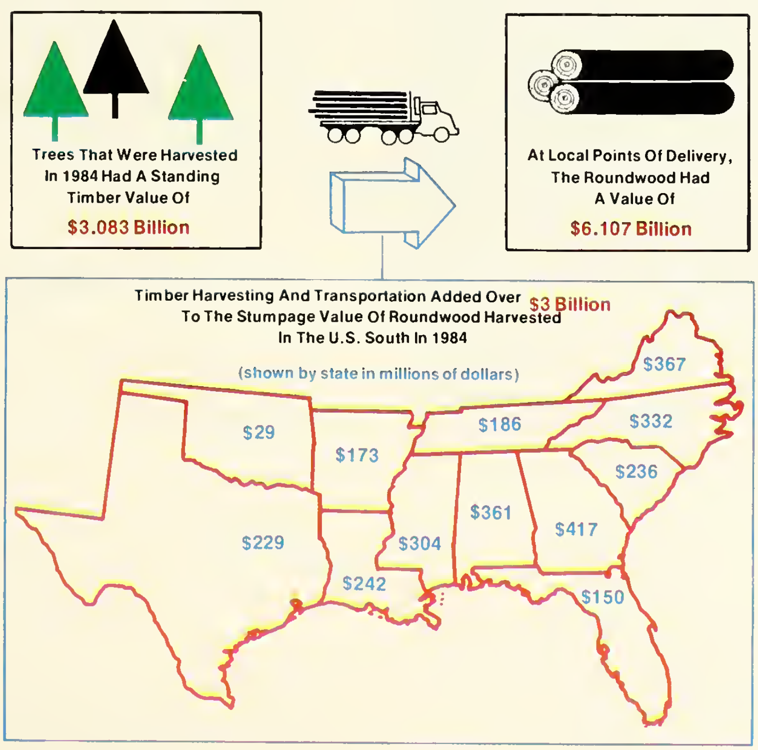


Figure 2

controlled process in operation. A competent staff of well-trained employees exercise the control and technology necessary to produce the paper products of the twentieth century. The quality of the employee is readily apparent in a brief discussion with any one of them.

"The picture changes dramatically when we go into the woods from which the raw materials are emerging. Here we find some men signing their paychecks with "X's," working in the mud, mosquitoes, snakes, briars—men sweating in the summer and shivering in the winter; men who haven't expected much or received much from life."

Improvements have been made since the image above was described, but there are still many organizational and training problems that need to be addressed in the industry. Training programs for loggers have encountered difficulties, for example, from the reluctance of companies to deal directly with woods labor. For reasons of legal liability, an arm's length relationship between firms producing roundwood and firms consuming roundwood is maintained. This relationship ensures that woods workers are not deemed to be employees of firms purchasing roundwood. It is very difficult to initiate and support training programs for woods workers, except through the cooperation of the contractors themselves.

Timber Harvesting Mechanization. Since World War II, machine use in timber harvesting has increased dramatically in most areas of the world. Timber felling, for example, has progressed from axes and crosscut saws, to bow saws, to chain saws, and to machines with shears or circular-saw felling heads. General advances in technology are only partly responsible for increased mechanization in timber harvesting:

"The mechanization of timber harvesting is a long-term dynamic process, the ultimate aim of which is to ensure an adequate supply of wood at a cost acceptable to processing plants. The form of the wood produced, whether lumber or wood fibre, will be determined by the end-usage. An intensification of mechanization in timber harvesting today is the result of a number of factors: the rise in the level of technology generally, the need for cost maintenance or cost reduction on behalf of the forest-based industries, the need for increased man-day productivity because of the shortage of adequately trained labor, and the availability of capital for investment in heavy and relatively costly equipment.

With the intensification in the mechanization of timber harvesting, mental attitudes and ways of thinking about these operations have to be or are being changed. Timber harvesting is changing from a plant cropping operation to an operation producing industrial raw material. The industrial production approach is being extended beyond the mill walls into the forest" (Silversides 1972).

The American Pulpwood Association in a recent policy paper (1985) stated:

"Partial mechanization is certainly achievable but there are still some barriers to full mechanization. Interest in concept development for full mechanization (prototypes) has fallen dramatically. The industry may be in a period in which the further spread of partial mechanization will be the predominant technical achievement. If the past is a key to the present, major effort towards full mechanization with emphasis on handling small diameters will again occur, probably spurred by labor shortages and resulting shortages of pulpwood. In addition, applied studies on ergonomics (the fit between man's work habits and machines) could well result in the major future productivity increases."

In the absence of a comprehensive research and development program on the mechanization of harvesting, U.S. research has focused largely upon designing and developing individual machines. Comprehensive programs in Canada, Western Europe, and Scandinavia have worked toward integrated harvesting systems designed to fit specific timber resources, harvesting requirements, and manufacturing processes. The U.S. Forest Service has carried out some regional studies on the mechanization of harvesting systems, but these have been constrained by budget and priorities. Private sector efforts in the U.S. have primarily been by trial and error, in small job shops, and by adapting agricultural and construction equipment.

Objective

There are many problems that constrain the biological effectiveness and economic efficiency of timber harvesting in the southern U.S. These problems arise from such factors as fragmented forest land ownership and diverse goals, diverse forest stand and terrain conditions, differing market conditions for various types of industrial wood, and the size, organization, and capabilities of logging operations.

The objective of the present study has been to identify the major problem areas that physically and economically constrain timber harvesting in the South. A 10-year research planning statement has been developed to serve as a guide for future timber harvesting research. The planning statement includes a list of priorities for the identified problems, and estimates of the manpower and funding needed to carry out the proposed program.

Program Description

As a result of meetings with individuals and a brainstorming session with a widely representative group of industry operators, academics and researchers, six problem areas in timber harvesting were identified: **management, labor, machines and systems, economics, technology transfer, and new technology.**

1. Management

The future prosperity of the logging industry in the South depends in large part on the decision-making skills of individual contract loggers. Loggers are vital to the present and future southern forest products industry, and efforts should be made to increase their business knowledge, their capacity to manage people, and their receptiveness to new ideas involving methods and equipment.

Within this problem area, four major contractor responsibilities have been selected as priority topics for research. These are equipment selection, equipment repair and replacement, labor incentives, and timber procurement. Specific research projects should be developed and the results transferred to logging contractors.

Equipment Selection. Loggers must know for each site what timber is to be cut, what roads must be constructed, and what environmental limitations are placed upon their work. The limitations, production capacity, operating range, and cost of different machines must be known. Contractors must achieve balanced machine combinations to benefit from optimum logging systems. More than 70 percent of loggers responding to a recent survey indicated that their most important equipment-related problem is how to achieve a mix of equipment that allows an even flow of production (Reed 1985).

Equipment Repair and Replacement Strategies. The profitability of a logging firm depends in large part on managerial decisions respecting equipment repair and replacement. A number of methods of analysis have been developed to help logging contractors decide when to repair and when to replace equipment. For each machine there is an optimum time to sell or trade, a time determined by factors such as depreciation, maintenance downtime and cost, and technical obsolescence.

Incentive Systems. Innovative wage incentive systems can lower unit production costs, improve production output, and raise employee's earnings. There are many forms of incentive programs—some are based on individual performance, some on group or crew performance, and some include mechanics, with production depending upon machine availability. To be successful, incentives must provide a direct link between work performance and compensation.

The system selected should be simple so that employees can understand it and compute their own pay. It should also provide for changes in method, and should not restrict potential earnings. The possible impact of new wage systems has been demonstrated for timber harvesting systems in Sweden (Werner 1986). Since nationwide changes in how Swedish forest workers are paid began in 1975, productivity and the frequency and severity of woods accidents have changed significantly.

Wood Procurement Strategies. Four wood procurement strategies are commonly used by forest products companies in the U.S. South: owning land for timber harvest, leasing land for timber harvest, assisting private nonindustrial forest landowners to increase timber production on their lands, and buying wood on the open market (Kronrad et al. 1985). These strategies should be evaluated from the position of timber buyers as well as timber sellers. Wood procurement policies influence corporate profits and stability of raw material sources, as well as timber-growing profits and perceptions of NIPF landowners.

"The future prosperity of the logging industry in the South depends in large part on the decision-making skills of individual contract loggers."

2. Labor

In the past 20 years, the tasks performed by forest workers have changed. Different skills are required today than was the case even 10 years ago. Periodic surveys have established the number, age, education, and experience of loggers and other woods workers. Continuing surveys are needed to clearly characterize the work force and to provide a better knowledge base for training programs to improve their efficiency and safety.

Training Programs. Training programs for forest workers should be carefully evaluated to ensure they reflect current needs. New techniques and equipment for training forest workers should also be evaluated. Equipment simulators, audio-visual and other classroom aids, for example, should be considered for on-the-job teaching and demonstration. In an industry which is becoming more and more technical, experience isn't necessarily the best teacher.

The organization of the forest industry precludes some companies from developing direct relationships with woods labor. Woods labor typically is employed by a logging operator under contract to the conversion plant. Under these circumstances, training programs should be conducted by state or university extension services working with the logging contractors. Contractors and other interested parties must coordinate efforts to improve labor/management relations.

Employee Compensation. Wage incentive systems were presented earlier as an important issue for management. These systems are also important to labor. Pay incentives should be readily understood by workers, and should specifically encourage production and safety goals. Innovative systems need to be developed and tested.

Selection and Retention of Workers. Studies and trials of various methods of employee selection should be undertaken. Logging contractors with stable, highly productive labor forces should be analyzed to determine how they have succeeded where others have failed. Stable labor forces have better safety and production records than those with high turnover. As woods work changes from individual labor to crew or team work, labor turnover becomes move disruptive and results in greater hidden costs.

Scientific management is responsible for many of today's confrontations with labor. In timber harvesting and the extraction of other primary products, men have often been considered as easily replaceable extensions of machines. Such attitudes are changing, however, and employee participation in production decisions is increasingly encouraged.

Ergonomics. Basic studies in ergonomics (man-machine relationships) are almost non-existent in the southern logging industry. Such studies are extremely important to improved timber harvesting. The human part of the man-machine system has a direct impact on safety, performance, and productivity. Proposed studies of forest machinery should include the operator's perceptions on ease of operation, safety, and comfort, as well as ease of service and maintenance.

"The human part of the man-machine system has a direct impact on safety, performance, and productivity."

"... research is needed to understand and mitigate potential adverse efferts on soils, water, and remaining or succeeding vegetation."

3. Machines and Systems

Rather than recommending research on new equipment concepts and development, the 10-year research program recommended for machines and systems emphasizes operating and maintaining existing equipment.

Engineering Characteristics of Trees. In addition to tree diameter and height, information on width of crown, weight of components, branch size and arrangement, and center of gravity is essential for improved harvesting equipment design and application. Mechanized harvesting of small timber concerns many forest products companies, logging contractors, and public and private landowners. Accumulating felling heads are currently popular for small timber. They permit felling and handling trees in multiples, and have clear advantages in productivity and cost over single-tree felling methods. Continuous felling machines designed to accumulate trees in larger bunches may be the next development in harvesting small timber. Prototypes of such machines exist in the A-line Swather (Prince Albert Pulp Ltd., Prince Albert, Saskatchewan, Canada) and the Canadian National Research Council short rotation harvester.

Engineering Characteristics of Forest Stands. Stand characteristics have a direct impact on timber harvesting operations. Tree spacing, for example, influences the movement of machines within a stand. Understanding the effects of stem spacing could result in greater machine mobility and higher productivity.

Visibility is also an important characteristic of forest stands. Visibility varies among stands of different species, densities, and ages, and at different times of the year. Underbrush in forest stands directly impacts timber harvesting, particularly thinnings, whether workers are on the ground or operating machines.

Engineering Characteristics of Forest Soils. Trafficability is the capability of a machine to pass over terrain, with or without a load. Mobility involves the time a vehicle requires to pass over terrain and complete its mission. Trafficability and mobility are important concepts in timber harvesting, whether dealing with skidding tractors, forwarders, harvesters, or trucks. Both concepts depend upon soil strength, a characteristic which often depends upon soil moisture. A major problem affecting timber harvesting is wet weather and its impact upon soil strength and machine trafficability. The application of Thornthwaite's evapotranspiration work should be explored. The work applies to soil moisture, and thus indirectly to soil strength. It may permit the prediction of soil conditions and scheduling of harvesting operations for various soils following rains of different intensities.

In the past, most soil trafficability studies have involved agricultural and military machines and machine applications. Most forestry studies have investigated soil compaction by wheels and tracks, and the effects of such compaction on stand establishment and tree growth. Research is needed to increase our knowledge of these relationships.

Micro-Terrain and Equipment Design. Micro-terrain determines the ground clearance needed and the speed at which vehicles can travel in the woods. Micro-terrain thus affects operator comfort and machine control at different speeds. Terrain profile data and analyses are needed to provide equipment designers and manufacturers with information for producing machines which can automatically adjust their speed to ground conditions, and machines which can adjust to the vibrations encountered by the operator.

Environmental Impact by Machines. Timber harvesting can dramatically alter a forest environment, and research is needed to understand and mitigate potential adverse effects on soils, water, and remaining or succeeding vegetation. Timber harvesting can adversely affect sites, for example, by compacting the ground and creating ruts, possibly causing erosion and reducing future timber growth rates. Soil and water impacts must be considered in designing and applying timber harvesting systems for clearcuts and partial cuts, for different forest environments encountered in the South.

Thinnings are specialized timber harvests, often designed to promote the volume and value growth of residual trees. The environmental consequences of thinning include damage to roots and stems of residual trees, as well as to soils and water. Soil compaction and rutting, and root and stem damage can be controlled through improved equipment design and operation. Machines designed specifically for thinnings in the U.S. South, for example, must be relatively small and maneuverable. New or modified types of running gear, and spring- or shock-absorber suspension systems are needed to help reduce soil compaction, ruts, and root system wounds. Sideways and tractive slip causes tear wounds on root systems and tree boles. These problems may be addressed through research on steering geometry and torque control through hydrostatic transmissions.

Performance Capability of Harvesting Equipment. Machine performance depends on how well a machine is designed, and how well it is applied to the type, extent, and conditions of work required (Figure 3). Machine size is important to performance, yet size must be considered in relation to machine form and other design factors. A general study of the morphology of forestry machines is needed as background to specific studies of machine design and application. Some specific studies needed are:

> ***Relationships between tire widths and soil impacts on different sites,***
>
> ***Cost and benefit relationships between wide, low-pressure tires and dual tires,***
>
> ***Comparisons of choker, grapple, and clam bunk skidders under different timber and site conditions,***
>
> ***Comparison of tandem bogie versus single large wheel (could affect the design and configuration of many forestry machines), and***
>
> ***Potential application of all-terrain vehicles in thinnings and on small tracts (including their use with skidding arches, load-carrying trailers, and other equipment).***

In addition to the examples above, machine designs and applications that have been successful in the U. S. South and elsewhere in the world should be evaluated for potential use in the southern U.S. As examples, adding unpowered axles may increase vehicle load capacities; "Big Stick" loaders may serve a dual purpose if used to skid or winch felled trees; and an inexpensive yarder similar to the "Logger's Dream" should be re-evaluated for the increasing number of tree-length and full-tree harvesting operations.

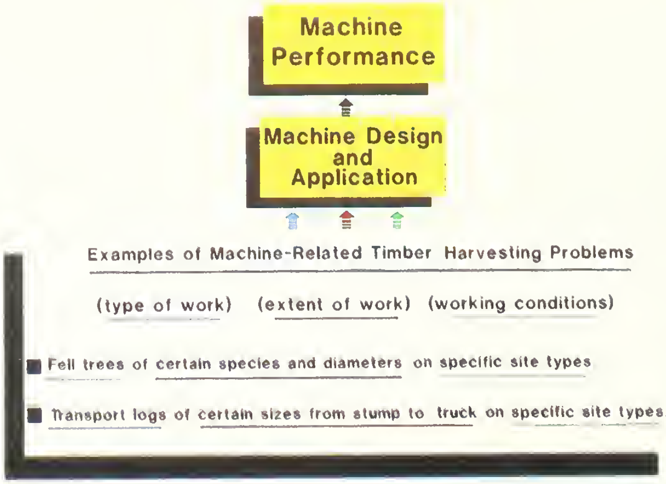
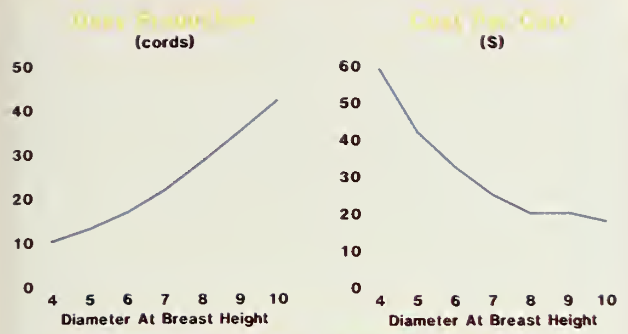


Figure 3



Includes Cutting, Skidding, Loading And Overhead For Tree-Length Logging, Chainsaw Felling And Cable Skidding (Tufts 1977)

Figure 4

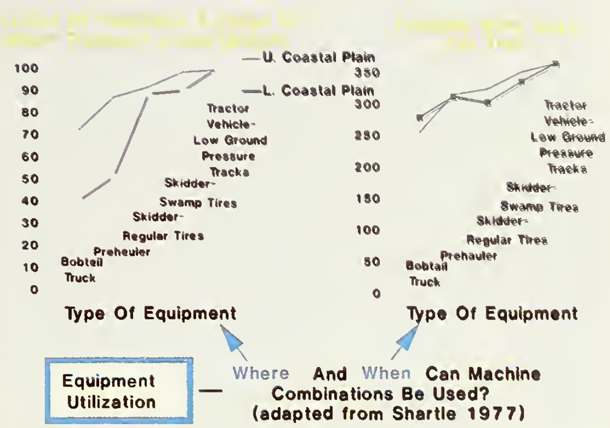


Figure 5

4. Economics

The economics problem area includes a number of issues which affect the cost and productivity of harvesting operations. Some of these issues have been studied previously, but all are worthy of more intensive study and effort to improve industry awareness of the findings.

Tree Size, Productivity, and Cost. Most semi-mechanized logging systems in the South have lower production rates and higher per-unit harvesting costs when harvesting smaller trees (Figure 4). As new harvesting equipment is developed and applied, research is needed to describe new production/cost/tree size relationships. The influence of tree size on productivity and cost is especially important in southern forests. Since 1952, there has been a 22-fold increase in the inventory of southern pine plantations (U.S. Forest Service 1987). Average tree sizes are smaller for plantations than for natural pine stands. The Forest Service projects that within 15 years, more than 35 percent of southern softwoods will be in plantations.

Terrain and Equipment Utilization. Equipment utilization has two aspects—*where* and *when* can the equipment be used? Figure 5 presents an example for various in-woods transport equipment for pine plantations in two regions of the Atlantic Coastal Plain. The percent of plantations which are operable shows *where* the equipment can be applied, and possible work days per year indicates *when* the machines can be used. Figure 5 represents a relatively small region of the South, and similar studies are needed for different machines, terrain, and stand types in the region.

Tract Size and Volume. Tract size and volume directly affect harvesting costs and production rates:

"Literature and research support the conclusion that large tracts (50 to 125 acres) have significant economic advantages over small tracts (less than 50 acres). Average costs increase rapidly on tracts below 50 acres and are prohibitive on tracts below 10 to 20 acres" (Cubbage 1983).

"Low volume per se, not low volume per acre, is the cause for inefficient and expensive forest harvesting and management" (Garratt 1957).

Studies are needed to define the potential for reducing harvesting costs by consolidating forest tracts in the South through purchase, cooperative agreement, or other means.

Harvest Intensity and Cost. Harvest intensity depends on stand conditions and forest management objectives. Harvesting productivity and costs may differ greatly for clearcuts and partial cuts, and therefore may affect the unit price a landowner receives for standing timber. The relative costs and benefits of different harvest intensities need to be established for different stand and market conditions.

Impact of Quotas. Forest products companies benefit from the high productivity, freedom from strikes, and relatively low capitalization of contract loggers. These loggers usually have substantial financial commitments for logging equipment, however, and depend on the cash flow from weekly or monthly production. When a wood-consuming mill imposes a quota on wood, loggers may have cash-flow problems; many such cases result in bankruptcy. Quotas affect the stability of the logging industry, and benefits, costs and alternatives should be investigated thoroughly.

Harvesting and Stand Establishment. The equipment needed to prepare a site for planting or seeding after harvest depends on the logging debris, stumps, and trees left on the site. Relationships between slash characteristics and machine size and effectiveness in site preparation have not been fully developed. If low cutting feller-bunchers are used, for example, and entire trees are removed from the site, what is the effect upon subsequent site preparation operations? In some areas of the South, unmerchantable trees are harvested for energy, further reducing debris after logging, and site preparation costs for planting or seeding. In addition to the direct costs of harvesting and regenerating a timber stand, environmental effects must be considered. More intensive harvesting may allow greater use of site preparation methods that do not require heavy machinery and soil disturbance (Bullard and Watson 1986). Further study is needed to define cost and environmental trade-offs between timber harvest and site preparation intensities for different site and stand conditions in the U.S. South. Studies of timber harvesting and site preparation should consider new site preparation and stand establishment methods. Intermittent-furrow or injection planting machines, for example, are better suited to rough, cutover land than the continuous-furrow machines presently used in the South. Today's site preparation practices may in turn impact future timber harvesting. When stands originate from bedded sites, for example, ditches and mounds may become obstacles to harvesting equipment (Shartle 1977).

Changing Wood Forms and Utilization Standards. Wood-processing firms constantly strive to reduce raw material and processing costs. Examples of these changes include pulping of sawmill residues, chip storage outside mills rather than roundwood storage at mills, the use of whole tree chips, changes in species mix, and the increased use of 5D wood (dead, down, dying, diseased, and defective). Processing changes include the use of smaller trees by sawmills, and the use of different raw materials for particle board, waferboard, and other panel products that are replacing plywood in many applications. Continuing study of the changing forms and specifications of wood raw materials is needed as fiber and solid-wood requirements evolve over time.

Relifing Harvesting Equipment. Relifing is an equipment strategy often used in the aircraft industry. Old machines are completely rebuilt to the mechanical efficiency of new machines. Relifing is a cost-effective strategy under some equipment cost-price structures. Studies are needed to identify potential cost savings from relifing harvesting and site preparation equipment.

Economics of Truck Transport. Opportunities to reduce the transportation costs of wood moved by truck must be identified. The need to recognize cost differences in hauling timber is clearly shown by a study conducted for the Canadian Department of Transportation: *Operating Costs of Trucks in Canada–1984*. On a ton-mile basis, it costs over twice as much to haul bulk commodities across Canada with a two-axle, gas-powered truck than with a five-axle, diesel truck with semi-trailer. Although transporting timber in the southern U.S. involves labor costs, fuel costs, and load limits different from those of Canada, the cost saving possibilities in the South merit study. The 1979 American Pulpwood Association producer census, for example, showed that 50 percent of pulpwood trucks used in the South were two-axle, gas-powered units, and more than 60 percent of them were over 6 years old.

Economic engineering studies are needed to evaluate conventional three- axle trucks, two-axle semi-trailer combinations, and other transportation options in the U.S. South as tree-length timber harvesting and transportation become more important. In some cases, actual trucking tests may not be necessary. The Cummins Engine Company, Inc., of Columbus, Indiana, for example, has developed a vehicle mission simulation program to help choose the vehicle with the optimum power train combination for the work involved. Information on optional gear ratios for logging trucks considering reasonable combinations of highway mileage, secondary road mileage, and expected slope conditions for different areas of the South needs to be develcped using operations research techniques.

Specific studies of all phases of truck logging operations are needed to provide information on potential reductions in production costs. Loading, for example, may be accomplished with self-loading trucks or with independent loaders. Standing time for trucks in the woods should be minimized. The best time may depend on timber volume to be loaded, truck capacity, and length of haul. After loading, on-the-road driving skills are important factors influencing costs. Gear shifting practices should be evaluated through tachometer tests. Delays in unloading trucks reduce hauling efficiency and production. Charges for demurrage at the mill or the use of shuttle trailers should be studied. The traffic flow at wood-receiving facilities should be analyzed using operations research techniques.

Macroeconomic studies. Very few macroeconomic studies of the logging industry or its major sectors have been undertaken. Such studies are needed to understand aggregate improvements in the productivity of capital and labor in the South. Microeconomic and cost studies are common, but do not indicate the performance of timber harvesting at the industry level.

5. Technology Transfer

New technology in timber harvesting is distributed in published material, workshops and demonstrations, and through the increased use of video technology and educational television programs. More effective transfer of new knowledge related to timber harvesting, is needed throughout the southern United States. Failure to apply new technologies wastes valuable resources, and leads to social and economic penalties. Logging contractors and woods laborers must receive new technologies to develop safe, cost efficient, and competitive operations.

Although adoption is lagging, new knowledge is accumulating at an increasing rate. The gap between what is known and what is applied continues to widen. Direct, purposeful transfer of technology is essential for increased adoption. It has been proposed that efforts concentrated in a few "centers of excellence" offer a greater chance of long term success than spreading the effort widely. Such "centers of excellence" must include practical training, however, or they may become prestigious centers of learning out of touch with the people actually doing the job in the field (Richards and Axelson 1986).

6. New Technologies

Electronic Data Management. Equipment to record, analyze, and print inventory, cost, and production data is available, but is not widely used in the logging industry. Its introduction into the timber harvesting industry should be accelerated.

Computer Software Development. Universities should cooperate with private industry in software research, development and application in timber harvesting. Microcomputer software has already been used in some feller bunchers and harvesting machines, but has not been widely adopted. Microcomputers can greatly improve consistency and efficiency of work in repetitive tasks, and additional research and development is needed to expand their use in timber harvesting.

Geotextiles and Plastics. Many new materials are available for application in harvesting operations. The use of geotextiles in forest roads and landings, and millyards should be investigated. Such materials may extend the harvesting period and reduce lost equipment time. New fibers, such as Kevlar, are used in off-road tires and safety clothing, and new plastics are available to replace metal in machines to decrease weight and improve performance, and to replace steel cables and chains in skidding and loading operations.

Loran. Loran (long-range navigation) has a number of potential uses in forestry, in fire fighting, and in spraying operations. It can be used to monitor the location and movement of a fleet of vehicles or other equipment from a control center. Research is needed to investigate the extent to which this technology can be used to improve the efficiency of timber harvesting.

"The gap between what is known and what is applied continues to widen. Direct, purposeful transfer of technology is essential for increased adoption."

Program Implementation

The nature and complexity of the problems identified, the research opportunities suggested, and the potential payoff from successful research and demonstration in timber harvesting require a major commitment from public agencies, universities, and companies with forestry interests. It is unrealistic to think that these problems will be solved in the near term. Therefore, a commitment to a sustained timber harvesting research effort is recommended to achieve the potential contribution of such a research program to long-term economic growth and productivity, the well-being of the southern forests and forest environment, and to the present and future generations of forest workers and landowners.

Manpower and Funding Requirements

Total research and development expenditures in forestry exceed $49,000,000 per year. About $1,000,000, or approximately 2 percent, are spent on forest engineering research each year. The 1984 sawtimber harvest in the South was valued at over $6 billion at the first delivery point, with stumpage comprising about half of this value. Only 2 percent of the total forestry research budget is addressing problems associated with 50 percent of the production in value of delivered wood; that is, only $1,000,000 are being spent annually on investigating problems of an industry which produces more than $3 billion in value each year.

The expenditure of funds proposed in this report is significant and represents a much larger commitment of resources to timber harvesting and related research than is currently allocated. Recommended research expenditures are small, however, in comparison with research expenditures on other forestry activities in the South. Further, recommended research expenditures are small in comparison with the production values involved.

Research subjects are prioritized under the six general headings of the proposed program (Table 1). Data required to accurately estimate the costs of the recommended research are lacking. However, it was assumed that a scientist-year costs $150,000, an adjustment from the 1977 figure used by the U.S. Forest Service (Callaham 1981). The scientist-year cost includes operating costs, and capital and personnel costs to support a scientist, and may therefore include the cost of one to four technicians or mechanics.

No attempt has been made to specify which research topics might be undertaken by governmental agencies, universities, or the private sector. Not all projects would begin or end at the same time because of constraints on funding, facilities, and manpower. Over the proposed 10-year period, however, the recommended program could be implemented at an average annual cost of $1,395,000. While this expenditure would more than double the present annual expenditure on timber harvesting research in the South, it would still amount to only 4.7 percent of total forestry research and development expenditures in the region.

Table 1. Recommended 10-year program of research in timber harvesting and transportation.

Priority Number	Subject	Estimated Scientist-years	Funding At $150,000 Per Scientist-year
	Management		
1	Equipment Selection	4	$ 600,000
2	Equipment Repair and Replacement Strategies	4	600,000
3	Incentive Programs	2	300,000
4	Wood Procurement Strategies	3	450,000
		13	$ 1,950,000
	Labor		
1	Sociological Aspects	3	450,000
2	Training Programs	2	300,000
3	Methods of Payment	2	300,000
4	Selection and Retention of Workers	3	450,000
5	Ergonomics	5	750,000
		15	$ 2,250,000
	Machines and Systems		
1	Engineering Characteristics of Trees	3	450,000
2	Engineering Characteristics of Forest Stands	3	450,000
3	Engineering Characteristics of Soils	4	600,000
4	Impact of Micro-terrain on Equipment Design	3	450,000
5	Environmental Impact by Machines	4	600,000
6	Performance Capability of Harvesting Equipment	4	600,000
		21	$ 3,150,000
	Economics		
1	Tree Size, Productivity, and Cost	2	300,000
2	Terrain and Equipment Utilization	3	450,000
3	Tract Size and Volume	2	300,000
4	Harvest Intensity and Cost	3	450,000
5	Impact of Quotas	2	300,000
6	Harvesting and Stand Establishment	4	600,000
7	Changing Wood Forms and Utilization Standards	3	450,000
8	Relifing Harvesting Equipment	2	300,000
9	Economics of Truck Transport	4	600,000
10	Macroeconomic Studies	3	450,000
		28	$ 4,200,000
	Technology Transfer		
1	Studies on Various Techniques of Technology Transfer	3	$ 450,000
	New Technologies		
1	Electronic Data Management	5	750,000
2	Computer Software Development	5	750,000
3	Geotextiles and Plastics	2	300,000
4	Loran	1	150,000
		13	$ 1,950,000
5	(Note: Due to rapid rates of technological change, additions may be required.)		

Recommended Program 10-Year Totals.

Program Description	Estimated Scientist-years	$
Management	13	$ 1,950,000
Labor	15	2,250,000
Machines and Systems	21	3,150,000
Economics	28	4,200,000
Technology Transfer	3	450,000
New Technology	13	1,950,000
TOTAL	93	$13,950,000

References

American Pulpwood Association. 1985. 1985-86 Strategic Plan. Publication 84-A-12 American Pulpwood Association, Inc., 1619 Massachusetts Ave., N.W., Washington, DC.

Berger, Fred. 1972. Training the Southern Forest Worker. Proceedings of the 21st Annual Forestry Symposium, Louisiana State University, Baton Rouge, LA.

Brown, Nelson. 1934. Logging–Principles and Practices in the United States and Canada. John Wiley and Sons, New York.

Bullard, Steven, and William Watson. 1986. Timber Harvesting Technology: Environmental and Site Preparation Costs. *International Journal of Environmental Studies* 27:261-266.

Callaham, R. Z. 1981. Criteria for Deciding About Forest Research Programs. U.S.D.A. Forest Service General Technical Report WO-29, Washington, DC.

Cubbage, Fred. 1983. Economics of Forest Tract Size in Southern Pine Harvesting. Southern Forest Experiment Station, USFS Research Paper 50-184.

Duerr, W. A. 1985. Forestry Economics As Problem Solving. Copyright William A. Duerr, Blacksburg, VA.

Garratt, George. 1957. Small Woodlands and Utilization. American Forests 63(11):29, 30. 50-55.

Kronrad, Gary, E. C. Franklin, and J. E. deSteigeur. 1985. Evaluating Landowner Assistance Programs and Other Wood Procurement Options. *Southern Journal of Applied Forestry* 9(3):186-191.

Moeller, G. H., and D. T. Seal. 1983. Technology Transfer in Forestry. Proceedings of an I.U.F.R.O. Conference, Edinburgh, U.K., Forestry Commission Bulletin 61. HMSO.

Reed, A. S. 1985. Key Factors in the Success of Every Logging Business. Proceedings of the 3rd SAF Region V Technical Conference, "Timber Harvesting: The Link Between Management and Utilization," Madison, Wisconsin.

Richards, E. G., and S. A. Axelsson. 1986. Forestry in Post-War Europe. FAO/ILO/ECE Timber Committee. 16th Session, Joint Committee on Forest Working Techniques and Training of Forest Workers, Oosterbeek, Netherlands.

Shartle, S. A. 1977. An Analysis of Southern Pine Characteristics Relative to Future Equipment Designs. MSc. Thesis. VPI and SU, Blacksburg, VA.

Silversides, C. R. 1972. The Mechanization of Timber Harvesting. Proceedings of the 21st Annual Forestry Symposium, Louisiana State University, Baton Rouge, LA.

Trimac Consulting Services, Ltd. 1984. Operating Costs of Trucks in Canada–1984. Department of Transport, Ottawa, Canada.

Tufts, Don. 1977. Factors Influencing the Economics of Thinning Pine Plantations. Second Annual Seminar for Forestry Professors, LSU/MSU Logging Center, Bay St. Louis, MS.

U. S. Forest Service. 1987. The South's Fourth Forest: Alternatives for the Future (Review Draft). USDA Forest Service, Washington, DC.

Werner, Marit. 1986. Developments in New Wage Forms in Swedish Forestry. Proceedings of the IUFRO World Congress, Ljubljana, Yugoslavia. University of Maine Agric. Exp. Sta. Misc. Report 317.

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