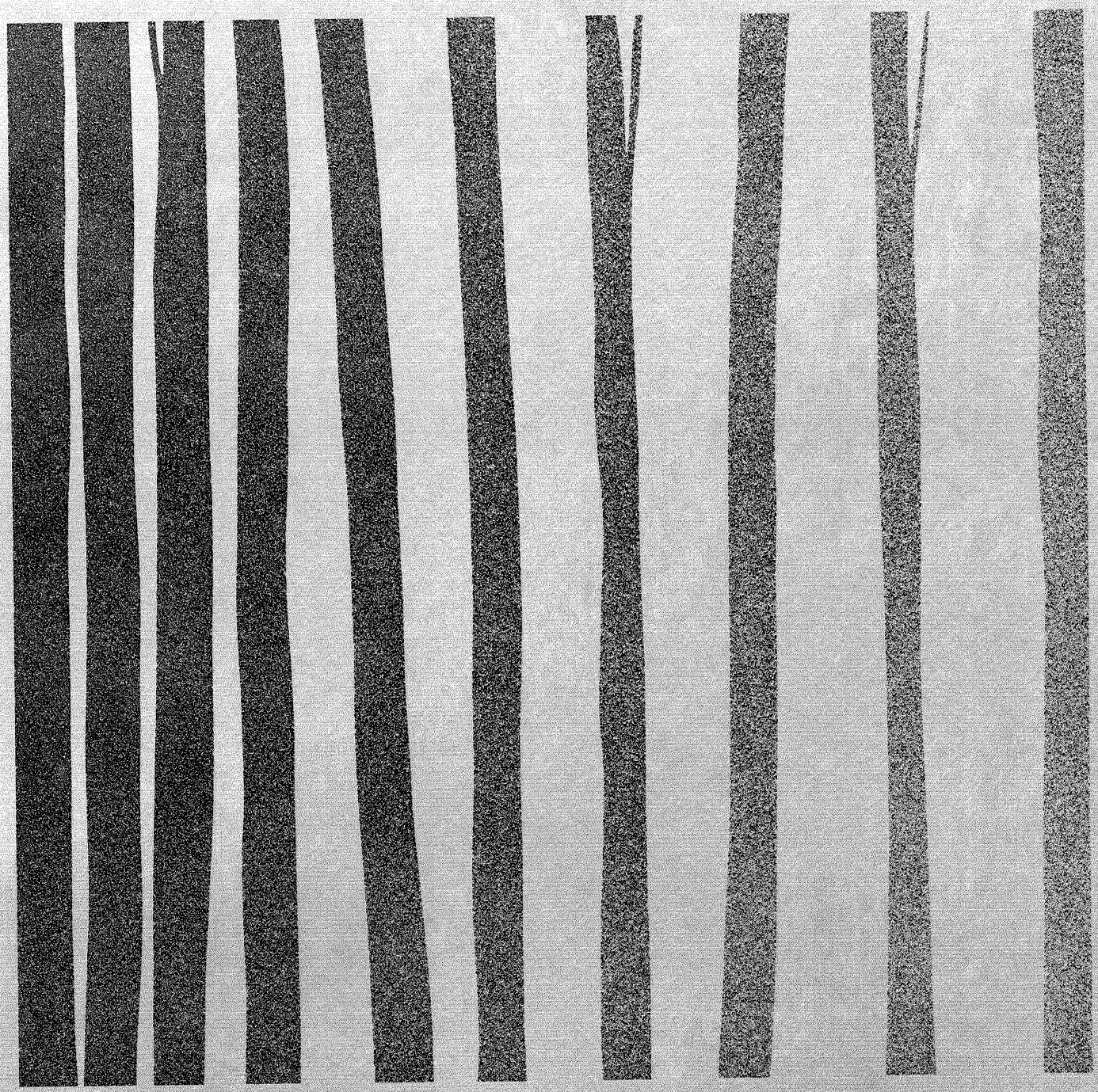
United States
Department of
Agriculture

Forest
Service

North Central
Forest Experiment
Station

General Technical
Report **NC-113**

Hardwood Thinning Opportunities in the Lake States



Each contributor submitted camera copy and is responsible for the accuracy and style of his or her paper.

North Central Forest Experiment Station
Forest Service--U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108

Manuscript approved for publication July 28, 1986

1986

HARDWOOD THINNING OPPORTUNITIES IN THE LAKE STATES

Proceedings of a Symposium

Escanaba, Michigan

April 20, 1984

John A. Sturos, Compiler

North Central Forest Experiment Station

USDA Forest Service

Houghton, Michigan

Sponsored by:

Department of Forestry, Michigan Technological University
North Central Forest Experiment Station, USDA Forest Service
Bay de Noc Community College
Michigan Association of Timbermen
Michigan-Wisconsin Timber Producers Association

PREFACE

This is an exciting time for forestry in the Lake States where we have an expanding resource base, particularly hardwoods, and are close to major markets. We have the industrial technology to produce the fiber and energy needed to meet market demands, and we have plenty of labor, due in part to reductions in other industries.

Major industrial expansions are taking place in the northern Lake States, the largest of which is the $500 million Champion International pulp mill at Quinnessec, Michigan. Several new waferboard plants have been built in Minnesota and Wisconsin; in Michigan, a new oriented strandboard plant has been built by Weyerhaeuser in Grayling, and Louisiana-Pacific has built a new medium density fiberboard plant in Newberry. In addition, large investments have been made or announced in hardwood lumber mills and other smaller wood products companies in northern Michigan. In total, the recent expansion in Michigan alone approximates $1 billion in capital investment and will create about 1,300 new jobs.

The primary fiber resource to supply these plants is the abundant hardwood stands. Northern hardwoods are the main "crop" on 10 million acres of forest land in the Lake States. Most of today's northern hardwoods are second-growth stands that grew after the clearcutting and high-grading that took place between 1900 and 1930. These stands are typically even-aged, composed of poles 5 to 9 inches in diameter, often poor in quality, slow growing, and in need of thinning.

The industrial expansion in the Lake States encourages us to more intensively manage our hardwood stands and allows us to get into intermediate operations such as hardwood thinning. Besides providing fiber for industrial consumption, these thinnings will enable us to accelerate the growth of high-quality crop trees. This will ensure that high-value veneer and sawlogs, the backbone of this hardwood region for many years, will continue to be available in the future.

Research on managing and utilizing northern hardwoods has been in progress for many years by public agencies, the universities of the region, and industry. Much information has been developed and is available for use by land managers. This symposium is one method of transferring the available technology to potential users; I hope that this is only a start in improving our technology transfer efforts. Also, I am sure that the dialogue that took place during this symposium will provide direction for future research.

We are pleased to cooperate with universities, trade associations, public and private landowners, and others in our research. We have been especially pleased to cooperate with Michigan Technological University, Bay de Noc Community College, the Michigan Association of Timbermen, and the Michigan-Wisconsin Timber Producers Association in co-sponsoring this symposium.

ROBERT A. HANN
Director
North Central Forest Experiment Station

CONTENTS

	Page
Some Strategic Considerations in Managing Hardwood Forests in the Lake States Dr. Henry H. Webster	1
The Lake States' Hardwood Resource John S. Spencer, Jr.	6
Silvicultural Considerations in Thinning Richard M. Godman	26
Harvesting Hardwood Thinnings John A. Sturos and Michael A. Thompson	31
A 9-year Evaluation of Mechanized Thinning in Northern Hardwoods Gayne G. Erdmann, James A. Mattson, and Robert R. Oberg	54
Evaluation of 1978 Thinning Site James A. Johnson	69
Damage to the Residual Stand Resulting from Mechanized Thinning of Northern Hardwoods Johann N. Bruhn	74
Impact of Harvesting to the Soil C. C. Trettin and E. A. Padley	85
Hardwood Opportunities Utilizing the Pack-a-back System Richard F. Bierlich	91
Logger's Perspective of Thinning Hardwoods Marvin Roberts	93
Session II - Discussion	96
Economics of Thinning from the Forest Management Standpoint Dr. Gerald J. Thiede	102
Existing and Future Products from Hardwood Thinnings Edwin Kallio	108
Application of the System 6 Process to Hardwood Thinnings Hugh W. Reynolds and Edwin Kallio	114
Session III - Discussion	120
Panel on Forest Management Prospectives: Hardwood Thinning Opportunities on National Forest Lands in the Lake States Myron L. Smith	122

Large Industrial Forest Management Perspective of Hardwood Thinning
Ermine J. Venuto 124

Hardwood Opportunities on Wisconsin's State and County Forest
James E. Halvorson 127

Sawmill Industry Viewpoint
Richard Connor, Jr. 134

Research Needs for Hardwoods in the Lake States
David F. Karnosky 136

Converting Timber Stand Improvement Areas to Commercial Thinning in the Northeastern Area
Lloyd R. Casey 139

Timber Supply and Hardwood Thinning Opportunities on Michigan's Nonindustrial Private Forests
Eugene M. Carpenter 143

Summary of Hardwood Thinning Symposium
Craig Locey 149

Session IV - Discussion 151

SOME STRATEGIC CONSIDERATIONS IN MANAGING HARDWOOD FORESTS IN THE LAKE STATES

Dr. Henry H. Webster[1/]

Abstract.--Forest resources in our part of the country have recently taken on greatly increased importance for society. The hardwood component of forest resources seems to be taking on increased importance and potential. Carefully selected hardwood management practices pay off quite well. But three major questions at strategic level will require the most careful attention.

These are my major points. Each can be usefully, but modestly, expanded.

INTRODUCTION

It is my pleasure to take part in this important symposium. I will attempt to set the stage for your detailed discussions of hardwood thinning opportunities. My remarks quite frankly draw heavily on two earlier presentations, the first made at the 1982 SAF national convention in Cincinnati, the second made at the SAF regional technical conference held in Duluth during 1983. Several points made on those occasions are relevant here.

FOREST RESOURCES HAVE GREATLY INCREASED IMPORTANCE FOR SOCIETY

Forest resources were highly important in the original development of the Great Lakes region. They provided both raw material and financial capital for development of mid-continent United States. Their importance then declined significantly in a relative sense as other sectors of our economy and society expanded and prospered. Forest resources were then important primarily to the resources community itself. The dominant economy of the Great Lakes region (based in steel, heavy machinery, and automobiles) has recently undergone severe contraction as every casual newspaper reader is well aware. This effect is so serious that it is at the heart of political campaign arguments over industrial policy.

One notable result is a major effort to develop and diversify the regional economy. Major efforts are going forward in all of the Great Lakes states, with a substantial measure of interstate cooperation at several levels with overall leadership provided by the Great Lakes Governors Association. Forest resources and industries are an important part of these efforts. In Michigan, for example, there are just three target sectors at this point. Two involve renewable resources, namely forest resource and industries, and agricultural processing. The third is certain high-value parts of the automobile industries.

[1/]State Forester, Michigan Department of Natural Resources

Michigan's efforts to develop forest resources and industries are spearheaded by Governor Blanchard's 25-point initiative announced in this city last December 14. This initiative involves major proposals for improving the business climate for forest products industries, for assuring future timber supplies, for coordinating public and private forestry activities, and for creating innovative new arrangements (including funding) to carry these matters forward. Rather similar efforts are going forward in Wisconsin and Minnesota. And at the same time the nationally-known Conservation Foundation is carrying out an analysis of major regional forest policy issues. This analysis is intended to help positive timber-based development go forward with adequate attention to naturalistic and recreational values of forest resources.

These activities all illustrate one very simple point: Forest resources are again a major part of the fundamental social and economic agenda of this region. This simple fact places a premium on professionally competent, technically adequate, and socially sensitive management of forest resources. Our sessions here today help to lay part of a strengthened basis for such management.

HARDWOOD RESOURCES ARE EMERGING

Hardwoods have historically taken second place to softwoods in a considerable number of situations. Softwoods have been generally more useful due to a number of factors, particularly length of fibers and usefulness in construction. High-quality hardwoods used in furniture manufacture have been an exception to this overall pattern.

Breakthroughs in utilization and marketing of hardwoods have taken place to varying degrees several times in recent decades. We appear to be approaching what may in fact be a major breakthrough. Technologic developments and external economic forces seem to be converging toward this result.

Several technologic developments appear to be increasing the usefulness of a considerable number of hardwood species. These developments include the press-drying process for paper production, and the saw-dry-rip process for lumber production. In both cases, hardwoods and softwoods appear to be more nearly interchangeable than was previously the case. This is to the considerable relative advantage of hardwoods.

External economic forces relate especially to rising transportation costs, and their effect on alternative sources of timber products for the large market centers of the Great Lakes region. Our major cities have historically been supplied to major extent with paper and building products from the Deep South, eastern Canada, and the Pacific Northwest. Transportation costs have increased a great deal since this pattern was established. Energy costs affected by OPEC are the root of this. Production closer to market centers has become substantially more attractive as a result. Development of the various types of composite board industries in the Lake States has been substantially a result of this set of economic forces.

These developments and forces suggest that a major breakthrough concerning hardwoods may be occurring. This can be said even if we recognize that some apparent earlier breakthroughs only half to two-thirds happened.

In all of this there is an important central issue. How do we go about matching industrial processes and forest resources? To what degree do we change industrial processes to take advantage of kinds of timber that grow fairly naturally and easily? Or to what degree do we change forest resources to grow timber in greatest demand for today's industrial processes? What balance do we strike between these two different approaches? This is at the heart of questions concerning management of hardwoods versus conversion to softwoods. There is no single, simple, and universally applicable answer. But major efforts to more effectively use relatively abundant hardwood resources do appear to me to be a most important direction. This amounts to running to the wide side of the field in simple resource terms. In addition, industrial processes can be adapted more quickly than extensive areas of forests can be converted and brought to maturity.

"The wide side of the field" is an important concept. Our region currently has lower timber prices than other major forested regions of the United States. This is a result of less intense utilization than in the South and Pacific Northwest. These lower prices are now a positive attractant for timber industry development as timber supplies in these other U.S. regions, and in Canada, tighten up appreciably for a variety of reasons. We should take care not to lose this advantage immediately. Management must intensify. However, real effort is needed to focus on practices that are both economically efficient and compatible with continuing low cost of final product.

CAREFULLY SELECTED HARDWOOD MANAGEMENT PRACTICES PAY OFF QUITE WELL

We can now turn our attention to management practices designed to assure a stable supply of improved hardwood timber in the future.

The fact is that some such practices pay off quite handsomely in hardheaded financial terms if viewed as moderately long-term investments.

Pay off can be usefully measured via real rates of return for complete management regimes for particular forest types. Real rates of return are over and above inflation: they measure how rapidly investments in management practices "grow into" increased values at harvest. The effects of management in increasing volume, improving quality, and shortening time required to reach a given stand condition are all reflected in higher rates of return. If timber prices increase faster than prices for other goods and services this is also reflected. Real rate of return plus the overall inflation rate equals interest rate that can be compared with that offered at the bank or elsewhere. Management regimes for particular forest types assume that the most appropriate silvicultural practices for each type are applied in a technically correct manner in sequence at optimum times. It is further assumed that management is applied only on productive sites. These assumptions are powerful statements concerning the absolute need for technically skilled application of silvicultural practices.

Real rates of return in the range of 9 to 12 percent per year have been calculated in competently done analyses for several regional forest types. For example, such rates have been calculated for the northern hardwood type, and (in a more restricted sense) for good quality oaks on productive sites. Similarly, rates in this same range have been calculated for our principal pine

types. Rates of return for active timber management are markedly lower in the aspen type and in secondary softwood types such as spruce-fir. This difference in returns among types has a simple, elemental cause: aspen and spruce-fir grow about as well by themselves as they do with deliberate silvicultural effort. The other types are substantially more responsive.

Rates of return can also be calculated for individual practices. This has been done in a number of major analyses made over the past twenty-five years. Such calculations tend to show higher rates of return for intermediate practices than for regeneration; indeed they tend to show higher rates for intermediate practices (e.g. thinning) carried out relatively late in the rotation than for generally similar practices carried out earlier.

A part of these higher rates for late practices is spurious: the arithmetic mechanics of compound interest automatically raises rates of return for shorter-term as compared with longer-term investments. But there is a valid point with practical application in those forest types that regenerate fully and easily with little managerial attention, as do a number of hardwood types. Management regimes for these types can appropriately begin with thinning or other intermediate practices. Such regimes generally pay off at higher rates than do those for types where major regeneration efforts and expenditures are necessary.

THREE MAJOR FACTORS REQUIRE ATTENTION

These high rates of return give a promising picture for deliberate management of hardwood resources. Thinning is obviously an important part of such management.

Three matters of large scope require our most serious collective attention, however, if this promise is to be fulfilled. The first is the cost advantage to timber industries now provided by relatively low-cost timber in our region. From a developmental perspective it is important to prolong this advantage. Can we do so as management becomes more intensive? We probably can if we focus adequately. But this won't happen automatically. There is particular reason to worry about complex forms of management that can readily run up costs in relation to output. Traditional individual tree management of northern hardwoods, with thinning carried out by traditional means, is perhaps an outstanding example. Therefore it is particularly important to develop simplified management approaches for this type, as it is also important to develop efficient methods and machinery for carrying out specific practices such as thinning.

The second crucial question is the matter of investment. We must liberate ourselves from the idea that nothing can be invested in producing improved forests. Of course, it costs less in an immediate sense if thinning or other practices can be done on a wholly commercial basis. But to limit ourselves to that basis alone may mean continuing in a classic low-level trap. Past practices have given us somewhat ragged forests. If we limit ourselves to improvement that can be immediately financed from current receipts we are perpetuating this condition unnecessarily. The point of keeping costs down is not to avoid investment. Rather it is to invest in practices and situations

that give a lot of improved final result in relation to amount of investment. That is the point of the excellent rates of return cited earlier.

The third crucial question concerns expansion of market and utilization opportunities for hardwoods. We have already noted technologic developments and economic forces that are fostering such expansion. But this will not happen automatically. It will require sustained effort by many organizations both public and private. It will require sustained effort in basic research, in specific technologic development, in plant improvement, and in efforts to attract additional forest products firms to our region.

A united front is essential in these efforts. To my eye, the Lake States forest resources community is developing much greater cohesiveness than was ever previously the case, even though we still have some distance to go. And we have new allies who are interested in forest resources for their regional developmental potential. That is most encouraging.

THE LAKE STATES' HARDWOOD RESOURCE

John S. Spencer, Jr.[1/]

Abstract.--The Lake States contained 34.3 million acres of commercial forest land in 1977 in hardwood forest types--75 percent of the total commercial area. The aspen and maple-birch types with 12.9 and 10.9 million acres, respectively, lead all others. Thinning is the appropriate treatment, from a silvicultural viewpoint, for an estimated 3.0 million acres, half of which is in the maple-birch type.

"One hot day during the close of August, Margolis ran amok. He complained that perspiration kept running down his glasses, and although he could not see without them, he could not see with them either. Although it was intensely hot, Wagner ran the line through the hardwood lowland at full speed, trying to get away from the maddening insects. Margolis, inhaling small insects with every breath, ran into a springy cedar snag, which catapulted him through the air. He snorted like an infuriated bull when he got up and charged the snag with a wild burst of speed. The snag did not break, however, but threw him backwards into the brush again. This time he ran at it with his hand axe, exclaiming while he hacked, 'There, damn you, -- take that, and that! And when it came down, triumphantly, 'and THAT!'"

These words, written about 1937 by Harry G. Gafvert, member of the first Forest Survey team to inventory the timber resources of the Lake States, tell us something of the sense of purpose and direction instilled in those young men of long ago as they completed their precedent-setting survey. The words also tell us, perhaps, of an early application of thinning, the subject of this symposium. The rest of the paper portrays the hardwood resource as it exists presently in the Lake States.

OLD SURVEY METHODS

The survey Mr. Gafvert helped complete between 1933 and 1936 came about because of a public concern that the country might be running out of timber--an understandable fear given the Nation's insatiable appetite for timber and the general absence of applied forest management in the 19th and early 20th centuries. The legislative foundation for nationwide forest inventories was laid in 1928 with passage of the McSweeney-McNary Forest Research Act.

1/Principal Resource Analyst, North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minnesota.

Foresters used a system of sampling in the Lake States that was developed in Sweden. Cruise lines were run 10 miles apart in an east-west direction across the State. Crews measured 1/5-acre plots every 10 chains (660 feet) along these lines. Field work continued year-round, and in isolated areas the crews camped on the line to keep from dead-heading long distances back to a road at night. Working conditions were demanding in the mid-1930's, with the lack of good maps, down parkas and sleeping bags, lightweight camp gear, insulated boots, and even reliable insect repellent.

NEW SURVEY METHODS

A few things have changed since that first survey. We are now called Forest Inventory and Analysis rather than Forest Survey. Our primary legislative mandate now is the 1974 Forest and Rangeland Renewable Resources Planning Act, which broadened the scope of state-wide inventories. Sampling techniques changed also to combine information obtained from aerial photos with data measured on the ground -- commonly called a two-stage sampling technique. Field plots measured on the ground are a subsample of aerial photo points examined under a stereoscope. The field plots are a cluster of 10 points located 70 feet apart, covering an area of about one acre. The crew establishes a variable-radius plot at each of the 10 points. Field crews still work year-round, however, and they share many of the difficulties of their counterparts of the past. The data generated from every inventory is largely purchased by the sweat of these hard-working and unsung people.

LAKE STATES TIMBER RESOURCE

The inventory information that follows is dated 1977, but it comes from three surveys of different dates. The Michigan and Minnesota inventories are dated 1980 (Spencer 1983) and (Raile and Smith 1983) and 1977 (Jakes 1980) and (Spencer 1982), respectively. Fieldwork for the new inventory of Wisconsin was completed in January, 1984, and preliminary data are available for three of the five Forest Survey Units. However, statewide data are not complete. Therefore, data from the 1968 survey, which were computer-updated to 1977 for the National Assessment (USDA Forest Service 1982), are used here.

AREA

Forest land in the United States amounted to 736 million acres in 1977--one-third of the Nation's total land area (table 1). The Pacific Coast and South, with 29 and 28 percent of the total forest land, respectively, lead all other regions (fig. 1). The Lake States, with 5 percent of the Nation's land area, contain 7 percent of its forest land, 50 million acres.

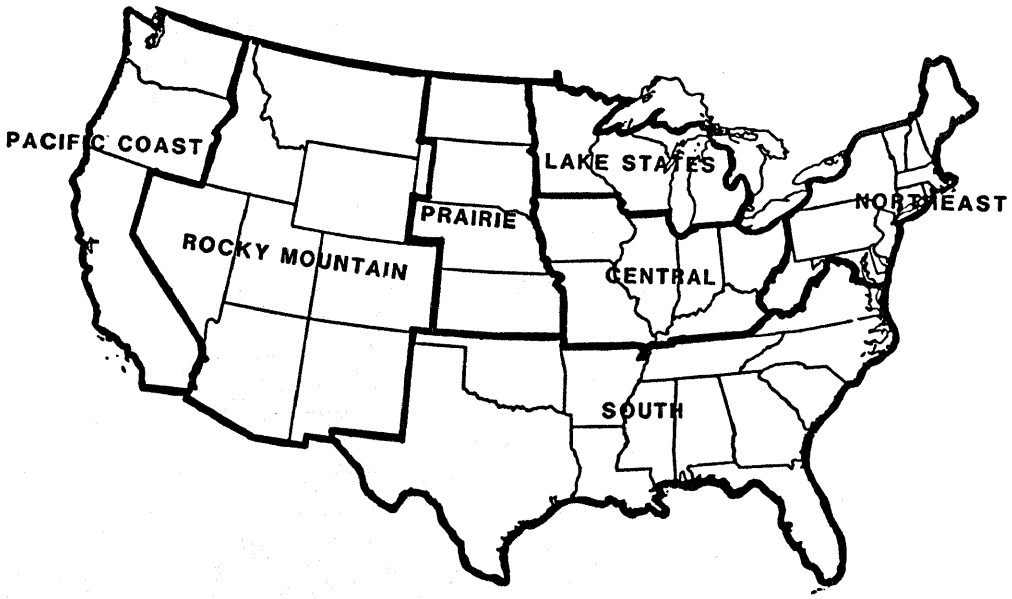


Figure 1.--Regions of the United States.

Table 1.--Area of forest land by land class, and region, United States, 1977

(In million acres)

Region	Total forest land	Commercial forest land	Productive-reserved	Other forest land
Pacific Coast	214.3	70.6	4.1	139.6
South	206.9	188.0	2.1	16.8
Rocky Mountain	137.8	57.8	8.4	71.6
Northeast	83.1	77.4	3.8	1.9
Central	40.5	39.2	0.7	0.6
Prairie	3.1	2.6	--	0.5
Lake States	50.0	45.7	1.8	2.5
All Regions	735.7	481.3	20.9	233.5

Although the Pacific Coast Region contains the largest area of forest land, only one-third of it is commercial forest land. Nearly two-thirds is unproductive or deferred forest land--either incapable of producing crops of industrial wood because of adverse site conditions, or temporarily deferred from harvesting until studies under RARE II are completed to determine whether the land should be included in the wilderness system. The South, then, contains the largest area of commercial forest, 188.0 million acres. Ninety-one percent of the Lake States' forest land is commercial forest, 45.7 million acres. Productive-reserved forest accounts for 1.8 million acres and unproductive forest makes up the remaining 2.5 million acres.

Among the Lake States, Michigan leads in forest and commercial forest area (table 2). Minnesota leads in area of productive-reserved forest (primarily the Boundary Waters Canoe Area Wilderness and the Voyageurs National Park), and unproductive forest.

Table 2.--Area of forest land by land class, Lake States, 1977

(In million acres)

State	Total forest land	Commercial forest land	Productive-reserved	Other forest land
Michigan	18.4	17.5	0.6	0.3
Minnesota	16.7	13.7	1.2	1.8
Wisconsin	14.9	14.5	--	0.4
Lake States	50.0	45.7	1.8	2.5

Nationwide, commercial forest area has declined by 3.6 percent since 1952. The Northeast was the only region to show a gain, largely because of abandoned farmland reverting naturally to forest. The Lake States declined 10.6 percent, second only to the Prairie States' 13.9 percent drop:

Region	Change
Northeast	+ 6.0
South	(-)2.1
Pacific Coast	(-)5.4
Central	(-)6.0
Rocky Mountain	(-)9.6
Lake States	(-)10.6
Prairie	(-)13.9
All Regions	(-)3.6

Among the Lake States, Minnesota showed the biggest decline between 1952 and 1977, 2.9 million acres or 17.5 percent (table 3). Much of this was due to conversion of commercial forest land to productive-reserved forest.

Table 3.--Area of commercial forest land in the Lake States, 1952, 1962, 1970, and 1977

(In million acres)

Year	Total	Michigan	Minnesota	Wisconsin
1952	51.0	19.1	16.6	15.3
1962	49.2	19.1	15.4	14.7
1970	47.8	18.8	14.5	14.5
1977	45.7	17.5	13.7	14.5

Two forest types dominate Lake States timber stands, accounting for 56 percent of the commercial area--the aspen-birch type (32 percent) and the maple-birch type (24 percent) (table 4). The aspen-birch type has received increased attention, especially in Minnesota, since the advent of the wafer-board industry. The aspen-birch type is most extensive in Minnesota where it comprises 50 percent of the commercial forest. The maple-birch type is most widespread in Michigan, accounting for 35 percent of that State's commercial area.

Table 4.--Area of commercial forest land in the Lake States, by forest type, 1977

(In million acres)

Forest type	Total	Michigan	Minnesota	Wisconsin
White-red-jack pine	3.7	1.7	0.8	1.2
Spruce-fir	6.9	2.6	2.9	1.4
Oak-hickory	5.4	1.8	0.9	2.7
Elm-ash-cottonwood	3.1	1.3	0.7	1.1
Maple-birch	10.9	6.1	1.3	3.5
Aspen-birch	14.9	3.8	6.9	4.2
Nonstocked	0.8	0.2	0.2	0.4
All types	45.7	17.5	13.7	14.5

The proportion of area in each stand-size class reveals much about what has happened in the past to those stands. In the West where old-growth stands are common, two-thirds of the commercial area is in sawtimber stands (table 5). In the South where much of the forest is intensively managed, the commercial area is fairly evenly divided among the three stand-size classes. The Lake States is the only region where sawtimber stands do not predominate. This reflects the continuing maturation and rebuilding of stands from the cutover and burned over conditions prevalent in the late 19th and early 20th centuries.

Table 5.--Percent of commercial forest land in each stand-size class, United States, 1977

(In percent)

Region	Sawtimber	Poletimber	Sapling and seedling	Nonstocked
South	38	31	28	3
Northeast	40	29	29	2
Pacific Coast	66	14	14	6
Rocky Mountain	67	20	9	4
Central	42	27	28	3
Prairie	40	28	14	18
Lake States	25	47	27	1
All regions	45	28	24	3

Poletimber stands are somewhat more widespread in Minnesota, where they account for 51 percent of the area, than in Wisconsin (46 percent) or Michigan (45 percent) (table 6). The proportion of sawtimber stands is greater in Michigan (29 percent) than in Minnesota (23 percent) or Wisconsin (23 percent). The proportion of nonstocked commercial forest in the Lake States is lower than in any other region.

Table 6.--Area of commercial forest land in the Lake States, by stand-size class, 1977

(In million acres)

Stand-size class	Total	Michigan	Minnesota	Wisconsin
Sawtimber	11.5	5.1	3.1	3.3
Poletimber	21.4	7.8	7.0	6.6
Sapling and seedling	12.1	4.4	3.4	4.3
Nonstocked	0.7	0.2	0.2	0.3
All classes	45.7	17.5	13.7	14.5

The percent of area in hardwood forest types in the Lake States by stand-size class parallels the percent for all forest types (table 7). However, the proportions for individual forest types vary considerably. Sapling-seedling stands make up 36 percent of the aspen forest type and 27 percent of the elm-ash-cottonwood type, but only 18 percent or less of other hardwood types. Seventy-two percent of the paper birch type and 52 percent of the aspen type are in poletimber stands. Other hardwood types contain 43 percent or less of poletimber stands. Sawtimber stands are most prevalent in the oak-hickory and maple-birch types, with 41 and 40 percent, respectively.

Table 7.--Area of commercial forest land by hardwood forest type, stand-size class, and state, Lake States, 1977

(In thousand acres)

Forest type	All Lake States	Michigan	Minnesota	Wisconsin
Oak-hickory				
Sawtimber	2,165	684	453	1,028
Poletimber	2,189	782	361	1,046
Sapling and seedling	978	308	80	590
All stands	5,332	1,774	894	2,664
Elm-Ash-Cottonwood				
Sawtimber	993	453	195	345
Poletimber	1,358	471	389	498
Sapling and seedling	871	402	155	314
All stands	3,222	1,326	739	1,157
Maple-birch				
Sawtimber	4,410	2,480	675	1,255
Poletimber	4,662	2,568	494	1,600
Sapling and seedling	1,832	1,050	115	667
All stands	10,904	6,098	1,284	3,522
Aspen				
Sawtimber	1,580	534	907	139
Poletimber	6,724	1,505	3,281	1,938
Sapling and seedling	4,619	1,368	1,663	1,588
All stands	12,923	3,407	5,851	3,665
Paper birch				
Sawtimber	197	35	142	20
Poletimber	1,393	270	758	365
Sapling and seedling	337	70	97	170
All stands	1,927	375	997	555
All hardwood types				
Sawtimber	9,345	4,186	2,372	2,787
Poletimber	16,326	5,596	5,283	5,447
Sapling and seedling	8,637	3,198	2,110	3,329
All stands	34,308	12,980	9,765	11,563

Fifty-six percent of the area of hardwood forest types grows stands that are aged 50 years or younger, and 70 percent of them grows stands 60 years of age and younger (table 8). The longer-lived oak-hickory and maple-birch types contain smaller proportions in the younger age classes--only 56 percent of both types is in stands less than 60 years old. This compares with 90 percent of the aspen type and 78 percent of the paper birch type, both composed of shorter-lived species.

Table 8.--Area of commercial forest land by hardwood forest type and stand-age class, Lake States, 1977

(In thousand acres)

Stand-age class (years)	All types	Oak-hickory	Elm-ash-cottonwood	Maple-birch	Aspen	Paper birch
1-10	3,789	459	332	716	2,167	115
11-20	3,178	328	296	651	1,759	144
21-30	2,164	171	242	455	1,178	118
31-40	4,442	528	308	906	2,423	277
41-50	5,736	744	333	1,731	2,486	442
51-60	4,865	738	416	1,678	1,619	414
61-70	2,801	581	347	996	662	215
71-80	1,937	477	247	795	317	101
81-90	1,636	428	232	758	160	58
91-100	1,318	332	169	706	87	24
101-120	1,522	394	191	870	55	12
121+	920	152	109	642	10	7
All ages	34,308	5,332	3,222	10,904	12,923	1,927

Site index indicates the quality of a site in terms of the height of a free-growing tree at age 50 of a representative species of the forest type. Among hardwood forest types in the Lake States the weighted average site index is 62.4 feet. Michigan is highest with 65.2 feet. Wisconsin and Minnesota follow with 60.8 and 60.4 feet, respectively.

Highest average site indices are in the aspen type (65.8 feet) and the maple-birch type (63.1 feet), followed by the paper birch type (58.4), the elm-ash-cottonwood type (57.4 feet), and the oak-hickory type (57.1 feet). Considering all hardwood types together, 43 percent of the commercial forest area grows stands whose site index is 60 feet and shorter, and 72 percent of the area grows stands whose site index is 70 feet or less (table 9).

Table 9.--Area of commercial forest land by hardwood forest type and site-index class, Lake States, 1977

(In thousand acres)

Site-index class (feet)	All types	Oak-hickory	Elm-ash-cottonwood	Maple-birch	Aspen	Paper birch
11-20	1	--	--	--	1	--
21-30	92	16	31	22	17	6
31-40	1,332	425	378	236	206	87
41-50	4,427	1,260	672	1,194	1,024	277
51-60	8,870	1,570	887	2,932	2,780	701
61-70	10,145	1,191	630	3,575	4,121	628
71-80	6,436	603	326	2,062	3,255	190
81-90	2,410	211	168	698	1,296	37
91+	595	56	130	185	223	1
All classes	34,308	5,332	3,222	10,904	12,923	1,927

The weighted average basal area of growing-stock trees at least 5 inches d.b.h. in hardwood forest types in the Lake States is 79.8 square feet per acre. Stands are somewhat more dense in Michigan, averaging 84.7 square feet, followed by Minnesota (79.0 square feet) and Wisconsin (74.8 square feet). The maple-birch type contains the densest stands, averaging 93.2 square feet per acre (table 10) -- 95.4 square feet is the average in Michigan, 90.7 in Wisconsin, and 90.3 in Minnesota. The paper birch type is second in average basal area of its stands with 81.7 square feet per acre, followed by the oak-hickory type (77.9 square feet), the elm-ash-cottonwood type (75.5 square feet), and the aspen type (69.9 square feet).

Table 10.--Area of commercial forest land by hardwood forest type and basal-area class of growing-stock trees, Lake States, 1977

(In thousand acres)

Basal-area class (sq.ft.per acre)	All types	Oak-hickory	Elm-ash-cottonwood	Maple-birch	Aspen	Paper birch
0-20	2,071	224	233	299	1,223	92
21-40	3,358	360	437	567	1,801	193
41-60	5,633	1,003	557	1,076	2,713	284
61-80	6,292	1,239	591	1,766	2,347	349
81-100	6,156	1,160	479	2,239	1,895	383
101-120	5,185	830	420	2,242	1,407	286
121-140	3,690	389	323	1,801	938	239
141+	1,923	127	182	914	599	101
All classes	34,308	5,332	3,222	10,904	12,923	1,927

VOLUME

Since 1952 the Nation's volume of growing stock has increased 18 percent during the same time the area of commercial forest land declined by almost 4 percent. The Pacific Coast is the only Region where the growing-stock volume declined during the 25-year period. Pacific Coast volume dropped 11 percent during the period as old growth timber continued to be liquidated. Growing-stock volume in the Lake States increased 76 percent between 1952 and 1977--faster than any other region. Softwood volume rose from 6.7 to 12.3 billion cubic feet during the period, a gain of 84 percent, while hardwood volume increased from 18.3 to 31.8 billion cubic feet, a gain of 74 percent (table 11).

Table 11.--Volume of growing stock on commercial forest land by region, year, and softwoods and hardwoods, United States, 1952, 1962, 1970, and 1977

(In billion cubic feet)

Year and species group	Pacific Coast	South	Rocky Mtn.	Northeast	Central	Prairie	Lake States
1952							
Softwoods	251.6	58.2	87.5	20.0	0.9	--	6.7
Hardwoods	12.6	78.2	4.0	43.2	21.1	1.1	18.3
All species	264.2	136.4	91.5	63.2	22.0	1.1	25.0
1962							
Softwoods	241.8	71.6	93.1	24.0	1.1	0.1	9.1
Hardwoods	14.9	84.5	4.5	52.8	24.6	1.1	24.5
All species	256.7	156.1	97.6	76.8	25.7	1.2	33.6
1970							
Softwoods	230.8	84.9	94.4	27.9	1.3	0.1	10.4
Hardwoods	17.6	91.9	4.9	60.3	26.3	1.2	28.5
All species	248.4	176.8	99.3	88.2	27.6	1.3	38.9
1977							
Softwoods	219.1	97.1	94.9	31.0	1.6	0.1	12.3
Hardwoods	16.9	104.9	4.9	67.3	27.7	1.3	31.8
All species	236.0	202.0	99.8	98.3	29.3	1.4	44.1

Among the Lake States, growing-stock volume increased the fastest in Michigan where it gained 91 percent between 1952 and 1977 (table 12). Softwood volume increased substantially faster than hardwood volume in Michigan and Wisconsin. In Minnesota the reverse is true.

Table 12.--Volume of growing stock on commercial forest land by softwoods and hardwoods, Lake States, 1952, 1962, 1970 and 1977

(In billion cubic feet)

Year and species group	Total	Michigan	Minnesota	Wisconsin
1952				
Softwoods	6.7	2.4	2.7	1.6
Hardwoods	18.3	7.6	4.3	6.4
All species	25.0	10.0	7.0	8.0
1962				
Softwoods	9.1	3.6	3.4	2.1
Hardwoods	24.5	10.7	6.1	7.7
All species	33.6	14.3	9.5	9.8
1970				
Softwoods	10.4	4.3	3.4	2.7
Hardwoods	28.5	12.2	7.2	9.1
All species	38.9	16.5	10.6	11.8
1977				
Softwoods	12.3	5.4	3.5	3.4
Hardwoods	31.8	13.7	8.0	10.1
All species	44.1	19.1	11.5	13.5

Two-thirds of the Nation's softwood volume is found in the West (table 13). Another one-fifth is in the South. The Lake States Region contributes a meager 3 percent of the softwood volume, but this proportion has grown from 2 percent in 1952. The bulk of hardwood volume in the U.S. is in the South (41 percent) and the Northeast (26 percent). The Lake States Region grows a respectable 12 percent of the hardwood volume, up from 10 percent in 1952.

Table 13.--Volume of growing stock on commercial forest land by region and softwoods and hardwoods, United States, 1977

(In billion cubic feet)

Region	Total	Softwoods	Hardwoods
Pacific Coast	236.0	219.1	16.9
South	202.0	97.1	104.9
Rocky Mountain	99.8	94.9	4.9
Northeast	98.3	31.0	67.3
Central	29.3	1.6	27.7
Prairie	1.4	0.1	1.3
Lake States	44.1	12.3	31.8
All Regions	710.9	456.1	254.8

Michigan leads the Lake States in growing-stock volume with 43 percent of the total (table 14). Michigan's volume increased faster between 1952 and 1977 (91 percent) than Wisconsin (69 percent) or Minnesota (64 percent).

Table 14.--Volume of growing stock on commercial forest land, by state and softwoods and hardwoods, Lake States, 1977

(In billion cubic feet)

State	Total	Softwoods	Hardwoods
Michigan	19.1	5.4	13.7
Wisconsin	13.5	3.4	10.1
Minnesota	11.5	3.5	8.0
Lake States	44.1	12.3	31.8

The aspens (Populus tremuloides and P. grandidentata) are the dominant species group in the Lake States in terms of growing-stock volume with 8.2 billion cubic feet, more than twice as much as the 3.8 billion cubic feet of hard maple (Acer saccharum and A. nigrum), its closest competitor (table 15). Aspen was considered a weed species for years after it became widely established following intensive cutting of softwood and subsequent slash burning and wildfires. But now it is regarded as a highly valuable resource by the paper and waferboard industries and as vital food and cover for ruffed grouse, deer, and other wildlife species.

Table 15.--Volume of growing stock on commercial forest land by major species and state, Lake States, 1977

(In billion cubic feet)

Species	Total	Michigan	Minnesota	Wisconsin
Aspen	8.2	2.6	3.4	2.2
Hard maple	3.8	2.7	0.2	0.9
Soft maple	3.0	2.3	0.1	0.6
Paper birch	2.8	0.8	1.3	0.7
Select red oak	2.8	1.2	0.6	1.0
Balsam fir	2.1	0.8	0.9	0.4
Northern white-cedar	2.0	1.3	0.4	0.3
Ash	1.7	0.7	0.5	0.5
Basswood	1.7	0.7	0.4	0.6
Jack pine	1.6	0.6	0.6	0.4

Increasing volumes per acre nationally explain how growing-stock volumes can climb at the same time commercial forest area is declining. In 1952 the U.S. average volume per acre was 1,208 cubic feet, but in 1977 it was 1,477, a 22 percent jump.

The differences in volumes per acre among regions reflect differences in stand-size class areas and average tree size. Commercial forests in the Pacific Coast Region, which are predominantly sawtimber stands, average 3,346 cubic feet per acre, almost twice as high as the next region. The Lake States, where poletimber stands predominate, average 964 cubic feet per acre, considerably lower than the national average:

Region	Growing-stock volume per acre 1977
	(Cubic feet)
Pacific Coast	3,346
Rocky Mountain	1,728
Northeast	1,270
South	1,074
Central	748
Prairie	544
Lake States	964
All Regions	1,477

Volumes per acre also vary widely by ownership class. Nationwide, the National Forests have the highest average growing-stock volume per acre, reflecting conditions in the West where most of the National Forests are found. In the Lake States, forest industry-owned land boasts the highest average volumes per acre, suggesting that these tracts were of higher than average site quality when they were acquired and that they have received good management. Other public-owned forests in the Lake States have the lowest average volume per acre, reflecting, among other things, the poor condition of much tax-forfeited land that came into county, municipal, or state ownership years ago:

Ownership Class	Growing-stock volume per acre 1977	
	United States	Lake States
	(Cubic feet)	
National Forest	2,575	1,116
Other public	1,606	851
Forest industry	1,545	1,186
Farmer and misc. private	1,082	954
All owners	1,477	964

Farmers and miscellaneous private parties own 51 percent of the growing-stock volume in the Lake States (table 16), just as they own 51 percent of the commercial forest area. Other public owners account for 25 percent, National Forests for 14 percent, and forest industry for 10 percent.

Table 16.--Volume of growing stock on commerical forest land by ownership class, Lake States, 1977

(In billion cubic feet)

Ownership class	Total	Michigan	Minnesota	Wisconsin
National Forest	6.1	2.8	1.9	1.4
Other public	11.0	3.8	4.5	2.7
Forest industry	4.6	2.4	0.6	1.6
Farmer and misc. private	22.4	10.1	4.5	7.8
All owners	44.1	19.1	11.5	13.5

GROWTH AND REMOVALS

Nationwide, the total volume of growth and removals has increased since 1952. Net annual growth of growing stock in the U.S. gained 56 percent during the period, and timber removals increased 20 percent. In 1976 the volume of removals was 66 percent of the volume of growth. The ratio of removals to growth is much higher for softwoods (82 percent) than it is for hardwoods (45 percent).

In the Lake States, growth and removals volumes have increased since 1952 also. Growth increased 37 percent and removals gained 44 percent between 1952 and 1976. The 1976 removals volume was 46 percent of growth, compared to 66 percent nationally. The softwood ratio of removals to growth is only 36 percent compared to 82 percent nationally. The hardwood ratio is 51 percent compared to 45 percent nationally.

The highest ratio of removals to growth in the Lake States is in Minnesota with 55 percent (table 17).

Table 17.--Net annual growth and removals by softwoods and hardwoods, Lake States, 1976

(In million cubic feet)

State	All species		Softwoods		Hardwoods	
	Growth	Removals	Growth	Removals	Growth	Removals
Michigan	678	274	206	56	472	218
Wisconsin	556	268	146	44	410	224
Minnesota	349	194	120	69	229	125
Lake States	1,583	736	472	169	1,111	567

Comparisons of growth and removals can lead to erroneous conclusions in areas such as the Lake States where stands are young and growth includes a substantial volume in trees too small to be a significant part of the removals volume. A more meaningful comparison is one between removals and the yields from land managed under cutting prescriptions representing expected or average future conditions. Such comparisons are not available for all the Lake States yet, but the one for Minnesota suggests that removals could be substantially higher.

Growth rates (growth as a percent of inventory) in the United States have increased since 1952, especially for softwoods. In spite of rising volumes of growth, growth rates in the Lake States have declined since 1952 as shown in the following tabulation. This situation is not unusual in states with young stands in which the inventory has been increasing rapidly. In such cases growth volumes cannot keep pace with inventory volumes, and growth rates drop.

Region and species group	Growth rate	
	1952	1976
	(Percent)	
United States:		
Softwoods	1.8	2.7
Hardwoods	3.5	3.7
Total	2.3	3.1
Lake States:		
Softwoods	4.6	3.8
Hardwoods	4.7	3.5
Total	4.7	3.6

The largest share of timber removals from growing stock in the U.S. was harvested as saw logs, and the next highest share was pulpwood. The proportions of these two products are reversed in the Lake States, as shown in the following tabulation:

Product	United States	Lake States
	(Percent)	
Saw logs	45	25
Pulpwood	24	43
Veneer logs and bolts	9	1
Fuelwood	2	3
Misc. indus. prod.	2	4
Logging residues	10	5
Other removals	8	19
Total	100	100

Seventy-seven percent of the 1976 Lake States' timber removals from growing stock was composed of hardwood species (table 18). Hardwoods, primarily aspen, accounted for 65 percent of the pulpwood harvested in the region. Wisconsin produced the largest proportion of pulpwood of all species (38 percent), as well as the largest share of hardwood pulpwood (42 percent). Eighty-four percent of all saw logs harvested were hardwoods, much of it aspen and hard maple. Half of all the saw logs harvested were from Michigan.

Table 18.--Timber removals from growing stock by item and softwoods and hardwoods, Lake States, 1976

(In million cubic feet)

Item	All species	Softwoods	Hardwoods
Pulpwood	313.9	108.4	205.5
Saw logs	183.4	28.9	154.5
Misc. indus. prod.	26.9	6.8	20.1
Fuelwood	24.8	0.6	24.2
Veneer logs and bolts	9.9	1/	9.9
Logging residues	34.9	4.4	30.5
Other removals	141.9	20.0	121.9
Total	735.7	169.1	566.6

1/Less than 50 thousand cubic feet.

THINNING AREA ESTIMATED

The North Central Station recently estimated the area of commercial forest that would benefit from various kinds of treatment for each of the 11 states in its region, as part of a national effort. Criteria for determining treatment class were based on Forest Inventory and Analysis data normally collected in the field. The criteria used were patterned as closely as possible after those used in the Forest Industries Council's Forest Productivity Project (Minnesota, Wisconsin and Michigan Forest Productivity Reports 1979). Each of the 11 states was treated the same way. Variables used to determine whether thinning was an appropriate treatment included forest type, site index, stand age and basal area. For example, stands were targeted for thinning in the maple-birch type whose site index was at least 55 feet, were 90 years or less in age, and whose basal area was 110 to 140 square feet per acre. A different range of these variables was applied for each forest type.

Other treatment classes included regeneration without site preparation, regeneration with site preparation, type conversion, intermediate cut, shelterwood cut, partial cut, salvage cut, cull tree removal, and no treatment.

Our study showed that thinning is the appropriate treatment, from a silvicultural viewpoint, on 3.0 million acres of hardwood types in the Lake States (table 19), 9 percent of the commercial area of hardwood types. The maple-birch type accounts for the largest area, 49 percent of the thinning total. Seventy percent of all sapling and seedling stands targeted for thinning are in the aspen type, and 60 percent of all poletimber stands for which thinning is a potential treatment is in the maple-birch type.

Table 19.--Area of commercial forest land in thinning treatment class by hardwood forest type, and stand-size class, Lake States, 1977

(In thousand acres)

Forest type and stand-size class	Lake States	Michigan	Minnesota	Wisconsin
Oak-hickory				
Poletimber	658	231	93	334
Sapling and seedling	27	4	-	23
Total	685	235	93	357
Elm-ash-cottonwood				
Poletimber	196	57	58	81
Sapling and seedling	55	32	5	18
Total	251	89	63	99
Maple-birch				
Poletimber	1,301	764	90	447
Sapling and seedling	140	91	1	48
Total	1,441	855	91	495
Aspen				
Poletimber	20	3	11	6
Sapling and seedling	550	223	87	240
Total	570	226	98	246
Paper birch				
Poletimber	-	-	-	-
Sapling and seedling	15	6	2	7
Total	15	6	2	7
All hardwood types				
Poletimber	2,175	1,055	252	868
Sapling and seedling	787	356	95	336
Total	2,962	1,411	347	1,204

Fifty-eight percent of the area of hardwood types targeted for thinning is in stands whose site class, a measure of productivity based on the volume of annual growth per acre produced by fully-stocked natural stands, is 50-85 cubic feet (table 20). Another 21 percent of it grows less than 50 cubic feet per acre annually. If economic constraints were applied, many of these stands would not be considered viable thinning opportunities.

Table 20.--Area of commercial forest land in thinning treatment class by hardwood forest type and site class, Lake States, 1977

(In thousand acres)

Forest type and site class (cubic feet of growth per acre per year)	Lake States	Michigan	Minnesota	Wisconsin
Oak-hickory				
120-165	-	-	-	-
85-120	113	58	10	45
50-85	443	175	77	191
Less than 50	129	2	6	121
All classes	685	235	93	357
Elm-ash-cottonwood				
120-165	-	-	-	-
85-120	11	4	1	6
50-85	34	17	5	12
Less than 50	206	68	57	81
All classes	251	89	63	99
Maple-birch				
120-165	24	22	-	2
85-120	251	141	14	96
50-85	902	543	41	318
Less than 50	264	149	36	79
All classes	1,441	855	91	495
Aspen				
120-165	11	5	4	2
85-120	202	92	25	85
50-85	341	121	66	154
Less than 50	16	8	3	5
All classes	570	226	98	246
Paper birch				
120-165	-	-	-	-
85-120	-	-	-	-
50-85	9	4	-	5
Less than 50	6	2	2	2
All classes	15	6	2	7
All hardwood types				
120-165	35	27	4	4
85-120	577	295	50	232
50-85	1,730	861	188	681
Less than 50	620	228	105	287
All classes	2,962	1,411	347	1,204

LITERATURE CITED

Forest Industries Council. Minnesota forest productivity report, 1979. Washington, D.C.; 1979. 19 p.

Forest Industries Council. Wisconsin forest productivity report, 1979. Washington, D.C.; 1979. 18 p.

Forest Industries Council. Michigan forest productivity report, 1979. Washington, D.C.; 1979. 18 p.

Jakes, P. J. The fourth Minnesota forest inventory: area. Resour. Bull. NC-54. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1980. 37 p.

Raile, G. K.; Smith, W. B. Michigan forest statistics, 1980. Resour. Bull. NC-67. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983. 101 p.

Spencer, J. S., Jr. The fourth Minnesota forest inventory: timber volumes and projections of timber supply. Resour. Bull. NC-57. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1982. 72 p.

Spencer, J. S., Jr. Michigan's fourth forest inventory: area. Resour. Bull. NC-68. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983. 39 p.

U.S. Department of Agriculture, Forest Service. An analysis of the timber situation in the United States 1952-2030. Forest Resour. Report No. 23. Washington, D.C.; 1982. 499 p.

SILVICULTURAL CONSIDERATIONS IN THINNING

Richard M. Godman[1]

Abstract.--For producing sustained yields of high-value northern hardwood veneer and sawlogs on medium and better sites in the Lake States, the author recommends uneven-aged management for tolerant sugar maple and even-aged management for less tolerant species such as basswood, white ash, yellow birch, and northern red oak. Suggestions for improving growth and quality development include: (1) selecting the best uniformly spaced crop trees to leave and release on the basis of crown size and stem form; (2) early thinning of sprout clumps down to the single best stem; (3) maintaining proper stand density by following recommended stocking level guides; (4) taking stand variation into account when marking; (5) thinning at regular 10-to 12-year intervals; and (6) using even-aged density levels for the first two thinnings in second-growth stand even if uneven-aged management is to be practiced later.

During this meeting we will review thinning in naturally established stands. This thinning phase of stand treatment is only part of the application of a silvicultural system. Over the last decade we have developed a better understanding of management methods and of the silvicultural systems that can be used in our northern hardwood stands. Treatments making up a silvicultural system include reproduction cuttings to establish a stand of preferred species followed by a series of intermediate cuttings to develop the stand for desired products and then to reproduction cuttings again. It seems easier to understand the choice and use of a silvicultural system if stand management is recognized as either even-aged or uneven-aged management. The pros and cons of the system that can be used for management methods are becoming clearer, and we know what can be done and what can be expected from various combinations of stand treatments.

As a quick review of some of the more recent changes regarding northern hardwood management, we recognize that simply applying a given silviculture system will not automatically produce the results that we want. We have to tailor stand treatments to the silvical characteristics of the species; one example is knowing the frequency of seed crops for the various species. Another example is providing seedbed conditions that give optimum germination temperatures. Optimum germination temperatures are not known for all our species. Recently we have found that northern red oak germinates at low temperatures just like sugar maple--under the snow. In our shelterwoods we also try to correlate shade levels that will hold back competition while stimulating seedling growth.

A number of factors that influence tree quality are: the role of forks and fork correction; how merchantable log height can be increased; controlling

---

[1]Retired Principal Silviculturist, North Central Forest Experiment Station, USDA Forest Service, Forestry Sciences Laboratory, Rhinelander, Wisconsin.

epicormic branching; crown closure; conditions that result in winter survival; and others, just to name a few.

Some of the major points we have learned about stand management that will assure us of having good quality stands can be summarized as follows:

1. Different species have different regeneration requirements.

2. The composition of the stand determines the proper stand density.

3. The individual tree, as well as the surrounding competition, tends to control its quality development.

4. Stand, as well as tree quality, must be developed through proper thinning schedules.

5. Species preference or composition determines whether even-aged or uneven-aged management is preferred. Either system can be used with sugar maple, but less tolerant species are mostly even-aged species; special shelterwood overstory and understory treatments are required to establish them.

6. Some successful regeneration methods reported for the Northeast and Canada do not work in the Lake States, and differences also exist within the Lake States region itself. For example, strip thinning on the Upper Peninsula Experimental Forest in Upper Michigan works well for regenerating yellow birch as long as there is a good birch seed supply, and advanced regeneration has been eliminated. Similar trials on the Argonne Experimental Forest failed miserably because of droughty conditions in July and August. We had birch regeneration, but we lost it to drought and competition with grass and raspberry plants.

The silviculture of established stands is simpler than the silviculture required to regenerate a new stand. Most of the young hardwood stands have developed following heavy cutting about 40 to 80 years ago. They tend to be even-aged, even-sized, and predominantly sugar maple. Occasionally some mixtures of white ash and basswood along with other species are present. The composition that we see today on the ground was established reproduction at the time the mature overstory trees were harvested, so what you see as advanced regeneration in the understory is normally what you get in the new stand, unless something is done to change the situation at regeneration time. We think that the best silviculture for these stands is to maintain proper thinning density. Initial thinning in second-growth stands will usually develop best under even-aged stocking levels. This was a big change in our thinking. The past recommendation was to leave a residual stand containing 85 square feet of basal area (Arbogast 1957). Currently, we recommend using the minimum stocking levels from figure 6 in the Northern Hardwoods Manager's Handbook (Tubbs 1977) for the first thinning in 5- to 9-inch dbh pole-size stands to bring them under even- or uneven-aged management. These cuts are heavy enough to get good responses and operable cuts. We have cut these pole-size stands down to 60 square feet of basal area by releasing crop trees and removing over half of the original stand basal area or cubic-foot volume, but the cut is primarily from below and leaves

a uniform stand of the best dominant and codominant trees. The next operable thinning will be made after about 20 years and to the average stocking level shown in the Northern Hardwoods Manager's Handbook (Tubbs 1977). Remember that the proper thinning density changes with average stand diameter. Therefore, in theory, no two stands are really ever marked the same because no two stands ever have the same average stand diameter.

If the stand has more basswood or hemlock, figures 7 and 8 of the Manager's Handbook recommend leaving higher residual basal areas for a given stand diameter. The reasoning for this is that the crown sizes of basswood and hemlock are much smaller for a given diameter than they are for sugar maple, white ash, and other wide-crown species. Thinning operations in higher residual density hemlock stands, overmature hemlock-yellow birch stands, and old-growth northern hardwoods stands should not remove more than 40 percent of the original stand basal area (Jensen 1943) or more than 40 percent of the gross volume (Gilbert and Jensen 1958). The reasons for these recommendations are that hemlock and yellow birch are very sensitive to sudden exposure following heavy cutting and that post-logging decadence in overmature stands is reduced by lighter thinnings in overmature stands. In thrifty hemlock-hardwood stands, light partial cuttings that remove less than one-third of the stand have been suggested for maintaining a productive stand (Eyre and Zillgitt 1953). Initial thinning treatments can often be heavier in smaller and younger stands than in larger and older stands, but for yellow birch it has been suggested that no more than 40 percent of the basal area be removed at one time (Godman and Marquis 1969).

One important overriding principle in thinning is the uniformity of stocking left in the residual stand. Uniformity enhances stem quality development as well as growth rate. Differences in stem quality are also related to site quality and species composition. In the Lake States, site quality for sugar maple ranges only from about site index 40 to 70 at age 50. On a given sugar maple site, site index for faster growing basswood and ash is usually 10 to 15 feet higher. The best stem quality occurs on site indices greater than 60. Stand quality in northern hardwoods is always enhanced when straight, long, clean-boled basswood and ash stems occur in mixtures with sugar maple, red maple, yellow birch, and other northern hardwood species.

Tree quality has to be continually developed due to forking in most northern hardwood species. All sugar maple trees in the overstory fork because of the frequent loss of the terminal bud. Maintaining proper density and crown closure next to forks are the most important in controlling forking. These factors correct the lower forks and result in greater merchantable log heights. Stem form and natural pruning are generally good in basswood and ash but relatively slow in developing in the maples and yellow birch. Proper crown size is the main factor that controls epicormic branching following thinning. In unthinned stands all crowns tend to be reduced, and their size must be gradually increased to inhibit epicormic sprouting. Crown release and shelterwood studies have shown that fully crowned dominant and codominant trees can be fully released without the risk of lowering bole quality.

When marking young stands, the best trees should be selected following crop tree guidelines. It is necessary to follow this practice in successive thinnings as quality must be constantly developed. After four thinnings, most

residual trees have been developed into good quality stems, but some poor quality trees are still present.

In early thinnings, all undesirable or defective trees cannot be removed in a single cut--again, proper density should be maintained even if it means leaving some of these poorer trees. One NEVER rule, especially in two-storied stands, is that residual basal area per acre should never be less than 50 square feet. This rule prevents creation of large openings that usually result in quality loss on bordering trees.

Thinning of sprout clumps should be done in the earliest cuts. Recent findings indicate that thinning to the single best low-union stem is preferred. This applies to all the sprouting species. Another thing to remember is, if stumps are cut low, only low sprouts will be produced.

Thinning frequency is extremely important in developing quality as well as maintaining growth and salvaging mortality. Our results show that growth in stands thinned to prescribed levels starts to drop between the tenth and fifteenth year. In other studies, irregular thinning intervals resulted in minimal quality improvement as compared to trees that were not selected as potential crop trees. In general, it appears that periodic thinnings give the best results when they are done at regular 10- to 12-year intervals.

It should be emphasized that by using even-aged guidelines for the initial and second thinnings, the growth and early quality development are improved and stand structure will begin to emerge, even though the stand is to be managed later as uneven-aged. The main reason is that proper density during the early thinnings is lower than the 85 square feet that was previously recommended for uneven-aged management (Arbogast 1957).

In conclusion, the best silviculture in thinning is to:

1. Consistently maintain the proper stand density--when in doubt, leave stocking slightly heavier than the guides to maximize quality development.

2. Select to leave individual trees, within the stocking level guide, on the basis of crown size and stem form.

3. NEVER cut below 50 square feet in stands 5 inches dbh and larger, even if it means leaving an undesirable tree.

4. Recognize stand variation when marking.

5. Thin sprout clumps early and heavily.

6. Maintain periodic thinnings at regular 10- to 12-year intervals.

7. Use even-aged density levels for the first two thinnings even if the stand will be managed uneven-aged later.

LITERATURE CITED

Arbogast, Carl, Jr. Marking guides for northern hardwoods under the selection system. Sta. Pap. 56. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station (now North Central Forest Experiment Station); 1957. 20 p.

Eyre, F. H.; Zillgitt, W. M. Partial cuttings in northern hardwoods of the Lake States. Tech. Bull. 1076. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lakes States Forest Experiment Station (now North Central Forest Experiment Station); 1953. 124 p.

Gilbert, Adrian M.; Jensen, Victor S. A management guide for northern hardwoods in New England. Sta. Pap. 112. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1958. 22 p.

Godman, Richard M.; Marquis, David A. Thinning and pruning in young birch stands. In: Birch symposium proceedings. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1969: 119-127.

Jenson, Victor S. Suggestions for the management of northern hardwood stands in the Northeast. J. of For. 41: 180-185; 1943.

Tubbs, C. H. Manager's handbook for northern hardwoods in the North Central States. Gen. Tech. Rep. NC-39. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977. 29 p.

HARVESTING HARDWOOD THINNINGS

John A. Sturos and Michael A. Thompson[1]

Abstract.--Five case studies of thinning hardwoods were done on gentle and difficult terrain (slopes up to 50 percent) using both fully mechanized and semimechanized systems. Tracked and rubber-tired feller/bunchers were evaluated in conducting several thinning patterns. Grapple skidders, forwarders, and a combination of a radio-controlled winch and forwarder were used to transport whole trees, tree-length logs, or shortwood to roadside. Slashers processed the tree-length material into pulpwood and fuelwood; whole-tree chippers produced fiber and fuel chips. Information is presented on the harvesting operations, equipment costs, and productivity. Typical yields ranged from 50 to 75 tons/acre of whole-tree chips.

INTRODUCTION

The growth in population and associated economic and industrial activity in the United States has caused the projected demand for hardwoods to increase from 3.0 billion cubic feet in 1976 to 9.6 billion cubic feet in 2030 (Hair 1980). Although the U.S. grows more hardwoods than ever before, use has been limited because of timber quality and availability problems. Most of our pole-size northern hardwood forests are in deplorable condition and in dire need of thinning--stands are characterized by far too many small and low-quality trees per acre. The result is overutilization of high-quality, preferred hardwoods and underutilization of small and low-quality hardwoods.

The magnitude of the problem is realized when one considers that there are an estimated 32 million acres of northern hardwood forests in the eastern United States, a large portion of which are occupied by overstocked poletimber stands. To meet the projected demand for hardwoods, acceptable methods of thinning must evolve to improve the growth and quality of the residual trees. Only by removing the smaller, poorly formed trees and undesirable species will the growth of higher quality, larger trees and preferred species be encouraged.

Little documentation is available in the Lake States on the cost and productivity of logging equipment to thin hardwoods. Loggers well realize that a machine may work profitably in one stand but not in another. Information on cost and productivity of logging equipment and systems over a wide range of conditions is essential to develop profitable and silviculturally attractive solutions to mechanical thinning. Economic factors such as high interest rates, sharp increases in fuel cost and other operating costs, along with the marketing

---

[1]Principal Mechanical Engineer and General Research Engineer, North Central Forest Experiment Station, USDA Forest Service, Houghton, Michigan.

problem for small-size forest products, emphasize the need to search for ways to make logging operations more cost-effective and productive. Damage to the site and residual stand must also be considered. We need to determine the relative numbers and kinds of wounds generated by mechanized thinning operations and the circumstances under which they occur. From this information, guidelines can be developed for timber sale planning and marking that will minimize the impact of harvesting equipment on residual stocking.

To advance the state of the art of thinning hardwoods, we need to conduct a number of case studies under a variety of conditions and approaches to thinning. This paper summarizes five case studies in northern Michigan and Wisconsin from 1974 to 1982.

CASE I - 1974 MECHANIZED THINNING

This study was initiated to determine the cost and productivity of a mechanized system to thin pole-size northern hardwoods under four harvesting strategies (Biltonen et al. 1976, Arola and Miyata 1981). The study area was a 50-acre block divided into 5-acre compartments. The soil was sandy loam, and the topography was essentially flat. The stand contained 13 cords of hardwood pulpwood per acre and about 2,700 board feet of sawtimber per acre. The basal area was about 100 square feet per acre in trees 6 inches diameter at breast height (dbh) and larger. The stand contained 350 trees per acre (all sizes) and had an average dbh of 6 inches with a dbh range of 2 to 28 inches. Red maple was the dominant species (55 percent), followed by sugar maple (25 percent), and other species (20 percent).

Equipment and Manpower

The mechanized system used consisted of a John Deere[2] 544 loader fitted with an accumulating Rome grapple shear, a Clark 667 grapple skidder, a Trelan D-60 whole-tree chipper, a loader to feed the chipper, a maintenance truck, a fuel truck, a chain saw, two truck/tractor units, four chip vans, and a landing tractor. Seven people--four equipment operators, a supervisor, and two truck drivers--were required for the operation.

Productivity and Cost

The total production of the system was 1,829 tons over 106 scheduled hours (SH) or an average of 17 tons per SH. The average productivity and the average cost of extracting this material (excluding stumpage, road building, and miscellaneous overhead costs) are given by equipment type in table 1. The overall average for all thinning treatments was $11.34 per green ton. (All dollar amounts in this paper are 1983 dollars.) Hauling was the major component of this cost (37 percent).

---

[2]The use of trade, firm, or corporation names is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others which may be suitable.

Table 1.--Average productivity and cost per ton[a] by equipment type - Case I.

Equipment type	Stems/PH[b]	Stems/SH[b]	Tons/PH	Tons/SH	Cost[c] per ton (dollars)	Percent of total cost
John Deere 544 feller/buncher	133.3	88.8	27.2	17.5	2.00	18
Clark 667 grapple skidder	135.0	72.5	31.3	16.8	2.42	21
Trelan D-60 whole-tree chipper	172.3	82.2	34.8	17.2	1.97	17
Two road tractors					3.05	27
Four chip vans					0.38	3
Landing tractor					0.75	7
Maintenance truck					0.70	6
Fuel truck					0.07	1
TOTAL					11.34	100

[a]Average of all thinning treatments.
[b]PH = productive hour; SH = scheduled hour.
[c]Based on a labor cost of $10/SH.

CASE II - 1978 STRIP-WITH-SELECTION THINNING

The objective of this study was to further evaluate the economic and silvicultural benefits of using a mechanized harvesting system to thin northern hardwood pole-size stands under the strip-with-selection system (Johnson et al. 1979). This thinning system was concluded to be the most favorable in an earlier study (Biltonen et al. 1976). The study area consisted primarily of sugar maple (73 percent) and American elm (22 percent). The initial stocking was 254 trees per acre, resulting in 116 square feet of basal area per acre.

Equipment and Manpower

The harvesting system used in the operation consisted of a Drott 40LC feller/buncher, a John Deere 740 grapple skidder, a Morbark 22-inch whole-tree chipper, five truck/tractor units, five chip vans, a maintenance truck, and a fuel truck. The crew consisted of three equipment operators and five truck drivers.

The Harvest

The scope of the study was limited to the production of 1,000 tons of green chips from the thinned area for a contract with a local utility company for a trial whole-tree chip burning experiment. This limited the total area thinned to 13 acres that was harvested using the strip-selection thinning pattern. The selectively thinned area between the strips was thinned to a basal area of about 68 square feet per acre. The average yield was 78.1 green tons per acre--much higher than the 46.8 green tons per acre obtained in the 1974 thinning study (Case I). The higher yield was due to the fact that the timber sale required the removal of all elm trees due to Dutch elm disease.

Productivity and Cost

The total production of 1,000 green tons of whole-tree chips by the mechanized whole-tree harvesting system was accomplished in a period of 33 SH. This gave a productive rate of 30.3 tons per SH. The Drott 40LC feller/buncher averaged 94.0 stems per productive hour (PH) or 71.7 stems per SH. The potential felling and bunching productivity was not met due to a malfunctioning accumulator arm on the feller/buncher; therefore, the feller/buncher averaged only 1.3 stems per cycle.

Skidding productivity was increased by keeping skid distances short. The average skid distance was 321 feet in the woods and 72 feet on the access road that permitted one skidder to feed the chipper. The skidder averaged 11.4 stems per cycle or 4.2 tons per cycle. With an average cycle time of 5.1 minutes, the productivity of the skidder was 49.4 tons per PH.

The chipping rate was 41.5 green tons per PH. Each van load required an average of 6.0 skidder loads or 68.6 stems. Chipper productivity was hampered by limited chip van availability. Rain created poor road conditions which interfered with trucking efficiency.

The machine rates and estimated costs for harvesting this material (excluding stumpage, road building, and miscellaneous overhead costs) are given by machine in table 2. The total cost per green ton was $11.08 of which hauling represented 40 percent.

Table 2.--Scheduled hours (SH), productive hours (PH), machine rates, and cost per ton by equipment type - Case II.

Equipment type	Observed Time		Machine Rate		Cost[a] per ton (dollars)	Percent of total cost
	SH	PH	Fixed ($/SH)	Operating ($/PH)		
Drott 40-LC feller/buncher	39	29.10	23.37	18.80	1.85	17
John Deere 740A grapple skidder	33	20.20	25.71	27.50	1.73	16
Morbark 22-inch Chiparvestor	33	24.10	32.19	39.20	2.34	21
Five road tractors	165	2,080 mi[b]	8.56	0.49/mi	4.08	37
Five chip vans	165	2,080 mi[b]	1.25	0.05/mi	0.31	3
Maintenance truck	33	-	1.69	0.34/SH	0.40	3
Fuel truck	33	-	0.77	0.43/SH	0.37	3
TOTAL					11.08	100

[a]Based on a total system production of 1,000 tons and labor cost of $10/SH.
[b]Total distance traveled by trucks and vans was 2,080 miles (52 miles round trip, 25 tons/van).

CASE III - 1981 MECHANICAL SELECTIVE THINNING

The objective of this study was to determine the productivity and cost of mechanical selective thinning using three different feller/bunchers followed by grapple skidding and slashing. The study area was 21 acres of pole-size mixed hardwoods on the Watersmeet Ranger District of the Ottawa National Forest, Section 35, T45N, R38W. The soil was a moderately well drained sandy loam, and the topography ranged from level to 10-percent slopes.

The area was divided into three blocks ranging from 6.5 to 7.8 acres. The timber was mixed hardwoods with trees up to 24-inch dbh. Point sample cruises of each block resulted in the following species compositions and basal areas before thinning:

	Block A	Block B	Block C
	(percent)		
Sugar maple	67	62	81
Aspen	5	1	-
Elm	5	16	8
Red maple	13	2	1
Yellow birch	1	7	-
Basswood	2	6	6
Miscellaneous	7	6	4
TOTAL	100	100	100
Basal area (sq. ft./acre)	124	139	148

Operations and Equipment

All hardwoods, except aspen, had been marked for a selective thinning before cutting. All aspen, balsam fir, spruce, hemlock, and cedar were to be removed even though they were not marked. Before cutting, the stand was marked to yield basal areas of "cut" and "leave" trees within each block according to the following tabulation.

	Block A	Block B	Block C
	(sq. ft. per acre)		
"Cut" trees	37.5	43.5	35.4
"Leave" trees	86.6	95.6	113.1
Total Basal Area	124.1	139.1	148.5

Cut trees included both sawtimber (over 11 inches dbh) and pole-size trees (5 to 11 inches dbh). Pole-size trees were cut by the three feller/bunchers; sawtimber was cut by chain saw. In Block A, a Melroe Bobcat Model 1075 feller/buncher with a 16-inch shear was used. In Block B, the poletimber was felled and bunched with a Timbco Hydro-Buncher Model 2518 with an 18-inch shear mounted on a knuckle boom. In Block C, an Omark Hydro-Ax Model 311 feller/buncher with a 16-inch shear was used.

All pole trees were stacked on the ground in skidder-size bunches. They were then topped at a 5-inch diameter, and the merchantable boles were limbed by chain saw. The tree-length material was then skidded by a Garret Tree Farmer C5D grapple skidder to a landing for slashing into 100-inch pulpwood bolts by a truck-mounted Hood pulpwood slasher.

Sawtimber trees were felled and bucked into sawlogs and pulp bolts to a minimum diameter of 5 inches by a chain saw operator at the stump. Following bucking, the logs and bolts were either skidded with a John Deere 440 cable skidder or the grapple skidder to a roadside landing. Based on the basal area of only the cut trees in each block, the average tree diameters at breast height for blocks A, B, and C were 10.6, 10.4, and 9.3 inches, respectively.

The slasher wood from the small trees and the pulpwood bolts from the tops of the sawtimber trees were hauled 12 miles to a pulpwood yard where each load was weighed and the net weight obtained. Each truck load had been measured for average height and length and the number of stacked cords computed. Sawtimber bolts (100 inches long) were loaded and trucked 24 miles to a sawmill. For convenience of reporting, we converted sawlog board foot values to cords at the rate of 2 cords per 1,000 board feet, although the standard unit of measurement for sawlog bolts is board-foot volume. Time study and productivity data were taken on each phase of the harvest and transport operation.

Results

Volumes removed from each block were summarized into three product categories: sawtimber bolts; pulpwood from the tops of sawtimber trees; and pulpwood from poletimber (table 3).

Table 3.--Volumes removed from the three harvested blocks - Case III.

	Block A	Block B	Block C	Total
Sawtimber (board feet)	4,410	7,900	9,540	21,850
Pulpwood from topwood (cords)	9.47	19.68	20.64	49.79
Pulpwood from poletimber (cords)	13.05	17.53	31.55	62.13

The amount of material harvested in each block differed considerably. In Block A, 4,410 board feet of sawtimber and 22 cords of pulpwood were harvested; in Block C, 9,540 board feet of sawtimber and 52 cords of pulpwood were harvested. These differences stem from the variations in the blocks in stand composition, basal area, and other conditions. Block C obviously contained a much better stand of timber; therefore it is not appropriate to compare the productivity and harvesting costs of the three feller/bunchers.

Because the logger's cost data were not available, independent cost analyses were made that required certain assumptions. The economic life assumed for

the various pieces of equipment ranged from 1 year for the chain saws to 3 years for the skidders to 5 years for the feller/bunchers. We assumed all the equipment were scheduled to work 2,000 hours per year. The percent utilization assumed for the equipment ranged from 50 percent for the chain saws to 65 percent for the feller/bunchers to 67 percent for the skidders. The PH per year were obtained by multiplying the SH (2,000) by the percent utilization (table 4). The fixed and operating machine rates are also listed in table 4.

Table 4.--Equipment hourly machine rates - Case III.

Equipment	PH/year	Machine rates			
		Fixed		Operating	
		($/PH)			
Melroe Bobcat	1,300	14.09		9.00	
Timbco Hydro-Buncher	1,300	33.02		16.64	
Hydro-Ax feller/buncher	1,300	16.87		10.40	
Garret Tree Farmer grapple skidder	1,340	21.69		14.29	
John Deere cable skidder	1,340	14.22		9.73	
Pioneer chain saw (Model 440C)	1,000	0.63		1.75	
Sachs-Dolmar chain saw (Model 114)	1,000	0.43		1.59	
Stihl chain saw (Model AV Super)	1,000	0.53		1.68	
International truck	1,200	10.48	(.31/mi)	17.64	(.53/mi)
Prentice loader	1,200	4.78		9.84	
Slasher and truck	1,300	11.16		8.32	

The productivity and cost of producing pulpwood from the poletimber in the three blocks by the mechanized thinning system are of primary interest (tables 5 and 6). The productivity of the three feller/bunchers ranged from 3.4 to 4.7 cords per PH that resulted in a felling and bunching cost range of $7.76 to $15.52 per cord. This difference is most likely due to a difference in stand conditions between the three blocks. The skidding productivity and costs were quite constant over the three cutting blocks, ranging from 3.1 to 3.2 cords per PH and $12.68 to $14.38 per cord. The slashing productivity and costs ranged from 7.7 to 9.1 cords per PH, giving a cost range of $4.61 to $5.61 per cord. The overall cost to produce slashed wood decked at roadside (excluding trucking costs) ranged from $27.18 to $37.17 per cord. By including the costs to haul the slashed wood 12 miles to a pulpwood yard, the total cost ranged from $31.47 to $41.52. According to data in a recent Timber Mart-North, the average price at the mill for hardwood pulpwood is $41.00 per cord, and the stumpage for mixed hardwoods is $4.00 per cord. This indicates that producing pulpwood from hardwood poletimber thinnings is a marginal operation.

The existence of sawtimber (trees larger than 11 inches dbh) in the stand obviously improves the economics. In this case study, the costs to harvest sawlogs and pulpwood from sawtimber trees ranged from $16.30 to $24.52 per cord (table 7). Assuming the same selling and stumpage values (even though the sawlogs would average $10.00 to $20.00 per cord more), approximately $15.00 to $21.00 per cord were realized from which overhead and other related costs must be deducted.

Table 5.--Productivity of each phase of the harvesting operation on the three blocks based on scheduled and productive hours - Case III.

Machine	Cords/SH	Cords/PH
Block A		
Slasher wood:		
Melroe Bobcat	2.81	3.36
Chain saw top and limb	4.90	7.59
Grapple skidder	2.43	3.25
Slasher	3.25	9.06
Sawlogs and topwood:		
Chain saw fell and buck	2.04	3.40
Cable skidder	1.86	2.53
Block B		
Slasher wood:		
Timbco	3.28	3.79
Chain saw top and limb	3.88	8.59
Skidders	2.59	3.20
Slasher	2.57	7.83
Sawlogs and topwood:		
Chain saw fell and buck	2.08	3.51
Skidders	2.08	2.65
Block C		
Slasher wood:		
Hydro-Ax	4.06	4.71
Chain saw top and limb	6.78	14.36
Skidders	2.42	3.14
Slasher	4.86	7.73
Sawlogs and topwood:		
Chain saw fell and buck	3.34	5.56
Skidders	3.29	4.39

Table 6.--Cost analyses of producing pulpwood from the poletimber for the three blocks - Case III.

Machine	Operation	SH	PH	Total cost (dollars)	Cost/cord (dollars/ cord)
	Block A (6.46 acres, 13.05 cords)				
Melroe Bobcat	Fell and bunch	4.64	3.88	126.39	9.68
Chain saw	Top and limb	2.66	1.72	24.91	1.91
Garret Tree Farmer grapple skidder	Skid	5.38	4.02	187.68	14.38
Slasher	Slash	4.01	1.44	60.13	4.61
Truck	Haul			57.26	4.39
TOTAL					34.97
	Block B (6.84 acres, 17.53 cords)				
Timbco	Fell and bunch	5.34	4.62	272.15	15.52
Chain saw	Top and limb	4.52	2.04	40.57	2.31
Garret Tree Farmer grapple skidder	Skid	5.85	4.59	211.95	12.09
John Deere cable skidder	Skid	0.92	0.89	28.68	1.64
Slasher	Slash	6.83	2.24	98.28	5.61
Truck	Haul			76.32	4.35
TOTAL					41.52
	Block C (7.76 acres, 31.55 cords)				
Hydro-Ax	Fell and bunch	7.77	6.70	244.87	7.76
Chain saw	Top and limb	4.65	2.20	41.85	1.33
Garret Tree Farmer grapple skidder	Skid	6.47	4.65	219.07	6.94
John Deere cable skidder	Skid	6.59	5.36	181.09	5.74
Slasher	Slash	6.49	4.08	170.80	5.41
Truck	Haul			135.46	4.29
TOTAL					31.47

Table 7.--Cost analyses of producing sawlogs and pulpwood from tops of sawtimber trees - Case III.

Machine	Operation	SH	PH	Total cost (dollars)	Cost/cord (dollars/ cord)
	Block A (6.46 acres, 18.29 cords)				
Chain saw	Fell and buck	8.96	5.38	96.77	5.29
John Deere cable skidder	Skid	9.84	7.24	252.12	13.78
Truck	Haul			99.76	5.45
TOTAL					24.52
	Block B (6.84 acres, 35.48 cords)				
Chain saw	Fell and buck	17.07	10.11	160.62	4.53
John Deere cable skidder	Skid	9.80	8.09	272.16	7.67
Clark cable skidder	Skid	7.22	5.30	198.53	5.60
Truck	Haul			179.46	5.06
TOTAL					22.86
	Block C (7.76 acres, 39.72 cords)				
Chain saw	Fell and buck	11.89	7.14	112.11	2.82
John Deere cable skidder	Skid	10.93	8.00	279.04	7.03
Clark cable skidder	Skid	1.14	1.05	37.01	0.93
Truck	Haul			219.34	5.52
TOTAL					16.30

CASE IV - 1982 RED OAK THINNING

The objective of this case study was to evaluate three levels of mechanization for thinning red oak poletimber by the strip-selection method. The study area was a portion of a 100-acre red oak poletimber stand owned and administered by Washburn County, Wisconsin, and managed by the Wisconsin Department of Natural Resources. The gently rolling tract is located about 5 miles southeast of Spooner, Wisconsin, in Sections 11 and 14 of T38N, R12W. The stand consists of a mixture of northern red oak pole and small sawtimber trees plus some aspen pulpwood and sawlog trees with a merchantable basal area of 150 square feet per acre. The 100-acre tract was marked for a strip-with-selection thinning by Wisconsin DNR personnel. The goal was to reduce the basal area of the residual stand to about 80 square feet per acre while producing firewood and aspen pulpwood.

Operations and Equipment

Three separate plots were designated within the stand to obtain data on the cost and productivity of thinning hardwoods using three different harvesting techniques ranging from a labor-intensive operation to a mechanized system. The equipment and procedures used in each operation are as follows:

Mechanized system:

- Timberjack Timbco Hydro-Buncher Model 2518 felled and bunched the trees operating from marked strips (fig. 1).
- Trees were manually topped and delimbed.
- Tree-length logs were skidded to the landing with a John Deere 640 grapple skidder (fig. 2).
- Self-propelled Hood slasher produced firewood and aspen pulpwood (fig. 3).

Semimechanized system:

- Trees were manually felled, delimbed, and topped.
- Tree-length logs were winched to marked strips by the Radio Horse, a radio-controlled winch, where the winch operator bucked them into shortwood (fig. 4).
- Shortwood was forwarded to the landing with a Gafner Iron Mule Model 4501F (fig. 5).

Labor-intensive system:

- Trees were manually felled, delimbed, bucked, and piled at the stump with a two-man team (sawyer and helper).
- Shortwood was forwarded to the landing with a Gafner Iron Mule Model 4501F.

Results

General information on the three portions of the stand harvested by the three different logging operations is presented in table 8. Although all three thinnings took place on similar plots, there was some difference in the amount of wood removed and the basal area remaining.

Table 8.--General data on the three plots harvested by the different systems - Case IV.

	Labor-intensive	Semi-mechanized	Mechanized
Area (acres)	1.75	2.80	5.8
Plot length (feet)	380	700	1,000
Plot width (feet)	250	200	750
Basal area after thinning (sq. ft./acre) (trees >5 inches)	65	78	68
Average diameter (inches)			
Before thinning	6	6	6
Trees removed	6	8	7
Products removed (cords)			
Hardwood	24.8	46.8	86.5
Aspen	12.0	4.3	21.2
Cords/acre	21.0	18.2	18.6

The mechanized harvesting system consisted of four operations. The trees were felled and bunched with a feller/buncher; they were then delimbed and topped manually with a chain saw. The bunches of tree-length stems were then skidded to the landing by a grapple skidder on the strips made by the feller/buncher, and finally the tree-length logs were mechanically bucked by a slasher that sorted and decked the material into firewood and aspen pulpwood.

Following a strip-selection felling pattern, the Timbco feller/buncher averaged 130 trees per PH that resulted in 12.7 cords per PH. The full productivity of the feller/buncher was not achieved because the accumulator was not operational. Based on a fixed machine cost of $23.30 per SH, an operating machine cost of $19.81 per PH, a labor cost of $10 per SH, and a production of 107.7 cords, the felling phase was estimated to cost $4.30 per cord (table 9).

The productivity of the chain saw operator, including a helper, in delimbing and topping the bunched trees was 118 trees per PH or 12.8 cords per PH. The average time needed to top and delimb each stem was 0.44 minutes. Some stems were missed due to the bunched trees, but this did not seem to affect the subsequent skidding and slashing operations. The estimated cost of this phase of the operation was $1.98 per cord (table 9).

Grapple skidding with the John Deere 640 averaged 87 trees per PH or 8.7 cords per PH. The average skid distance was 980 feet, round trip. The skidder

averaged 8.4 trips per hour (a little over 7 minutes per trip), hauling a payload of about nine trees or 0.9 cords per load. He averaged a travel speed of 340 feet per minute (4 mph). The feller had collected an average of 5.4 trees into each bunch it made; the skidder combined these bunches into payloads of about nine trees. The estimated cost of skidding was $6.14 per cord (table 9).

Table 9.--Machine rate and cost for each harvesting phase of the mechanized system - Case IV.

Equipment type	Observed time		Machine rate		Total labor cost[a]	Total cost[b]	Cost per cord[c]	Percent of total cost
	SH	PH	Fixed ($/SH)	Operating ($/PH)	($)	($)	($/cord	
Timbco 2518 feller/ buncher	8.88	8.45	23.30	19.81	88.80	463.09	4.30	17
Chain saw for delimbing and topping	9.80	8.39	0.70[d]	1.29[d]	196.00[e]	213.68	1.98	8
John Deere 640 grapple skidder	14.22	12.19	18.74	20.74	142.20	661.50	6.14	25
Hood slasher	12.03	10.69	14.95	13.01	120.30	439.23	4.08	17
SUBTOTAL					547.30	1,777.50	16.50	
Shortwood truck	28.00	700 mi[f]	8.12	0.53/mi	280.00	878.36	8.16	33
TOTAL					827.30	2,655.86	24.66	100

[a]Labor cost is $10/SH.
[b]Total cost = labor cost + fixed cost + operating cost.
Total cost = labor rate x SH + fixed machine rate x SH + operating rate x PH = $10/SH x 8.88 SH + $23.30/SH x 8.88 SH + $19.81/SH x 8.45 PH = $463.09.
[c]Based on total system production of 107.7 cords from 5.8 acres.
[d]Two chain saws incurred fixed costs, and one incurred operating costs.
[e]This was a two-man operation with one sawyer and one helper who piled and removed slash. Therefore, total labor cost is $196.00 ($10/SH x 9.80 SH x 2).
[f]Total distance traveled was 700 miles (50-mile round trip with 8 cords per truckload).

Slashing was the final phase of the mechanized system with a productivity of 88 trees per PH or 10.1 cords per hour. The slasher had a self-loading grapple that picked up 3.4 trees per grapple load. During each cycle (load, slash, and unload), 6.5 trees were processed, producing 30.7 sticks. A total of 4,323 sticks was produced at 0.17 minutes per stick. This amounts to about 4.5 sticks per tree and a process time of 0.7 minutes per tree. The estimated cost of slashing was $4.08 per cord.

The trucking cost was estimated to be $8.16 per cord (table 9). It is based on a 25-mile haul (50-mile round trip) to a local firewood market. The total cost excluding stumpage and overhead was $24.66 per cord, of which trucking represented 33 percent and skidding 25 percent.

The semimechanized system was a three-man operation. One man did the felling, delimbing, and topping; the second man set up the radio-controlled winch, winched the tree-length logs to the marked strip road, bucked the logs into 100-inch sticks, and did a minor amount of piling; and the third man operated the forwarder.

For the study, 2.8 acres were thinned using this logging system. The area was long and narrow, about 200 feet by 700 feet, with a skid road down the center of the plot. Felling and winching were conducted as a "hot" operation and began on the outer edges and progressed toward the skid road. This procedure minimized winching through slash. The sawyer felled, delimbed, and topped 16 trees per PH or 2.0 cords per PH. Based on a total production of 51.1 cords and a labor cost of $10.00 per SH, the estimated cost of felling, delimbing, and topping was $8.65 per cord (table 10).

Table 10.--Machine rate and cost for each harvesting phase of the semimechanized system - Case IV.

Equipment type	Observed time		Machine rate		Total labor cost[b] ($)	Total cost ($)	Cost per cord[c] ($/cord)	Percent of total cost
	SH	PH	Fixed ($/SH)	Operating ($/PH)				
Chain saw	38.19	25.79	0.70[a]	1.29[a]	381.90	441.90	8.65	26
Radio Horse winch	37.87	25.72	1.54	1.75	378.70	482.03	9.43	28
Gafner 4501F forwarder	13.83	13.06	7.82	8.19	138.30	353.41	6.92	21
SUBTOTAL					898.90	1,277.34	25.00	
Shortwood truck[d]						416.98	8.16	25
TOTAL						1,694.32	33.16	100

[a]Two chain saws incurred fixed costs; one incurred operating costs.
[b]Labor cost is $10/SH.
[c]Based on total system production of 51.1 cords from 2.8 acres.
[d]The same trucking costs are assumed as in the mechanized system - Table 9.

The winch operator also averaged 2.0 cords per PH that included not only winching, but also bucking and a minor amount of piling. Seven winch locations were used, and, on the average, the snatch block was set up in three different

arrangements at each location. It took 19 minutes to relocate the winch and about 4 minutes to set up the snatch block. Some trees were winched as far as 150 feet; the average distance was about 60 feet. The average winch rate was about 150 feet per minute, and the average distance between piles of winched logs was 35 feet. Based on a fixed machine cost of $1.54 per SH for the winch, an operating cost of $1.75 per PH, a labor cost of $10.00 per SH, and a total production of 51.1 cords, the estimated cost of this harvesting phase was $9.43 per cord.

The forwarder averaged 3.9 cords per PH that amounted to 143 sticks per PH. It made 22 cycles, with an average trip distance of about 1,400 feet. The average load consisted of 2.3 cords or 85 sticks. Based on a fixed machine cost of $7.82 per SH, an operating cost of $8.19 per PH, and a labor cost of $10.00 per SH, the estimated cost of forwarding was $6.92 per cord that gives a combined cost to roadside of $25.00. Assuming the same trucking costs as in the mechanized system ($8.16/cord), the total cost was $33.16 per cord. The percent of total cost ranged from 21 percent for forwarding to 28 percent for winching, bucking, and piling.

In the labor-intensive system, the felling, delimbing, bucking, and piling were done by a two-man crew. The sawyer did the felling, delimbing, and bucking, while the second person acted as a helper by measuring 100-inch sticks, piling, clearing slash, and other minor duties. They averaged 13.5 trees per PH that produced 51.1 sticks or 2.2 cords per PH. Based on a total production of 36.8 cords and a labor cost of $10.00 per SH, the estimated cost of felling, delimbing, bucking, and piling shortwood at the stump was $11.84 per cord (table 11).

The Gafner 4501F forwarder averaged 4.3 cords per PH or 204 sticks per PH. The average round-trip distance was 720 feet for the 17 loads produced from 1.8 acres. The estimated cost of forwarding was $6.24 per cord that gives a combined cost to roadside of $18.08 per cord. Assuming the same trucking costs as in the mechanized system, the total cost was $26.24 per cord of which felling, delimbing, and bucking represented 45 percent and trucking 31 percent.

Of interest is a comparison of grapple skidding of tree-length logs in the mechanized operation with forwarding of shortwood in the semimechanized and labor-intensive systems. Although the grapple skidder had less than half the payload (about 0.9 cords/load) of the forwarder (about 2.3 cords/load), its higher travel speed and faster loading and unloading gave it twice the overall productivity of the forwarder. This higher productivity of the skidder did not significantly lower the cost of getting the material to the landing ($6.14 per cord for the skidder versus $6.24 to $6.92 per cord for the forwarder). The higher machine cost of the grapple skidder compared to the forwarder offsets the increased productivity, but this also suggests that a smaller grapple skidder should have been used.

In comparing the cost of producing roundwood at roadside and the delivered cost from the three systems, the mechanized operation gave the lowest cost with the labor-intensive system being a close second. The potential profit from each of these operations was determined by using the local firewood market. Stumpage was assumed to be $3.00 per cord, and overhead costs were assumed to be 15 percent for the mechanized operation and 5 percent for the other two systems. Using $38.00 per cord as the local value of firewood, the potential profit before taxes

was $6.64, $7.45, and $0.18 per cord for the mechanized, labor-intensive, and semimechanized systems, respectively.

Table 11.--Machine rate and cost for each harvesting phase of the labor-intensive system - Case IV.

Equipment type	Observed time		Machine rate		Total labor cost[b]	Total cost	Cost per cord[d]	Percent of total cost
	SH	PH	Fixed ($/SH)	Operating ($/PH)	($)	($)	($/cord)	
Chain saw	19.98	17.11	0.70[a]	1.29[a]	399.60[c]	435.66	11.84	45
Gafner 4501F forwarder	8.94	8.57	7.82	8.19	89.40	229.50	6.24	24
SUBTOTAL					489.00	665.16	18.08	
Shortwood truck[e]						300.29	8.16	31
TOTAL						965.45	26.24	100

[a]Two chain saws incurred fixed costs; one incurred operating costs.
[b]Labor cost is $10/SH.
[c]This was a two-man operation with one sawyer and one helper who piled shortwood, removed slash, etc.
[d]Based on total system production of 36.8 cords from 1.8 acres.
[e]The same trucking costs are assumed as in the mechanized system - Table 9.

The delivered cost per cord is the most important factor in any logging operation--especially so in marginal hardwood thinning operations. But there are other factors that should be considered, two of which are total capital investment and logging damage to the site and residual stand.

In this case study, the total capital investment of the mechanized harvesting system excluding trucking was $342,200; the semimechanized and labor-intensive systems required only $61,200 and $51,200 of investment, respectively. Only a limited number of loggers in the Lake States are able or willing to invest close to a half-million dollars in logging equipment. Therefore both mechanized and more labor-intensive systems should be considered in planning future thinnings.

Of the three systems studied in this case study, the least amount of damage to the residual stand was done by the semimechanized operation. By prebunching with the winch, the travel of the forwarder was limited to the strip road in the center of the plot.

It is interesting to note the difference in the productivity and cost of the mechanized harvesting in Case III (table 6) and Case IV (table 9). Felling

and bunching productivity in Case IV was about three to four times more than in Case III; skidding productivity in Case IV was about two to three times greater than in Case III. There are at least two reasons for this difference. One is that Case III was a pure selection thinning compared to the strip-selection thinning in Case IV. The strip-selection layout is obviously better suited to a mechanized operation by providing a well-marked route for the feller/buncher and skidder to follow. The second reason for this variation is the substantial difference in the amount of pulpwood produced per acre. In Case IV it amounted to 18.6 cords per acre compared to 2.0 to 4.1 cords per acre in Case III.

CASE V - 1982 STEEP SLOPE THINNING

The objective of this case study was to evaluate a commercially available feller/buncher in a strip-selection thinning on steep slopes. The study site consisted of 6.5 acres of northern hardwood poletimber located on the Munising Ranger District of the Hiawatha National Forest. The slope ranged from zero to 50 percent, and the average tree was 8.2 inches dbh. The stand consisted of 362 trees per acre (larger than 1.5 inches dbh) having a basal area of 132 square feet per acre, or 246 trees per acre (larger than 5.5 inches dbh) having a basal area of 122 square feet per acre. The major species were 52 percent sugar maple, 28 percent beech, and 20 percent red maple, black cherry, and yellow birch combined.

Strips were laid out every 45 feet up and down the slopes. A Timberjack Timbco Hydro-Buncher was selected as the feller/buncher most likely to successfully traverse the steep slopes. The Timbco felled and bunched the trees in the strips and selectively felled the marked trees between the strips, bunching them in the strips.

The average dbh of the 841 felled trees was 6.7 inches, the average number of trees per bunch was 5.6, and the Timbco productivity was 91 trees per PH. The cost of felling and bunching was estimated at $3.00 per ton or $7.50 per cord (assuming 2.5 tons equals 1 cord). The breakdown of the feller/buncher productive time is as follows: 18 percent for travel; 38 percent for shearing; and 44 percent for swinging and bunching.

SUMMARY

Northern hardwoods must be thinned to produce high value veneer and sawtimber in the long term. The major barriers have been the lack of markets for low-grade hardwoods and the low profit margin realized by the loggers in conducting the thinnings. New regional pulpwood and firewood markets have opened up for the Upper Peninsula of Michigan and northern Wisconsin. One of the most significant is the new Champion International pulp mill at Quinnessec, Michigan, which has increased interest in the equipment, methods, productivity, and cost of thinning northern hardwood poletimber.

Productivity and costs of five hardwood thinning case studies are presented in this paper. They range from fully mechanized whole-tree chipping operations to labor-intensive shortwood systems. Factors that affect productivity were not constant from one logging method or site to another. These factors include, but are not limited to, stand characteristics, plot size, skidding or forwarding distances, operator ability, weather, and unavoidable delays. Therefore the results presented are for specific case studies and do not imply long-term averages.

LITERATURE CITED

Arola, Rodger A.; Miyata, Edwin S. Harvesting wood for energy. Res. Pap. NC-200. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981. 25 p.

Biltonen, Frank E.; Hillstrom, William A.; Steinhilb, Helmuth M.; Godman, Richard M. Mechanized thinning of northern hardwood pole stands--methods and economics. Res. Pap. NC-137. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1976. 17 p.

Hair, Dwight. Timber situation in the United States--1952-2030. J. of For. 78(11): 683-686; 1980.

Johnson, James A.; Hillstrom, William A.; Miyata, Edwin S.; Shetron, Stephen G. Strip selection method of mechanized thinning in northern hardwood pole size stands. Res. Note No. 27. Houghton, MI: Michigan Technological University, Ford Forestry Center; 1979. 13 p.



Figure 1.--Timberjack Timbco Hydro-Buncher operating in a red oak poletimber stand.



Figure 2.--John Deere 640 grapple skidder bringing out its payload.

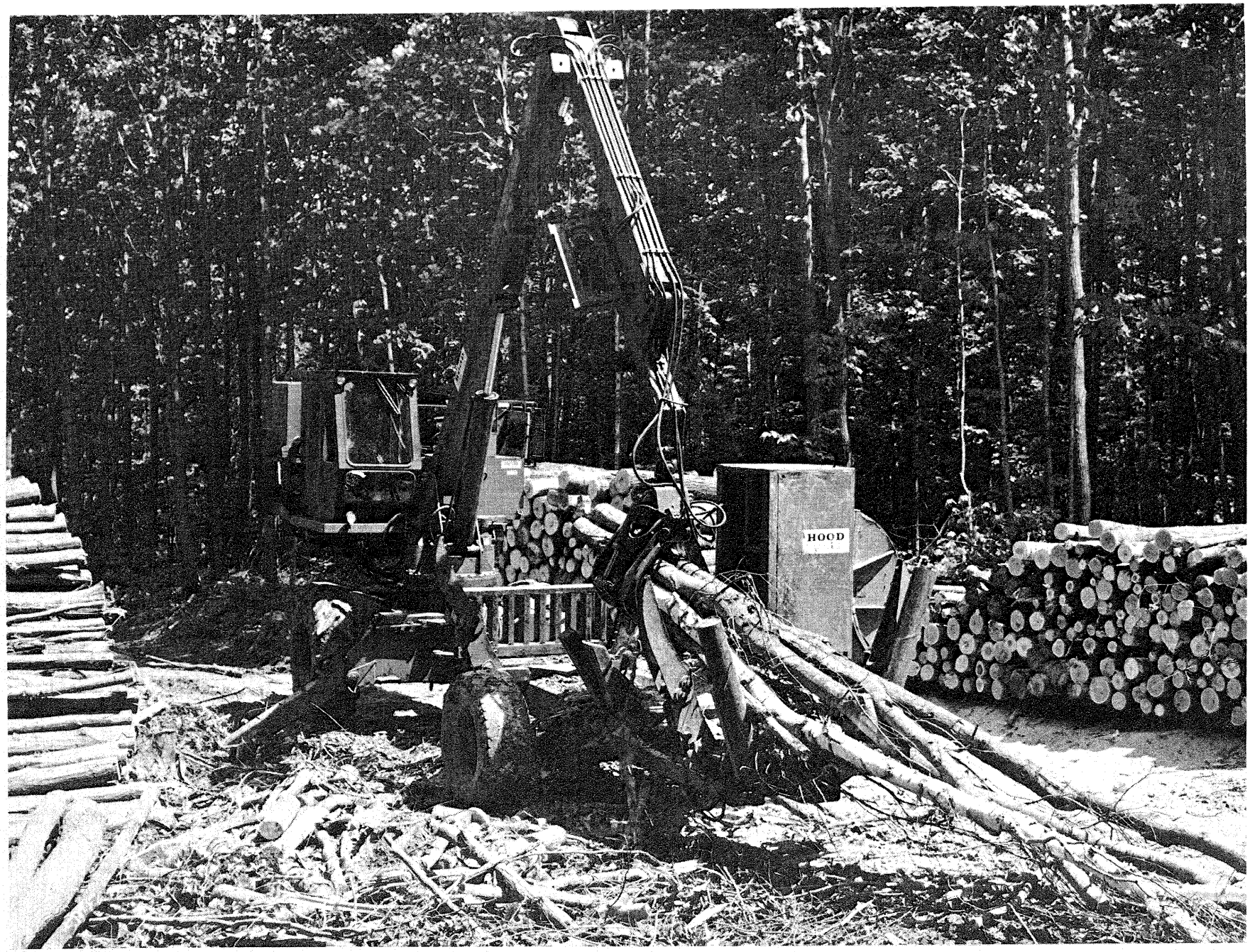


Figure 3.--Self-propelled Hood slasher producing pulpwood and firewood.



Figure 4.--Radio Horse winch anchored to a tree.



Figure 5.--Gafner Iron Mule forwarder loading shortwood from a bunch prepared by a radio-controlled winch.

A 9-YEAR EVALUATION OF MECHANIZED THINNING IN NORTHERN HARDWOODS

Gayne G. Erdmann[1], James A. Mattson[2], and Robert R. Oberg[3]

Abstract.-- Nine-year results are reported for five thinning treatments in a young even-aged stand of northern hardwoods in Michigan's Upper Peninsula. Of the thinning treatments, two left more potentially good quality crop trees with less damage and better spacing: a selective treatment using chain saw felling with no product recovery and a mechanized strip treatment with selection between strips. Mechanized felling and skidding systems generally appear promising for making the first cuts in selectively thinned or even-aged stands and for making shelterwood regeneration cuts in even-aged stands.

In 1974 a study was begun to determine the the feasibility of using mechanized systems to thin dense pole-sized stands of northern hardwoods to provide hardwood pulpwood and to improve growth and quality of the residual trees. The cooperators in that effort were Michigan Department of Natural Resources; Ahonen Lumber Company of Ironwood, Michigan; and the North Central Forest Experiment Station's Laboratory in Houghton, Michigan.

In this paper we report preliminary 9-year results on how five different thinning treatments affected d.b.h. growth, basal area growth, stand structure, and quality development of potential crop trees. We also appraise damage to potential crop trees by treatments, evaluate sapling development under the shelterwood overstory, and attempt to determine the best thinning methods of those tested.

PROCEDURES

Description of the study area

In the fall and early winter of 1974, five thinning treatments were installed in a 50-acre stand of northern hardwoods on State forest land in Section 36, T51N, R37W, Ontonagon County, in the Upper Peninsula of Michigan. The 48-year-old stand was predominantly even aged and pole size, but it also contained a good proportion of small saw log size trees (10 to 14 inches d.b.h.) and some larger, older residual trees. Before thinning, the stand contained about 13.5 cords of hardwood pulpwood and 2,700 board feet of sawtimber. The stand averaged 217 trees per acre of which 55 percent were red maple and 25 percent were sugar maple; and it averaged about 100 square feet of basal area per

---

[1]Principal Silviculturist, North Central Forest Experiment Station, USDA Forest Service, Forestry Sciences Laboratory, Rhinelander, WI.

[2]Research Mechanical Engineer, North Central Forest Experiment Station, USDA Forest Service, Forestry Sciences Laboratory, Houghton, MI.

[3]Forestry Technician, North Central Forest Experiment Station, USDA Forest Service, Forestry Sciences Laboratory, Houghton, MI.

acre (Biltonen et al. 1976). Smaller amounts of yellow birch, black cherry, red oak, hemlock, American elm, balsam fir, and black ash were also present. Site index at 50 years averaged about 60 for sugar maple. The soil is a sandy loam.

Treatments

Two 25-acre blocks, each 1,650 feet long by 660 feet deep, were laid out on each side of a logging road. Each block was divided into five 5-acre plots; each plot was 330 feet wide and extended 660 feet deep into the stand from the road (fig. 1).

The five thinning treatments included:

(1) Strip thinning only with mechanical felling and skidding.-- Plot A-1 was strip thinned with eleven 10-foot-wide clearcut strips. Ten 22-foot areas were left uncut between the 10-foot strips. Basal area before strip clearcutting was 109 square feet per acre in trees 6 inches d.b.h. and larger; residual basal area after cutting was 73 square feet per acre. Plot A-2 was strip thinned with nine 10-foot-wide clearcut strips; eight 30-foot areas were left uncut between the strips. Basal area before cutting was 94 square feet per acre; residual basal area was 68 square feet per acre.

(2) Strip thinning with selection between the strips and mechanical felling and skidding.-- Plots E-1 and E-2 were strip thinned with five 10-foot-wide clearcut strips. The four 70-foot-wide areas left between the strips were selectively thinned. Basal area before strip clearcutting and selective thinning on Plot E-1 was about 102 square feet per acre; residual basal area after thinning was 71 square feet per acre.

(3) Selection thinning with chain saw felling and no product recovery.-- Plots B-1 and C-1 were selectively thinned with a chain saw to leave a residual stand with 70 square feet of basal area per acre. Basal area before thinning on Plot C-1 was 126 square feet of basal area per acre; residual basal area after thinning was 65 square feet.

(4) Selection thinning with mechanical felling and skidding.-- Plots D-1 and D-2 were selectively thinned to leave a residual stand containing 67 square feet of basal area per acre. Basal area before thinning on Plot D-1 was 103 square feet of basal area per acre.

(5) Shelterwood thinning with mechanical felling and skidding.-- Plots B-2 and C-2 were marked to leave a residual shelterwood overstory stand with a high crown cover of about 70 percent or approximately 31,000 square feet of canopy cover per acre. Most thinning was done from below to develop the high crown canopy in the shelterwood overstory trees. Basal area before the shelterwood cut was 108 square feet per acre; residual basal area was about 60 square feet.

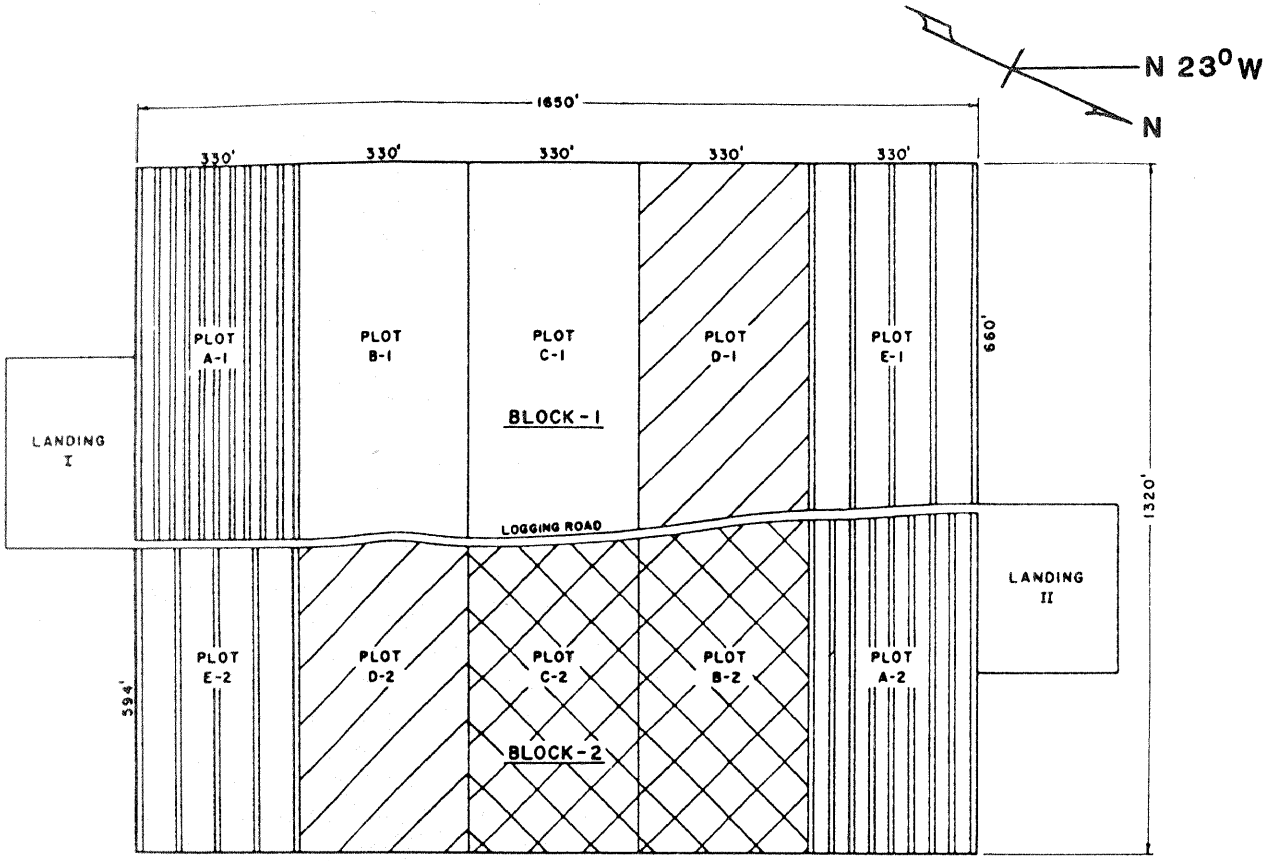


Figure 1.--Plot layout at the 1974 thinning study (Biltonen et al. 1976).

METHODS

In the fall of 1983, we remeasured d.b.h. and the extent of logging damage on trees that had been numbered and measured in 1974 on 6-foot-wide diagonals across plots A-2, B-2, C-2, D-2, and E-2. On each tree damaged by logging, we described the kind of injury and measured the location and the severity of each injury. Early in April 1984, we measured all trees 5 inches d.b.h. and larger on the center acre of one plot for each treatment in plots C-1, D-1, E-1, B-2, and C-2. We took these measurements to obtain a better sample for stand basal area growth and to get an idea of how the treatments affected potential crop trees and stand structure. We also inventoried the sapling reproduction on four randomly selected quarter-acre plots on shelterwood plot B-2 to determine how the reproduction was developing under the shelterwood cut.

RESULTS

Basal area growth

The limited data taken for this preliminary evaluation indicate that net basal area growth of all trees 4.6 inches d.b.h. or larger is quite variable. Basal area growth ranged from a low of 1.3 square feet to a high of 3.93 square feet per acre (table 1). We do not expect that such large differences between the treatments will remain once we have completely sampled the treatment areas for our 10-year evaluation.

An existing model for periodic net basal area growth in relation to beginning basal area for all trees 4.6 inches d.b.h. and larger indicates that net basal area growth for all these treatments should only vary from about 3.0 to 3.3 square feet per acre per year (Erdmann and Oberg 1973). The summers of 1974 through 1976 were extremely droughty, however, and basal growth generally averaged somewhat lower than we expected.

Diameter growth

Diameter growth at breast height varied more by species and original tree size class than by specific thinning treatments or residual stocking levels. Trees averaging 9.7 inches d.b.h. in the shelterwood treatment had a higher average annual d.b.h. growth than did trees averaging 6.8 to 9.0 inches in diameter in the other thinning treatments (table 2). In addition to having larger diameter trees initially, the shelterwood treatment also had the lowest residual basal area density following thinning. As a result of these two factors, the residual shelterwood overstory trees grew faster than trees left in the other treatments.

Our growth model for mean annual d.b.h. growth in relation to beginning basal area predicts about .23 inches of mean annual diameter growth for small saw log-size trees when starting with 60 square feet of basal area per acre (Erdmann and Oberg 1973). It also predicts .15 to .17 inches of mean annual diameter growth for pole-size trees when starting with 64 to 73 square feet of basal area per acre. Like basal areas, diameter increments were also lower than expected.

Table 1.-- Beginning and ending basal areas and average annual basal area growth by thinning treatments over a 9-year period following thinning

Thinning treatment	Basal area		Average annual basal area growth
	Beginning	Ending	
	-Sq.ft./A.-	-Sq.ft./A.-	-Sq.ft./A.-
Selection, chain saw felling and no product recovery (Plot C-1)	63.9	81.2	1.92
Selection, mechanical felling and skidding (Plot D-1)	65.7	101.1	3.93
Strips-with-selection, mechanical felling and skidding (Plot E-1)	70.6	82.3	1.30
Strip only, mechanical felling and skidding (Plot A-2)	68.6[a/]	91.6	2.56
Shelterwood, mechanical felling and skidding (Plot B-2)	60.5	78.2	1.97

a/ Based on 27.27 percent cut of the initial stand basal area in 1974.

Table 2.--Beginning and ending average d.b.h. and average annual d.b.h. growth by thinning treatments over a 9-year period following thinning

Thinning treatment	Average d.b.h.		Average annual d.b.h. growth
	Beginning	Ending	
	-Inches-	-Inches-	-Inches-
Selection, chain saw felling and no product recovery (Plot C-1)	8.50	9.74	0.14
Selection, mechanical felling and skidding (Plot D-1)	8.99	10.36	0.15
Strips-with-selection, mechanical felling and skidding (Plot E-1)	8.71	9.93	0.14
Strip only, mechanical felling and skidding (Plot A-2)	6.78	8.04	0.14
Shelterwood, mechanical felling and skidding (Plot B-2)	9.66	11.47	0.20

Stand structure

Stand structure in the mechanical selection, strip-with-selection, and chain saw selection plots (C-1, D-1, E-1) has changed considerably because of ingrowth into the saw log d.b.h. classes during the 9-year period following thinning (table 3). The number and basal area of stems has increased in the saw log diameter classes, but has decreased in the pole-size class. After 9 years, the only treatment that appears to be overstocked in both sawtimber and pole-size classes is the selection thinning with mechanical felling and skidding treatment.

Although none of the selection treatments will have an operable cut within 10 years after the initial cut, the expected mean annual net basal area growth of 2.5 to 2.8 square feet per acre for residual basal areas ranging from 82 to 100 square feet per acre (Erdmann and Oberg 1973) should produce operable cuts of 20 to 30 square feet per acre after another 10-year growth period.

Sapling development under the shelterwood cut

Only two sapling-size (0.5 to 4.5 inches d.b.h.) stems were present per acre immediately after the shelterwood cut was made in 1974 to leave a high shelterwood canopy containing about 70-percent crown cover. Nine years later, 2,085 saplings over 6 feet tall were well distributed per acre (table 4). Sugar maple accounted for more than 63 percent of these stems and more than 55 percent of the sapling basal area; red maple accounted for more than 34 percent of the stems and almost 42 percent of the basal area. Together these species made up more than 97 percent of the sapling stems and basal area. Small amounts (1 percent each) of yellow birch and black cherry were also present.

Most sugar maple stems inventoried appeared to be of seedling or seedling sprout origin, while most red maple stems were of sprout origin. Numbers of companion red maple stump sprouts have already declined drastically because of normal competitive mortality.

The new stand under the shelterwood overstory is well established and ready for the final overstory removal cut. It contains 38 percent more sugar maple stems and 23 percent fewer red maple stems than the original 1974 stand before thinning. Successional trends on this upland site are normal; moderately tolerant overstory red maples are gradually being replaced by more tolerant understory sugar maple trees in the absence of fire. This is a desirable improvement in species composition because red maple tends to be more defective than sugar maple on this site.

Damage to crop trees

In the spring of 1984, we recorded three types of injuries; those to the bole, root, and crown. Crown injuries, as reported previously, were again found to be of minor importance (Biltonen et al. 1976). Fifty out of 53 injuries or 94 percent of the injuries found on damaged crop trees were bole injuries, the remaining three injuries were a combination of both bole and root injuries.

A crop tree was considered seriously damaged when it had an injury 50 square inches or larger (Hesterberg 1957). Wounds initially under 50 square

Table 3.--Stand structure in the selection thinning plots (C-1, D-1, and E-1)

D.b.h. class	After cut in 1974				After 9 years				Selection goal			
	Trees		Basal area		Trees		Basal area		Trees		Basal area	
-Inches-	-No./A.-		-Sq.ft/A.-		-No./A.-		-Sq.ft./A.-		-No./A.-		-Sq.ft./A.-	
5-9	102		30		76		24		65		16	
10-14	31		22		52		38		28		22	
15-19	9	41	14	36	14	68	22	65	17	53	26	68
20+	1		1		2		5		8		20	
Total	143		67		144		89		118		84	

Table 4.--Sapling development 9 years after the shelterwood cut (Plot B-2)[a/]

Species	Saplings	Basal area
	-No./A.-	-Sq.ft./A.
Sugar maple	1,324	7.5
Red maple	712	5.7
Yellow birch	23	0.2
Black cherry	23	0.2
Other hardwoods	1	- [b/]
Conifers	1	- [b/]
Total	2,085	13.6

a/ Trees 1 to 4.5 inches in d.b.h.

b/ Less than 0.1 square feet of basal area per acre.

inches on crop trees in 1974 were usually healed over or closed after 10 years and were considered to be of minor significance.

The strip thinning plot(A-2) with the smallest average beginning stand diameter (6.8 inches) and the closest average spacing of 11.2 feet between trees had the highest number (12) of seriously damaged crop trees per acre (table 5). While strip thinning, the operator placed all cut trees from the clearcut strip into the uncut stand. This required repeated placement of small bunches and many back up movements by the feller-buncher with trees in the acccumulator head, which resulted in increased damage.

Selection thinning with mechanical felling and skidding had the second highest damage rate with 10 seriously damaged crop trees per acre (Plot D-1).

The shelterwood thinning with mechanical felling and skidding had the third highest damage rate with seven seriously damaged crop trees per acre (Plot B-2).

Only two trees per acre were seriously damaged on the mechanical strip-with-selection plot (E-1).

No seriously damaged crop trees were found on the selection thinning with chain saw felling and no product recovery plot (C-1). Chain saw felling causes some minor crown injuries but few bole and root injuries. Most of the bole and root injuries are caused by skidding; the rest are caused by the skidder or feller buncher actually bumping trees. Undoubtedly, some damage would have occurred to crop trees in the chain saw felling plots if the felled trees would have been skidded to a landing.

MANAGEMENT IMPLICATIONS

Silviculturally, selection thinning and strip thinning with selection between strips are better than strip thinning-only because they offer greater opportunities for: (1) selecting and releasing more high-quality crop trees, (2) concentrating growth more uniformly on those trees, and (3) limiting damage to crop trees during thinning.

For example, the strip thinning-only plot (A-2) had about 75 potential crop trees before the nine 10-foot-wide by 660-foot-long strips were clearcut through the 5-acre plot. This strip treatment removed 20 potential crop trees per acre and left 55 (table 6). If five 10-foot wide clearcut strips would have been used instead of the nine, only 11 potential crop trees would be cut and 64 would be left. If eleven 10-foot wide clearcut strips were used, 25 potential crop trees would be cut and only 50 would be left.

Thirty-three of 59 potential crop trees remaining after strip clearcutting with nine 10-foot-wide strips (Plot A-2) were saw log-size trees; the 26 remaining trees were poles (table 7). After we deduct potential crop trees with serious damage ($\geq$ 50 square inch wounds), only 24 saw log-size and 23 pole-size potential crop trees remain. This is not enough saw log-size crop trees for even-age management, but the stand still could be developed under uneven-age management with adequate numbers of saw log-size trees (47 out of 53 trees)

Table 5.--Effect of the five thinning treatments on potential crop trees after 9 years

Thinning treatment	Injuries	Types of injuries			Seriously damaged[a]
		Skidding	Machine	Felling	
	-No./A.-	-Percent-			-No./A.-
Selection, chain saw felling and no product recovery (Plot C-1)	0	-	-	0.0	0
Strip-with-selection, mechanical felling and skidding (Plot E-1)	2	100.0	0.0	0.0	2
Shelterwood, mechanical felling and skidding (Plot B-2)	12	41.7	50.0	8.3	7
Selection, mechanical felling and skidding (Plot D-1)	15	33.3	53.3	13.3	10
Strip only, mechanical felling and skidding (Plot A-2)	24	62.5	29.2	8.3	12
Total mechanical felling and skidding	53	237.5	132.5	29.9	31
Average	13.2	59.4	33.1	7.5	7.8

[a] Trees lost as potential crop trees due to a wound or combination of nearby wounds with more than 50 square inches of sapwood exposed.

Table 6.--Effect of the number of 10-foot wide clearcut strips on the number of potential crop trees cut and left after cutting a 5-acre plot 330 feet wide by 660 feet long

Ten-foot clearcut strips	Percent of area clearcut	Potential crop trees		
		Before cut	Cut	After cut
-Number-	-Percent-	-Number per acre-		
5	15.2	75	11	64
9	27.3	75	20	55
11	33.3	75	25	50

Table 7.--Effect of thinning treatments on the number of potential crop trees in sawtimber- and pole-size classes 9 years after thinning

Thinning treatment	After thinning in 1974[a/]			After 9 years[b/]		
	Saw log	Pole	Total	Saw log	Pole	Total
	-Number per acre-					
Selection, chain saw felling and no product recovery (Plot C-1)	46	17	63	46	17	63
Strip-with-selection, mechanical felling and skidding (Plot E-1)	42	15	57	41	14	55
Selection, mechanical felling and skidding (Plot D-1)	48	21	69	41	18	59
Shelterwood, mechanical felling and skidding (Plot B-2)	44	-	44	37	-	37
Strip only, mechanical felling and skidding (Plot A-2)	33	26	59	24	23	47

a/ Without deductions for seriously damaged trees.
b/ With deductions for seriously damaged trees (with more than 50 square inches of sapwood exposed wounds in 1974).

appearing from ingrowth within the next 20 years. Management options for five clearcut strips are better; for 11 clearcut strips they are worse.

Although the average d.b.h. of the residual overstory stand was too small (11.5 inches) for making a shelterwood cut under normal even-age circumstances, the shelterwood treatment demonstrates the economic feasibility of using mechanized felling and skidding for making the initial shelterwood regeneration cut in even-aged stands. Shelterwood cuts are also desirable for replacing low-quality northern hardwood stands of seed bearing age on good sites with adequate regeneration of higher quality stems or more desirable species.

On the shelterwood treatment (Plot B-2), 16 percent of the 44 potential saw log-size crop trees per acre or seven trees were seriously damaged. For a young stand, this level of damage is considered serious; but with mature residual trees in a shelterwood overstory left for only 5 to 8 years before the final removal cut, almost no losses would occur because the damaged wood would be slabbed off when sawn.

The selection thinning with chain saw felling and no product recovery treatment (Plot C-1) lost no potential crop trees because of damage. This left 46 potential crop tree-size saw logs and 17 poles per acre (table 7). On the strip-with-selection treatment (Plot E-1), only 4 percent of the potential crop trees or two trees per acre were lost to damage; leaving 41 potential crop tree-size saw logs and 14 poles per acre. On the selection thinning with mechanical felling and skidding treatment (Plot D-1), 14 percent of the potential crop trees or 10 trees per acre were lost to damage, leaving 41 potential crop tree-size saw logs and 18 poles per acre. Each of these selection treatments will have more than enough saw log-size crop trees for uneven-age management within the next decade. During subsequent thinning operations, major emphasis must be placed on protecting crop trees or little high-quality wood will be produced. As a result, mechanized logging methods will have to be somewhat restricted to eliminate any damage to the crop trees.

Skidding appears to be the major problem in damaging trees. Most of the damage in future thinnings could be prevented by using short wood (100-inch) skidding systems and by not harvesting during the spring bark slip season. Root and stem injuries can be minimized by logging when the ground is frozen. Skidder operators should be trained to stay on skid trails and to recognize and prevent damage. And finally, leaving poor-quality barked-up pivot trees until the end of the next thinning operation would prevent further damage.

LITERATURE CITED

Biltonen, F. E.; Hillstrom, W. A.; Steinhilb, H. M.; Godman, R. M. Mechanized thinning of northern hardwood pole stands. Res. Pap. NC-137. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1976. 17 p.

Erdmann, G. E.; Oberg, R. R. Fifteen-year results from six cutting methods in second-growth northern hardwoods. Res. Pap. NC-100. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1973. 12 p.

Hesterberg, G. A. Deterioration of sugar maple following logging damage. Sta. Pap. LS-51. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station; 1957. 58 p.

EVALUATION OF 1978 THINNING SITE

James A. Johnson[1/]

Abstract.--A strip selection thinning was conducted to determine the economic and silvicultural implications of a mechanized harvesting system. The selectively cut strips were thinned from an original basal area of 116 square feet per acre to a residual of 68 square feet. Individual tree diameter growth increased from 0.11 inches per year on the control to 0.20 inches per year on the thinned plots, an 82-percent increase. The increased length growth of trees on the thinned plots of 607-percent over the control, plus the diameter increase, provided a 92-percent cubic foot increase on cordwood trees and 107-percent board foot increase on sawlog trees.

The 1978 thinning study was located in Sections 1 and 2, T45N-R22W, in Alger County, Michigan and co-sponsored by Michigan Technological University, North Central Forest Experiment Station of the U.S. Forest Service, Michigan Department of Natural Resources, Marquette Board of Light and Power, and the Michigan Department of Commerce--Energy Administration.

The specific objectives were: (1) to test strip-with-selection thinning by means of a tracked, long-reach feller-buncher; (2) to determine production rates and costs for harvesting and transporting; (3) to evaluate residual damage and effects of compaction caused by harvesting equipment; (4) to measure tree response and reproduction established as a result of mechanized thinning; and, (5) to determine logistics and economics of utilizing chips as an alternate fuel for generating electricity in a conventional coal burning boiler.

The harvesting rates and costs, residual damage, and compaction were reported by Johnson, et al (1979). Objective (4) growth response, is reported in this paper.

STUDY AREA AND METHODS

The predominately pole-sized stand of 13 acres was composed of 73-percent sugar maple, 22-percent American elm and the remaining 5-percent was basswood, quaking aspen and black cherry. The stocking level before cutting was 254 trees per acre (average tree diameter 9 inch d.b.h.) and 116 square feet per acre of basal area. Because of severe incidence of Dutch elm disease, it was necessary to harvest all of the elm. This precluded the possibility of maintaining a desired uniform stocking of 70 square feet of basal area in these areas where elm predominated.

1/Research/Scientist, Ford Forestry Center, Michigan Technological University, Houghton, Michigan.

The control area was sampled with three one-fifth acre study plots and the thinned area with four one-fifth acre study plots. The plots were measured prior to harvesting in 1978 followed by a four year remeasurement. All trees 5 inches d.b.h. to a fixed minimum top diameter of 4 inches inside bark were measured. In addition sawlog size trees 11 inches d.b.h. and larger were measured to a variable top diameter with an 8 inch minimum inside bark diameter.

RESULTS

One of the major objectives of the study was to measure growth response and quality change following harvest. The following three tables summarize the changes four years after harvest.

Individual Tree Growth Comparisons

Table 1 summarizes the differences in growth response of individual trees on the control plots with those on the thinned plots. Diameter growth increased from .11 inches on the controls to 0.20 inches on the thinned trees, an 82-percent increase. A tree growing at the slower rate would take 146 years to reach 16 inches d.b.h. while a tree growing at the faster rate would only take 80 years, or 45-percent less time. Another example of the benefits derived from thinning is to compare the differences in carrying costs. At compound interest, the length of time the carrying charges (land and timber ownership) must be carried to produce mature timber is significant. For example, a one dollar carrying charge compounded at 7-percent for 40 years (time to grow an 8 inch tree to 16 inches at the faster rate) equals $14.97; at 73 years (time to grow an 8 inch tree to 16 inches at the slower rate) it would be $141.52. The carrying cost is 845-percent greater for the slower growing tree. Reducing the length of time to harvest, therefore, will greatly reduce investment costs and thereby yield a greater net return.

Table 1.--Individual tree growth comparisons of thinned and unthinned trees over a four year period.

Growth Component	Average Growth Per Tree Per Year				
	Control		Thinned		
	Growth	No. Trees	Growth	No. Trees	% Change
Diameter (in.)	0.11	154	0.20	85	82
Usable Length (Ft.)(4"Top) (Cordwood Trees)	0.14	157	0.99	85	607
Cubic Feet (Cordwood Trees)	0.26	162	0.50	94	92
Board Feet (Sawlog Trees)	2.70	25	5.60	18	107

An increase in usable length growth from .14 feet per year on the control compared with .99 feet on the thinned plots is 607-percent greater, a significant difference. This increased length and diameter growth translates into a 92-percent increase in cubic foot volume growth of the thinned cordwood trees over the non-thinned trees and a 107-percent increase in board foot volume of the sawlog trees.

Tree Quality Comparisons

Table 2 summarizes the changes in tree quality. Each tree in the study plots where graded by a tree grading system devised by Boyce and Carpenter (1968). The grading system is correlated with the Forest Service grade specifications for hardwood sawlogs. The grades are assigned according to the probability of a tree yielding a grade-1, grade-2, or grade-3 butt log when it reaches 16 inches d.b.h.

Table 2.--Tree quality changes following thinning.

Tree Quality[1/]	Trees/Acre				% Change
	Control	%	Thinned	%	
0	36.7	14	8.8	8	-43
1	46.7	18	22.5	19	6
2	138.3	52	78.8	67	29
3	43.3	16	7.5	6	-62
TOTAL	265.0	100	117.6	100	

1/ Boyce and Carpenter, 1968, USDA For. Serv. Res. Pap. NE-97.

The grades are defined as follows:

A grade-0 growing-stock is a softwood or hardwood tree with no potential for developing into sawlogs.

A grade-1 growing stock tree has 80-percent probability of yielding a grade-1 butt log.

A grade-2 growing stock tree has less than 80-percent probability of yielding a grade-1 butt log, but a 50-percent chance or better of yielding a grade-2 butt log.

A grade-3 growing stock tree has less than a 50-percent probability of yielding a grade-2 butt log, but a 50-percent chance or better of yielding a grade-3 butt log.

The first priority in thinning is to remove as many of the 0-grade trees as possible. Grade-0 trees were reduced from 14-percent to 8-percent a 43-percent reduction. The second priority removal was grade-3 trees, which were reduced from 16-percent to 6-percent a 62-percent reduction.

Removal of these lower grade trees increased percentage of grade-1 trees by 6-percent and grade-2 trees by 29-percent over the controls. One of the major goals of thinning hardwoods is to increase the growth on the higher quality trees and to reduce the time needed to bring them to maturity.

Net Annual Growth Per Acre

Table 3 summarizes the changes in net annual growth per acre. As a result of reduced stocking total cubic foot volume growth was reduced from 92.23 cubic feet per acre per year on the controls to 76.38 cubic feet on the thinned plots, a 17-percent reduction. The thinned plots have 56-percent less trees, but are growing 83-percent of the volume of the controls. As full stocking is attained annual growth will again equal or exceed the controls.

Table 3.--Net annual cubic feet growth comparisons of thinned and unthinned plots.

Growth Components	Net Annual Growth/Acre (Cu. Ft.) Control	Thinned	% Change
Ingrowth	1.26	3.98	216
Cordwood Repeaters	54.34	41.83	-23
Cordwood to Sawlog	2.27	5.60	147
Sawlog Repeaters	33.71	24.97	-26
Cordwood Mortality	-33.18	0	-100
Sawlog Mortality	-13.43	0	-100
Sawlog to Cordwood	0.65	0	-100
TOTAL EXCLUDING MORTALITY	92.23	76.38	-17
TOTAL INCLUDING MORTALITY	45.62	76.38	67
CUT VOLUME	0	382.8	100
TOTAL NO. TREES	270	118	-56

If mortality is considered, a major difference in production results. The controls lost 45.62 cubic feet per acre per year to mortality resulting in 40-percent less cubic feet net growth than the thinned plots. This mortality was recovered in the thinnings, thus providing a greater total volume yield per acre on the thinned plots.

When the cut volume of 95.7 cubic feet per acre per year is added to the net growth of 76.38 cubic feet the yield of thinned over unthinned is 277-percent greater. Periodic thinnings has the potential of capturing much of the volume that would otherwise succumb to mortality, thus providing greater total volume recovery over the rotation.

CONCLUSIONS

Thinning over-stocked hardwood pole-sized stands can result in major increases in diameter and volume growth over unthinned stands. Time required to reach maturity can be 45-percent less on thinned trees than unthinned trees. Periodic thinnings provide opportunity to concentrate growth on quality trees by removal of the low quality inferior growing stock. Thinnings also provide opportunity to utilize volumes that would otherwise be lost to mortality, thus increasing total volume yields over the rotation.

LITERATURE CITED

Boyce, Stephen G. and Roswell D. Carpenter (1968) Provisional grade specifications for hardwood growing stock trees. U.S. For. Serv. Res. Pap. NE-97, Northeastern Forest Exp. Sta., Upper Darby, PA. U.S.D.A. 11 p.

Johnson, James A., Willilam A. Hillstrom, Edwin S. Miyata and Stephen G. Shetron (1979) Strip selection method of mechanized thinning in northern hardwood pole-size stands. Michigan Technological University Res. Note. 27 13 p.

DAMAGE TO THE RESIDUAL STAND RESULTING FROM MECHANIZED THINNING OF NORTHERN HARDWOODS

Johann N. Bruhn [1/]

Abstract.--There is a definite need to standardize logging damage studies in order to facilitate meaningful comparisons between alternative thinning systems. Factors contributing to logging damage severity can be evaluated only through integration of damage study into harvest studies themselves.

Logging damage is most significant in stands managed under the selection system for sawtimber production and appears to be related to residual basal area. Damage may be minimized by reducing residual basal area, by favoring smaller and more maneuverable equipment, by avoiding spring and early summer thinning, by leaving 'bump' trees along paths of equipment travel, by marking crop trees, by increasing the skills and pride of equipment operators, and by marking stands to be thinned with full knowledge of the equipment to be used.

Logging damage is a concern of hardwood forest land owners deciding how, if at all, to harvest their resource. Choice of silvicultural system and harvesting equipment interact with operator skill and diligence to determine the extent of damage done to the residual stand and the value loss associated with that damage. Earlier studies have documented logging damage caused by conventional chainsaw felling in combination with various types of skidding equipment (Herrick and Deitschman 1956, Benzie 1959, Meyer et al. 1966, Lamson et al. 1984). Generally, skidding damage increases with equipment size and load size. It follows that substitution of mechanized thinning equipment for the chainsaw (Biltonen et al. 1976) can increase the expected frequency and severity of logging damage. For this reason, the extent of logging damage to residual stems in a number of mechanically thinned hardwood pole stands is being evaluated in conjunction with the U.S. Forest Service, North Central Forest Experiment Station, Houghton, Michigan. The objectives of these studies are 1) to conduct an immediate inventory of damage to the residual stands, 2) to evaluate the long-term effects of logging damage on residual stand quality, and 3) to identify means by which logging damage may be reduced.

Slower healing and greater defect can be expected to result from gouged wounds of similar size to wounds without wood penetration. Wood penetration, or gouging, is a common feature of feller/buncher wounds. Earlier reports do not mention wood pene-

---

[1/]Research Scientist, School of Forestry and Wood Products, Michigan Technological University, Houghton, Michigan 49931.

tration or gouging, although some probably occurred. In contrast to earlier studies, however, the thinning studies reported here involve mechanized felling and bunching as well as mechanized skidding.

Classic logging damage studies have frequently used wound surface area as one criterion to separate smaller inconsequential wounds from wounds sufficiently large to result in meaningful defect. Ohman (1970) used an index of surface area derived by multiplying maximum wound length by maximum wound width; he considered 50 sq.in. to be a useful threshold for evaluating root wounds on yellow birch and stem wounds on both yellow birch and sugar maple. Lavallee and Lortie (1968) also reported that mechanical injuries greater than 50 sq.in. in surface area could be considered important on yellow birch. Hesterberg (1957) found that 10-year-old stem wounds on sugar maple which originally exposed more than 150 sq.in. of surface area had a 50 percent chance of being associated with decay. Twenty-year-old sugar maple wounds greater than 60 sq.in. in area also had a 50 percent chance of being associated with decay.

Hesterberg (1957) also determined that wound width was related to the likelihood of defect development. After 10 years, over 50 percent of all sugar maple stem scars originally greater than 7 inches in width had given rise to decay. After 20 years, over 50 percent of all sugar maple stem scars 4 inches or wider had given rise to decay.

METHODS

Two thinning studies have been investigated to date. The first study comprises a 1981 mechanized selection thinning in pole-size northern hardwoods near Watersmeet, Michigan, on the Ottawa National Forest, in Michigan's Upper Peninsula. Three adjacent blocks of timber totaling approximately 21 acres were thinned with three different whole-tree feller/bunchers[1/]. Details of the thinning in each block are as follow.

Watersmeet A:

- Date of Harvest - June, 1981
- Area - 6.46 acres
- Initial Basal Area - 124.1 sq. ft. per acre
- Cut Basal Area - 37.5 sq. ft. per acre
- Residual Basal Area - 86.6 sq. ft. per acre
- Feller/Buncher - Melroe Bobcat Model 1075 with a 16 inch capacity shear mounted on a wheel-type undercarriage with tandem over-tire tracks

---

[1/]The use of trade, firm or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture or Michigan Technological University to the exclusion of others which may be suitable.

Watersmeet B:

Date of Harvest - June, 1981
Area - 6.84 acres
Initial Basal Area - 139.1 sq. ft. per acre
Cut Basal Area - 43.5 sq. ft. per acre
Residual Basal Area - 95.6 sq. ft. per acre
Feller/Buncher - Timbco Hydro-Buncher Model 2518 with an 18 inch capacity shear mounted on a knuckle boom and a track-type under-carriage

Watersmeet C:

Date of Harvest - August, 1981
Area - 7.76 acres
Initial Basal Area - 148.5 sq. ft. per acre
Cut Basal Area - 35.4 sq. ft. per acre
Residual Basal Area - 113.1 sq. ft. per acre
Feller/Buncher - Omark Hydro-Ax Model 311 with a 16 inch capacity shear mounted on the front end of a wheel-type undercarriage

Though one of the initial objectives of the Watersmeet thinning study was to compare the damage caused by the three feller/bunchers employed, this objective was dropped in light of the differences in stand structure between thinning blocks and the consequent differences in marking strategy. Unfortunately, resources permitted only feller/buncher wounds to be recorded for this study.

The second study comprises a 1982 strip-thinning with selection between the strips, conducted on approximately four acres of hardwoods dominated by red oak, managed by the Wisconsin Department of Natural Resources, near Spooner, Wisconsin. Due to the timing of this study, skidding wounds (along the cleared strip) as well as feller/buncher wounds were recorded together. Details of the thinning are as follow.

Spooner A:

Date of Harvest - June, 1982
Area - 4.1 acres, including strips.
- 2.8 acres, thinned area.
Initial Basal Area - undetermined.
Cut Basal Area - undetermined.
Residual Basal Area - 133.7 sq. ft. per acre, thinned area.
Feller/Buncher - Timco Hydro-Buncher Model 2518 with an 18 inch capacity shear mounted on a knuckle boom and a track-type under-carriage

In both studies, a 100 per cent survey was conducted of all injuries to stems over 1.0 inch d.b.h. The non-random spatial distribution of injury in each stand, resulting from the concentration of damage around paths of equipment passage, precluded less intensive sampling. Each feller/buncher operator in the Watersmeet study entered the stand wherever and as often as he saw fit, while the operator at the Spooner site was restricted to

reaching into the residual stand from the cleared strips.

All injuries which penetrated sufficiently to expose live inner bark were documented. The location of each injured tree was recorded by its azimuth and distance from permanent reference points in each stand. Wounded trees were characterized by species, diameter (d.b.h.), and location in the stand. Wounds were characterized by median height above ground, maximum vertical length, maximum horizontal width, depth of wood penetration, a descriptive code, and a color transparency of the injury.

RESULTS

At the Watersmeet thinning site, 989 wounds on 519 stems have been characterized and their locations in the three thinning blocks documented. At the Spooner thinning site, 635 wounds on 505 stems have been similarly documented.

Logging damage appears to be related to residual basal area and stocking (Table 1). As residual basal area increases, the percentage of residual basal area representing wounded stems generally increases, given comparable diameter distributions. The possibility exists, nevertheless, that portions of the differences in damage sustained by the four thinning blocks could be due to 1) physical factors of the different feller/bunchers themselves and/or 2) differences in the amount of basal area marked for removal in the different blocks. Interestingly, the Spooner block had both the largest residual basal area and the largest percentage of residual basal area wounded of all four thinning blocks. In the Watersmeet study, the thinning block sustaining the most damage (Block C) was also the block with the highest initial and residual basal area values and the lowest cut basal area. Unfortunately, skidding damage can not be separated from feller/buncher damage in the Spooner study, though skidding damage must have been concentrated along strip edges where bunches

Table 1.--Percentages of residual basal area and density damaged in four mechanically thinned hardwood stands

Stand	Residual Stand			
	Basal Area		Density	
	Total (sq. ft. per acre)	% of Total Wounded[c]	Total (no. stems per acre)	% of Total Wounded[c]
Watersmeet A[a]	87	6	744	18
Watersmeet B[a]	96	5	626	14
Watersmeet C[a]	114	13	527	40
Spooner A[b]	134	45	634	22

a/ includes only feller/buncher wounds
b/ includes skidding as well as feller/buncher wounds
c/ does not include destroyed stems

were deposited. Watersmeet data were collected prior to skidding. A survey of feller/buncher versus skidding injuries on two one-fifth-acre plots in each Watersmeet block, conducted by ranger district personnel, suggests that skidding damage was comparable in frequency to feller/buncher damage in each block.

At both study sites, stems were considered destroyed if they were severely bent or pushed over. In this sense, less than 1 per cent of the residual basal area or density on the Watersmeet study site was destroyed. On the Spooner site, however, 4 per cent of the residual basal area (7 per cent of the residual density) was destroyed. This included 12, 13, and 4 per cent of the 2 inch, 4 inch, and 6 inch diameter classes, respectively.

The frequency with which wounds meeting certain criteria of severity occurred on each of the four thinning blocks is presented in Tables 2 through 5. The relatively greater number of severely wounded trees on Watersmeet Block C than on Blocks A and B is over-shadowed by the data from Spooner. While a portion of the damage at Spooner is certainly due to skidding, other factors must have contributed to the greater severity of damage there than at Watersmeet. Such factors may include greater residual basal area, season of harvest, harvesting system design, and/or differences between equipment operators.

Table 2.— Numbers of stems wounded or destroyed by feller/buncher activity at Watersmeet Block A, and frequency with which selected criteria of wound severity were met, expressed as per cent of residual stocking by diameter class

dbh class (inches)	Residual stocking	Stem count (per acre)											
		Wounded or destroyed		Wound at least 7 in. wide		Wound at least 4 in. wide[c]		Wound LxW at least 50 sq. in.[d]		Wood penetrated or gouged		Broken top	Destroyed
		Roots[a]	Stems[b]	Roots	Stems	Roots	Stems	Roots	Stems	Roots	Stems		
2	382	0.3	1.9	---	---	---	---	---	0.2	---	0.5	---	0.8
4	143	0.8	5.6	---	0.3	---	1.2	---	1.9	0.3	2.3	0.3	1.5
6	132	0.6	5.7	---	0.8	0.2	2.6	0.2	2.3	0.6	2.5	---	0.3
8	60	0.9	3.6	0.3	0.6	0.3	1.5	0.3	1.5	0.8	2.0	---	---
10	20	0.9	1.7	---	0.5	---	0.8	0.3	0.9	0.6	0.9	---	---
12	4	0.2	0.5	---	0.3	---	0.5	---	0.5	---	0.5	---	---
14	2	0.2	0.8	---	0.2	0.2	0.6	0.2	0.8	0.2	0.3	---	---
16	1	0.2	0.2	---	---	0.2	0.2	0.2	0.2	---	0.2	---	---
18	1	---	---	---	---	---	---	---	---	---	---	---	---
Total	745	4.1	20.0	0.3	2.7	0.9	7.4	1.2	8.3	2.5	9.2	0.3	2.6

a/Mean height above-ground less than 2 in.; does not include injuries below-ground.
b/Mean height above-ground at least 2 in.
c/Includes wounds 'at least 7 in. wide'.
d/Estimated by multiplying maximum vertical wound length by maximum horizontal wound width.

Table 3.— Numbers of stems wounded or destroyed by feller/buncher activity at Watersmeet Block B, and frequency with which selected criteria of wound severity were met, expressed as per cent of residual stocking by diameter class

dbh class (inches)	Residual stocking	Stem count (per acre)											
		Wounded or destroyed		Wound at least 7 in. wide		Wound at least 4 in. wide[c]		Wound LxW at least 50 sq. in.[d]		Wood penetrated or gouged		Broken top	Destroyed
		Roots[a]	Stems[b]	Roots	Stems	Roots	Stems	Roots	Stems	Roots	Stems		
2	196	---	0.7	---	---	---	---	---	---	---	0.1	---	0.4
4	205	0.3	3.1	---	0.1	---	0.6	---	1.0	0.3	1.0	---	0.3
6	128	0.9	5.1	---	0.6	0.1	2.5	0.3	2.6	0.9	3.2	---	---
8	63	1.0	1.9	0.1	0.1	0.1	0.6	0.1	0.4	0.6	0.7	---	---
10	21	1.2	1.5	0.1	---	0.6	0.3	0.9	0.4	0.9	0.6	---	---
12	3	0.1	0.1	---	0.1	---	0.1	---	0.1	---	0.1	---	---
14	5	0.3	0.6	0.1	0.1	0.1	0.3	0.3	0.4	0.3	0.3	---	---
16	3	0.1	0.3	---	---	0.1	0.1	0.1	0.3	0.1	---	---	---
18	2	---	---	---	---	---	---	---	---	---	---	---	---
Total	626	3.9	13.3	0.3	1.0	1.0	4.5	1.7	5.2	3.1	6.0	---	0.7

a/Mean height above-ground less than 2 in.; does not include injuries below-ground.
b/Mean height above-ground at least 2 in.
c/Includes wounds 'at least 7 in. wide'.
d/Estimated by multiplying maximum vertical wound length by maximum horizontal wound width.

Table 4.— Numbers of stems wounded or destroyed by feller/buncher activity at Watersmeet Block C, and frequency with which selected criteria of wound severity were met, expressed as per cent of residual stocking by diameter class

dbh class (inches)	Residual stocking	Stem count (per acre)											
		Wounded or destroyed		Wound at least 7 in. wide		Wound at least 4 in. wide[c]		Wound LxW at least 50 sq. in.[d]		Wood penetrated or gouged		Broken top	Destroyed
		Roots[a]	Stems[b]	Roots	Stems	Roots	Stems	Roots	Stems	Roots	Stems		
2	70	---	1.3	---	---	---	---	---	---	---	0.4	---	0.8
4	194	0.9	9.8	---	---	0.1	0.8	---	1.2	0.1	2.8	0.1	2.3
6	114	1.9	8.0	---	0.1	0.1	1.3	0.1	1.7	0.1	3.2	---	0.1
8	82	2.2	9.7	---	0.8	---	3.0	0.1	3.2	0.1	4.6	---	0.1
10	46	2.1	7.9	---	0.5	0.1	1.8	0.3	1.9	0.1	3.0	---	---
12	13	0.9	1.9	---	0.1	0.1	1.2	0.1	1.0	---	0.9	---	---
14	6	0.5	0.8	---	0.1	---	0.5	---	0.5	---	---	---	---
16	2	0.4	0.8	---	0.1	---	0.5	0.1	0.4	---	0.1	---	---
18	0	0.3	0.3	---	---	---	0.1	---	0.1	---	---	---	---
Total	527	9.2	40.5	---	1.7	0.4	9.2	0.7	10.0	0.4	15.0	0.1	3.3

a/Mean height above-ground less than 2 in.; does not include injuries below-ground.
b/Mean height above-ground at least 2 in.
c/Includes wounds 'at least 7 in. wide'.
d/Estimated by multiplying maximum vertical wound length by maximum horizontal wound width.

Table 5.— Numbers of stems wounded or destroyed by feller/buncher activity at Spooner, and frequency with which selected criteria of wound severity were met, expressed as per cent of residual stocking by diameter class

dbh class (inches)	Residual stocking	Stem count (per acre)											
		Wounded or destroyed		Wound at least 7 in. wide		Wound at least 4 in. wide[c]		Wound LxW at least 50 sq. in.[d]		Wood penetrated or gouged		Broken top	Destroyed
		Roots[a]	Stems[b]	Roots	Stems	Roots	Stems	Roots	Stems	Roots	Stems		
2	191	0.4	30.7	---	1.1	---	1.1	---	2.9	---	0.4	7.1	15.7
4	229	0.7	47.1	---	3.2	---	11.4	---	18.6	0.4	4.3	7.1	9.3
6	108	1.1	32.5	---	6.8	---	20.0	0.4	18.6	0.4	6.4	3.2	1.4
8	116	2.5	32.5	1.1	1.4	1.1	24.3	1.8	24.3	0.4	10.7	0.7	---
10	66	2.1	25.7	0.4	1.2	1.1	21.8	0.4	21.8	---	8.6	0.4	---
12	19	2.5	11.1	0.4	7.5	0.7	10.7	1.1	10.4	0.7	4.3	---	---
14	4	0.4	2.1	0.4	1.8	0.4	1.8	0.4	1.8	---	0.4	---	---
16	1	---	1.1	---	0.7	---	1.1	---	1.1	---	0.4	---	---
18	---	---	---	---	---	---	---	---	---	---	---	---	---
20	---	---	---	---	---	---	---	---	---	---	---	---	---
22	---	---	0.4	---	---	---	0.4	---	---	---	---	---	---
Total	734	9.7	183.2	2.3	45.7	3.3	92.6	4.1	99.5	1.9	35.5	18.5	26.4

a/Mean height above-ground less than 2 in.; does not include injuries below-ground.
b/Mean height above-ground at least 2 in.
c/Includes wounds 'at least 7 in. wide'.
d/Estimated by multiplying maximum vertical wound length by maximum horizontal wound width.

DISCUSSION

The greater the residual basal area, given comparable diameter distribution, the more difficult it will be for a feller/buncher operator to remove marked stems without damaging the residual stand. Likewise, the greater the distance the feller/buncher must travel within the stand between established trails the greater will be the potential for damage to the residual stand. In order to minimize damage to the residual stand, harvesting equipment should be selected to maximize maneuverability and minimize machine size. Further, reduction of basal area to the lowest residual figure consistent with sound silviculture should also reduce damage by opening up the stand and allowing the harvesting equipment to maneuver as efficiently as possible.

The marking guidelines adopted must take into consideration the operating characteristics of the harvesting equipment to be used. The Watersmeet study site was originally marked for conventional chainsaw thinning, but was subsequently thinned mechanically without being re-marked. Feller/bunchers can not be expected to operate as deftly among the residual stems as a manually operated chainsaw. In particular, a feller/buncher can not be expected to remove individual stems from sprout clumps without

severely damaging residual sprout partners. Also, when deciding on the width of residual blocks for a strip thinning with selection between strips, it is important to know what kind of feller/buncher will be used. The residual blocks in the Spooner study were too wide for the Timco Hydro-Buncher to reach all marked trees between adjacent strips. As a result, either the center of each residual block will remain un-thinned, or a second thinning (causing additional damage) will be conducted to remove marked stems from the interiors of the residual blocks.

Other guidelines for reducing damage include 1) marking crop trees so that they will be easier to avoid, 2) restricting the logging season, and 3) leaving 'bump' trees as buffers along the edges of skid trails (Aho et al. 1983). Bark is looser during the spring and early summer; logging during this period results in more and larger wounds. Damage might have been significantly less severe on Watersmeet Blocks A and B and at Spooner if logging had been conducted later in the season. Conversely, damage to Watersmeet Block C might have been still more severe had that block been logged earlier in the season, as were Blocks A and B. 'Bump' trees, left along the edges of skid trails, protect the residual stems and should be removed last of all.

Wound dimensions probably should not be measured earlier than the second growing season following injury, especially on yellow birch. Yellow birch wounds have been shown to enlarge an average of 3.7 in. vertically and 1.2 in. horizontally over the 20 months following injury (Benzie et al. 1963). Sugar maple wounds enlarged little. In addition, bruising of birch stems can cause cambial death and eventual sloughing of the dead bark. Injury enlargement has not yet been measured in either the Watersmeet or the Spooner study.

Tree species also differ in the rate of defect development in response to various kinds of wounds. In a study of skidding wounds on yellow birch and sugar maple, root wounds did not cause direct loss of sugar maple log or lumber value; however, root wounds caused nine per cent of the yellow birch lumber value loss (Ohman 1970). Yellow birch root wounds leading to lumber value loss in 10 years 1) had maximum wound length times width (LxW) of 50 sq. in. or greater, 2) reached within four feet of the bole, and/or 3) were in contact with mineral soil. In both species, about two-thirds of all stem wounds leading to lumber value loss after 10 years had LxW of 50 sq. in. or greater.

No attempt is made to anticipate the significance of individual logging wounds to future stem quality. Total numbers of injuries recorded certainly involve some trees which would not have become sawtimber crop trees even had they not been injured, as well as some wounds which will not result in sufficient decay/discoloration to reduce log or lumber values. There is no way to know whether a particular tree was injured 1) solely because of its position in the residual stand relative to marked stems and feller/buncher operating characteristics, or 2) partially because

the equipment operator made a conscious choice at the time and decided that the stem to be injured had less potential to become a sawtimber crop tree than a neighboring stem which was spared. In most cases, however, feller/buncher and skidder operators do not have the time or the expertise to consider the implications of damaging one stem rather than another. Furthermore, there is often no motivation for operators to minimize logging damage; the financial incentive is simply to complete the harvest as quickly as possible. It would be a mistake to forget that operator pride and skill are as important for minimizing logging damage as any of the other technical considerations mentioned above.

Earlier studies of wound/decay relationships have used trees of large pole or sawtimber size, which might soon be harvested. The Spooner and Watersmeet studies considered injury to smaller size classes as well, which nevertheless will provide the sawtimber crop trees of the future. Concern for smaller diameter classes is justified if foresters are to have the maximum freedom to designate the sawtimber crop trees of the future. Ohman (1970) found that only 20 wounds (all less than one inch wide) of the 239 wounds studied, healed in 10 years. Sapling and pole-size stems may not reach sawtimber size for 20 years or more. Relatively small wounds on young trees may result in considerable defect by harvest age or in early removal. Lavallee and Lortie (1968) found that infected yellow birch wounds 20 years of age or older were severely decayed, with the associated decay columns extending between 3 and 5 times the wound length. As damage to residual stems increases, value of the average crop tree may decline, and the professional forester may find it necessary to disqualify potential crop trees due to logging injury.

Clearly, lower quality stems or stands will suffer less value loss due to a given level of damage than will similar higher quality stands. Likewise, stands to be harvested for fiber will lose less value due to a given level of damage than will similar stands to be harvested for sawtimber.

CONCLUSIONS AND RECOMMENDATIONS

A standardized approach to the study of logging damage is needed in order to systematically evaluate the effects of alternative harvesting systems on residual stem quality. Planning for the damage study should be as thorough as planning for study of the harvest itself; comparison of alternative harvesting systems is possible only if it is planned for in the overall study design.

Logging damage is apparently directly related to residual basal area. As residual basal area increases, given similar diameter distribution, there are more targets for injury, and maneuverability between stems becomes increasingly difficult. Logging damage can be reduced by leaving the smallest acceptable residual basal area. It follows that smaller, more maneuverable equipment should cause the least damage, other factors being equal. Damage

can also be held to a minimum by avoiding mechanized thinning in the spring and early summer, by marking stands with full knowledge of the equipment to be used, by increasing the skills and pride of equipment operators, by using 'bump' trees along paths of equipment travel, and by marking crop trees so that they can be consciously avoided.

More injuries are generally created than are noted. Smaller injuries and injuries to smaller stems are often ignored. Under the selection system of managing northern hardwoods, however, injuries to smaller stems may result in early harvest or in development of significant defect by harvest age. In either case, the forester will have fewer high quality stems from which to select crop trees. Destruction of smaller stems during thinning also reduces the forester's choice of crop trees. Of course, logging damage is much less important if the stand is ultimately harvested solely for fiber. The importance of logging damage also depends on the potential quality of the residual stand before logging damage. The poorer the original stem quality in the residual stand, the less impact a given level of damage will have on stand value.

LITERATURE CITED

Aho, P. E.; Fiddler, G.; Srago, M. Logging damage in thinned, young-growth true fir stands in California and recommendations for prevention. Res. Pap. PNW-304. Corvallis, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1983. 8 p.

Benzie, J. W. Small tractors, ground skidding reduce tree damage in selection harvest. Timberman 60: 42-43, 54; 1959.

Benzie, J. W.; Hesterberg, G. A.; Ohman, J. H. Pathological effects of logging damage four years after selective cutting in old-growth northern hardwoods. Journal of Forestry 61: 791-792; 1963.

Biltonen, F. E.; Hillstrom, W. A.; Steinhilb, H. M.; Godman, R. M. Mechanized thinning of northern hardwood pole stands. Res. Pap. NC-137. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1976. 17 p.

Herrick, D. E.; Deitschman, G. H. Effect of tractor logging upon hardwood stands. Forest Products Journal 9: 403-408; 1956.

Hesterberg, G. A. Deterioration of sugar maple following logging damage. Sta. Pap. 51. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station; 1957. 58 p.

Lamson, N. I.; Smith, H. C.; Miller, G. W. Residual stocking not seriously reduced by logging damage from thinning of West Virginia cherry-maple stands. Res. Pap. NE-541. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1984. 7 p.

Lavallee, A.; Lortie, M. Relationships between external features and trunk rot in living yellow birch. The Forestry Cronicle 44: 5-10; 1968.

Meyer, G.; Ohman, J. H.; Oettel, R. Skidding hardwoods - articulated rubber-tired skidders versus crawler tractors. Journal of Forestry 64: 191-196; 1966.

Ohman, J. H. Value loss from skidding wounds in sugar maple and yellow birch. Journal of Forestry 68: 226-230; 1970.

IMPACT OF HARVESTING TO THE SOIL

C.C. Trettin and E.A. Padley[1/]

Abstract.--Disturbances of the soil often result in compaction and erosion. Studies have shown that compaction may persist for many years following disturbance, resulting in altered soil moisture, soil aeration and soil strength regimes. These effects have been demonstrated to reduce forest growth. A study in northern Wisconsin found a 200 percent increase in bulk density of the surface soil following mechanized thinning operations. A controlled loading test with a forwarder also demonstrated a significant increase in bulk density which was not related to loading weights. These studies conclude that compaction results with the first few passes of a vehicle.

Mechanical disturbances of the soil often affect its condition by altering its structure as a result of compaction, puddling or erosion. Mechanical soil disturbances in a typical northern hardwood thinning system are most typically caused by felling, skidding, forwarding and decking operations. Often soil disturbances are not regarded as having any detrimental effect on the site. However, recent research has demonstrated that soil disturbance can have significant long term impacts on the site. Potential impacts of soil disturbance include: reduced productivity, poor seedling survival, nutrient loss, increased erodability, impaired trafficability and alterations in species composition.

It is the objective of this paper to present an overview of the potential effects of soil disturbance resulting from harvesting, and especially those effects associated with northern hardwood thinning systems. Factors affecting soil disturbance, conditions resulting from soil disturbance and effects of disturbance will be reviewed. A regionally important study on soil compaction resulting from mechanized thinning systems[2/] will also be discussed.

1/Research Scientist and Assistant Research Scientist, Ford Forestry Center, School of Forestry and Wood Products, Michigan Technological University, L'Anse, Michigan.

2/Padley, E.A., S.G. Shetron, C.C. Trettin. Soil Compaction Produced by Thinning Pole Sized Northern Red Oak Stand. Final Project Report - U.S.F.S. - 23-81-50. Michigan Technological University.

DISCUSSION

Soil Compaction

Compaction is the most significant effect resulting from mechanical disturbance of the soil. The direct effects of soil compaction are on the soil moisture regime, soil aeration and soil strength. Alterations of these properties can have significant effects on the residual stand as well as subsequent regeneration.

Compaction is affected by inherent soil and site factors, and by harvesting factors. The soil and site factors which have the most significant influence on compaction are a) texture, b) organic matter content, c) moisture content, d) litter thickness, e) soil structure (Alexander, 1980; Howard, 1981; De Kimpe et al., 1982). The degree of soil compaction has been shown to correspond with the field moisture state (Moehring et al., 1970, Sidle and Drlica, 1981, DeKimpe et al., 1982). Generally, susceptibility to compaction is highest at a moisture content of 60-100 percent of the water holding capacity of the soil. Therefore, it follows that wet, fine textured soils are more susceptible to compaction than dry, coarse textured soils.

The slope and relief of the site also have an influence on the degree of soil disturbance. Generally, as the slope and micro-relief increase the extent of disturbance will increase. Logging methods and types of logging vehicles will also have a bearing on the extent of soil damage. The volume of timber removed will also have an influence; the greater the cut volume the increased number of vehicle pasess required to remove the timber. Correspondingly, Hatchell et al. (1970) found that bulk densities were 52% greater on the log deck, 40% greater on primary skid trails and 23% greater on secondary skid trails, when compared to control plots. Similar increases in soil strength were also demonstrated, while infiltration rates were reduced 89% on log decks, 87% on primary skid trails and 78% on secondary skid trails over the control plots.

The effects of soil compaction on tree growth have been documented. Youngberg (1959) found a 78% increase in bulk density on skid trails versus undisturbed soil and a correspondingly significant difference in height growth rates of planted Douglas-fir (Pseudotsuga menziesii) on trails and undisturbed areas. Sixteen years after logging, Froehlich (1979) demonstrated a 12% reduction in incremental growth rates of ponderosa pine (Pinus ponderosa Laws.) growing in areas which had an 18% increase in bulk density, when compared to undisturbed areas. Went and Thomas (1981) evaluated the growth response of douglas fir to soil compaction, 32 years after logging. They found significant differences in bulk density when comparing skid trails to undisturbed areas. Growth measurements indicated a reduction in volume and density on skid trails when compared to undisturbed areas.

Although no growth studies exist which pertain to the lake states region, it may be inferred from other studies that there is justifiable concern for potential growth reductions associated with soil compaction. Russell (1973) reports that roots will rarely penetrate light-textured soil if its bulk density exceeds 1.7 gm/cc or a heavy textured soil if it exceeds 1.5 gm/cc. The factors associated with increased bulk densities which may

limit plant growth are reductions in moisture holding capacity and aeration, and increased resistance to root penetration.

Compaction of soils has been shown to persist for more than 15 years following logging (Froelich, 1979; Went and Thomas, 1981). Additionally, Hatchell (1970) demonstrated that one vehicle pass can cause as much damage as several passes on moist, medium textured soils. He also suggested that effects associated with compaction may be ameliorated through loosening and revegetation or mulching the disturbed area.

Soil Erosion

Soil erosion in forests is typically associated with logging operations and road construction. The erosion is caused by exposure of the mineral soil surface, disturbance of the subsoil and soil compaction (Pritchett, 1978). The extent of the erosion hazard is dependent on the degree of disturbance, but is typically most severe on skid trails and log decks and in other areas which have had the subsoil disturbed. Rice et al. (1972) reported that 16% of the harvested area had bare soil after selection logging with a tractor. Areas which have been severely disturbed should be remedied to minimize the erosion hazard. Other areas will typically revegetate naturally following the disturbance, controlling the erosion hazard.

Soil Compaction in the Lake States

A study was conducted in northern Wisconsin to assess soil compaction resulting from mechanized thinning of a northern red oak (Quercus rubra L.) stand. The thinning system was the strip selection method (Biltonen et al. 1976), which consisted of felling with a Timbco Hydro-Buncher and skidding with a John Deere 640 grapple skidder. The study area was characterized by a pole sized red oak stand occurring on a loamy glacial till soil (Typic Eutroboralf, coarse-loamy, mixed).

Three skidding strips were randomly selected. The strips were then divided at a point midway between the first and last cycle made by the grapple skidder, thereby identifying high use versus low use areas on the strips. The high use area had a mean of 12 vehicle passes compared to 6 for the low use area. The high and low use areas were subdivided into compartments for sampling. Bulk density was determined for the 0-5 cm soil layer using the modified excavation method (Bradford and Grossman, 1982). Three sampling periods were utilized; immediately following harvest, 3 months and 12 months after harvest. A control area was located adjacent to the harvested stand.

Results of this study indicate that there is a significant increase in bulk density of both the low use and high use areas when compared to the control, during each of the sampling periods, Table 1. There was no significant difference in bulk density between the high use and low use areas. Analysis of bulk densities between sampling periods demonstrated no significant changes in the treatment or control areas over the 12 month sampling period.

Table 1.--Mean air dry bulk densities by treatment area and sampling period

Treatment	Sampling Period		
	June, 1982	Sept., 1982	July, 1983
	Bulk Density (g/cc)		
High Use	0.80a[3/]	0.78a	0.75a
Low Use	0.77a	0.79a	0.79a
Control	0.42b	0.45b	0.44b

3/Where 'a' is significantly different from 'b' at the 95% confidence interval and no difference between 'a' or 'b'.

The results of the bulk density analysis indicte that increases in soil strength occur with the first few passes of logging equipment and that the compaction is not mitigated within twelve months of the disturbance. The moisture content of the soil was near field capacity during the time of logging. Howard et al. (1981) found that the maximum compactability of soils occurs at moisture levels near field capacity. This indicates that logging was conducted at the soil moisture content which most affected soil strength.

A comparison study was conducted at the same time to assess the effects on compaction by a forwarder (Gafner Iron Mule) under controlled loading conditions. The forwarder had three loading conditions: empty, half load and full load. Under each loading range, 4 and 12 passes were made over an undisturbed soil area. Bulk densities were determined for the 0-5 cm soil layer within sampling compartments.

Results of this study indicate that each of the treatments significantly increased bulk density when compared to the control area, Table 2. There were no significant differences between treatments. These data indicate that soil strength is affected by the first few passes of the vehicle and that the loading rate does not significantly contribute to the degree of compaction caused by this vehicle. This trial was also conducted at a soil moisture content near field capacity, which results in the greatest increases in soil bulk density (Howard et al., 1981).

Table 2.--Mean bulk densities by treatment for the controlled loading trail, following treatment.

Treatment	Bulk Density ----g/cc----
Empty, 4 passes	0.91a[4/]
Empty, 12 passes	0.85a
Half load, 4 passes	0.84a
Half load, 12 passes	1.00a
Full load, 4 passes	0.85a
Full load, 12 passes	0.80a
Control	0.47b

4/Where 'a' is significantly different from 'b' at the 95% confidence interval.

CONCLUSION

Soil compaction has a direct effect on soil moisture regimes, soil aeration and soil strength. Changes in these properties may have a significant effect on the residual stand as well as on regeneration. Recent research conducted in the Lake States supports studies conducted in other regions which indicate that: a) soil compaction occurs with the first few passes of a vehicle and that compaction readily occurs at moisture contents near field capacity, and b) compaction is not mitigated over short time periods.

Management operations on unevenaged stands should be designed to concentrate disturbances on the smallest practical area in order to minimize the extent of soil damage. Harvesting operations should be scheduled during periods of low soil moisture and curtailed, if possible, during saturated soil conditions. Soil interpretation guides for harvest scheduling have been prepared by the Soil Conservation Service for northern Michigan and may be utilized to plan harvesting operations to minimize disturbance on soils of different types.

LITERATURE CITED

Alexander, E.B. Bulk densities of California soils in relation to other soil properties. Soil Sci. Soc. Am. J. 44: 689-692; 1980.

Bradford, J.M.; Grossman, R.B. In-situ measurement of near-surface soil strength by the fall-cone device. Soil Sci. Soc. Am. J. 46: 685-688; 1982.

Biltonen, F.E.; Hillstron, W.A.; Steinhilb H.M.; Godman R.M. Mechanized Thinning of Northern Hardwood Pole Stands. Research Paper NC-137, North Central Forest Experiment Station, St. Paul, MN; 1976. 17 pp.

DeKimpe, C.R.; Bernier-Cardon, M.; Joliceour, P. Compaction and settling of Quebec soils in relation to their soil-water properties. Can. J. Soil Sci. 62: 165-175; 1982.

Froehlich, H.A. Soil compaction from logging equipment: effects on growth of young ponderosa pine. J. Soil Water Conserv. 34: 276-278; 1979.

Hatchell, G.E. Soil compaction and loosening treatments affect loblolly pine growth in pots. U.S.D.A. For. Serv. Res. Paper SE-72, SE Forest Exp. Station, Asheville, N.C. 1970.

Howard, R.F.; Singer, M.J.; Frantz, G.A. Effects of soil properties, water content and compactive effort on the compaction of selected California forest and range soils. Soil Sci. Soc. Am. J. 45: 231-236; 1981.

Moehring, D.M.; Rands, I.W. Detrimental effects of wet-weather logging. J. For. 68: 166-167; 1970.

Pritchett, W.C. Properties and Management of Forest Soil. John Wiley and Sons, New York; 1979: pp 444-446.

Rice, R.M.; Rothacher, J.S.; Megahan, W.F. Erosional consequences of timber harvesting: an appraisal. In: Watersheds in Transition. Amer. Water Resources Assoc. Proc. Ser. 14, Urbana, Ill. 1972.

Russell, E.W. Soil Conditions and Plant Growth. Longman Press, New York. 1973: pp 530-531.

Sidle, R.C.; Drlica, D.M. Soil compaction from logging with a low-ground pressure skidder in the Oregon Coast Ranges. Soil Sci. Soc. Am. J. 45; 1981: 1219-1224.

Thorud, D.B.; Frissell, S.S. Jr. Time changes in soil density following compaction under an oak forest. Minn. Forestry Research Note No. 257. College of Forestry, Univ. of Minn. 1976.

Went, S.; Thomas, B.R. Effects of skid roads on diameter, height and volume growth in Douglas-fir. Soil Sci. Soc. Am. J. 45: 1981: 629-632.

Youngberg, C.T. The influence of soil conditions following tractor logging on the growth of planted Douglas-fir seedling. Soil Sci. Soc. Am. Proc. 23; 1959:

HARDWOOD OPPORTUNITIES UTILIZING THE PACK-A-BACK SYSTEM

Richard F. Bierlich[1]

Abstract.--Presents Owens-Illinois, Inc. philosophy of timber harvesting in Northern Wisconsin and the Upper Peninsula of Michigan. With emphasis on the evironment, economics and utilization, tree length logging using pole skidders is compared with shortwood pack-a-back systems. The paper concludes the pack-a-back system is superior to all the criteria examined when compared with tree length pole skidding.

Owens-Illinois owns 264,000 acres of fee lands in Northern Wisconsin and the Upper Peninsula of Michigan, of which 112,000 acres are intensely managed northern hardwoods. As stewards of these lands, our professional foresters manage all of our lands to insure that we have a continuing forest crop available for harvest that insures the corporation of it greatest return on investment. With that in mind, we have adopted a logging system that meets these criteria for all of our forest lands.

In contrast to our competition in the Lake States, with the over constructed, over engineered, oversized and over financed harvesting systems, we at the Tomahawk operation prefer to merchandise at the stump by using training, recognition, and incentive programs for our professional timber workers. Through many trials and efforts, we have found the most efficient and productive system to be the pack-a-back system. We use the term "merchandising at the stump" in which our professional timber workers fell and buck the highest grade sawlogs, bolts, and pulpwood. Our utilization standards are second to none. We encourage our timber workers to buck up all products down to a one-inch top. In our present company operation, we have 50+ different sorts and products and deliver forest products to 21 different mills in the Upper Peninsula and Wisconsin.

In our selective harvesting in northern hardwoods, by using the pack-a-back system we find little or no damage to the residual stand, less compaction to the soil, minimal damage to the root system, reduction in road construction, and much smaller landings.

One real advantage we find in products forwarded roadside by the pack-a-back system, is a cleaner product for both sawmills and the paper mills. Pole skidded wood, cut especially in certain sandy sites, is heavily embedded with sand which is abrasive to debarking and pulpmill systems and adds to the contamination of our waste water system. Pole skidding systems are very sensitive to trucking and significant time is spent in building landings which also reduces our land base for growing forest products. Production with the pole skidding is very sensitive to trucking and has a very limited efficiency for sorting high-value products.

---

[1]Operations Manager, Owens-Illinois, Tomahawk Wisconsin.

Fuel savings are very obvious. A 4500 Series Iron Mule will consume about 5 gallons of fuel a day to skid 30 cords roadside. With the pole skidding system, one gallon per cord is consumed. This is based on the average 300-foot skid. It has been our experience that during the summer months, a timber worker using a pole skidder uses up a power saw chain about every 8 days and a new bar every 4 chains. The expected life of a chain saw is six months or less vs. the system we are presently using wherein a chain saw lasts up to three years. Our best timber worker under this system uses one bar and four chains each year.

Those of you that insist on using mechanized systems in harvesting northern hardwoods because of high compensation rates or because labor is not available, I say to you, this is a cop-out. With record unemployment rates in northern Wisconsin and the Upper Peninsula, with training, recognition, and incentives, I am sure we can obtain the labor necessary to harvest our forests.

For those of you that maintain that under this system you will incur high workers' compensation rates because of accidents, I might point out to you that as of March 15, 1984, our Northern Woodlands harvesting crew recorded 349 working days without a lost time accident. Our professional timber workers are required to wear hard hats, eye protection, hearing protection, leg protection, and safety toe foot apparel. All power saws are equipped with safety chains and chain brakes, and every timber worker is involved in a safety discussion with his immediate supervisor every two weeks.

In summary, the advantages of this system are:

A. Improved sorting of high-value products.

B. Less damage to residual stands.

C. Less soil compaction.

D. Longer skidding distances.

E. Cleaner forest products.

F. Less fuel consumed.

G. Less landing room.

H. Truckers preferance to pack-a-back piles wood vs. pole skidded which often includes many doubles.

I. Overall, leaving the stand aesthetically pleasing to the general public.

LOGGER'S PERSPECTIVE OF THINNING HARDWOODS

Marvin Roberts[1]

Abstract.--A practical, common sense approach to commercially thin hardwood stands is presented. The proper equipment, the right people, a good job of marking trees, correct job layout and planning enables the logger to reduce logging costs.

Thinning--selective logging--and uneven-aged management, three ways to say the same thing, and the only way to profitably manage northern hardwoods.

The fastest way to get many of our present hardwood stands to the point where it is profitable for the land holder to grow trees is through a series of thinnings. The logger that performs these thinnings, successfully, is a specialist and therefore many of his problems are unique. Before I get into these problems and some possible solutions, I would like to make a statement of fact which I believe to be absolutely necessary for any thinning operation.

All of the people involved--land holders, foresters, cutters, skidder operators, and managers--must know and understand the immediate and the long term goals of uneven-aged forest management. These goals must remain constant.

The methods of attaining these goals will vary with loggers, terrain, weather, markets and time, but the goals should not change. They are the stabilizing point in a very unstable business. It is like trying to run a race in which the position of the finish line keeps changing. You have to establish goals and then stay with them. It is very easy to lose sight of the long term goals when dealing with the everyday problems. There is a strong tendency to "go with the flow." This might be easy for awhile but the "flow" usually ends up in a waste treatment plant and our hardwood stands deserve better. Thinning means "planning for the future."

Recreational use of the forest is an actuality and must be recognized as such. When these forest visitors come around to see what you are doing, thinning is much easier to defend than any other type of logging. In most cases you won't have to defend thinning. The aesthetics of thinning make it the most attractive way to log. It might even prevent a burned skidder or other acts of vandalism.

Since uneven-aged management is a series of thinnings, it means that the re-entry periods are relatively short, usually in the 5 to 10 year time frame.

---

[1]District Land Manager, Champion International, Wakefield, Michigan.

This may allow the same logger to re-log or re-thin the same area several times in his life time. This will enable him to get familiar with all of the pecularities of the area. For example, where the timber is at, where to log in wet weather, skid trail and road locations, availability of gravel and whatever. All of these things should increase the efficiency of the logging operation.

After the initial thinning, the following loggers should be able to utilize the roads and landings used by the first logger. This has to be a large saving for them. Also, by reusing the same road every 5 to 10 years, the roads should remain in a useable condition. Each successive use of the road will tend to up-grade it and at minimal cost.

Each successive thinning should produce higher valued products. So the biggest problem is to make that initial thinning of a stand that yields only pulpwood or firewood. One of the more practical ways to accomplish this is to include a previously thinned or good patch of timber with each un-thinned tract. This will effectively spread the total logging costs over a larger volume and reduce the per unit logging cost. It will also result in a higher realiziation per average unit.

Another way to enable a logger to operate these initial cuts is to put up large timber sales with a lot of small blocks. Then don't require a lot of up-front money. Money is very expensive. A lot of blocks will enable the logger to better plan his work. This will give him the ability to cope with the changing markets and weather. This type of logger is generally very mobile and versatile and will log every day that the weather permits. With the marginal profits on these initial cuts he has to.

It takes special equipment to economically thin hardwoods. This is most evident in the early thinnings. The logger must be properly equipped for the job. You don't thin carrots with a D-8 Cat if the long term goal is to raise and harvest carrots. The proper equipment will vary with the logger and with the job to be done. Without going into the pros and cons of the various types of equipment, in thinning, the space to operate equipment is always limited. So, the general rule is--stay light, stay small, and stay mobile.

Also, I wish that foresters and managers would expect and demand the same end result from all loggers. Don't let logging equipment become an excuse for poor logging practices. This is not fair to the concientious logger. Good loggers just want to be treated fairly. They are not looking for a subsidy nor can they afford for their competition to be subsidized.

Some people enjoy doing quality work. They are quality rather than quantity oriented. They like to see the good results of their efforts. Stand improvement by thinning provides that opportunity. In most cases, results are apparent in relatively short periods of time. This can be very rewarding to quality type people. People do the thinning.

It is highly unlikely that you will be able to erase years of poor logging and mismanagement practices with one thinning cut. So when you mark a hardwood stand, please keep these two thoughts in mind. One--this is the first of a series of cuts. Second--marking will always be a compromise between economics and silviculture.

The first time a stand is marked can and should set the pattern for skid trails. The way the stand is marked dictates to a large degree what kind of equipment can be used to cut and skid. For example, if you are marking for a feller-buncher, you have to leave sufficient room to operate the machines. Once these skid trails are established, and if they are in the correct place, they will probably be used again and again in the successive thinnings.

In marking, don't be tight with the paint on each tree. Looking for paint wastes time. The ideal way to mark is with a paint "ring" around each tree. I personally believe that the "ring" is worth the extra paint and effort. The "ring" marking also enables the marker to better control his spacing etc.

The marker should be knowledgeable and practical. If trees are marked in a soft area, expect the skidder to leave ruts. If a large tree surrounded by saplings is marked, expect a lot of saplings to be damaged. If scattered trees are marked in thin areas, expect some trees to be left. It is not what is left that hurts, it is what is cut that does. Don't expect the impossible, but insist on the possible.

Don't get hung up on minimum volumes per acre. There are too many variables in the efficiency of loggers and in the thinning job. Ground conditions, haul distances and the season of operability, just to name a few. Recently, I saw an 80-acre hardwood tract that yielded two cords and 450 Bft per acre. The logger did a very good job of thinning with a minimal amount of logging damage and made money logging.

The bottom line for marking is--it takes a good job of marking to enable the logger to do a good job of thinning.

IN SUMMATION

Marking will always be a compromise between economics and silviculture. Operating space for cutting and skidding will always be limited. Quality people will do a quality job of thinning. Don't get hung up on minimum volumes per acre. Uneven-aged management means a series of thinnings, so some times it might be more practical to wait until the next cut to do or not do a certain thing. Don't keep changing the goals. Uneven-aged management is real. It is attainable! It does require a commitment to the future.

SESSION II - DISCUSSION

Q1. In managing hardwood stands, preparing timber sales and contracts, and working with the logger to help meet our silvicultural goals, some large culls or poorly developed trees are always left that no one would consider cutting. We then go back and deaden those trees with an ax, a chain saw, or whatever. My question is that if this is labor intensive and expensive, is there any research or development in progress on a better way to do it?

(Moderator Abramson) Dick, would you address that from Owens-Illinois' point of view?

A1. (Bierlich) I suggest that the operations people in the woodlands department insist that the mill use the fiber that is available. Pulp is residue, and I totally believe that. The paper mill superintendent cannot tell if chips come from veneer logs or twigs. Often when I walk into the woodsroom, I find the woodroom operator sitting there with nothing to do. They are worried about doubles, forks, and everything else. We should put them to work! We have the technology to use the fiber. This is the answer as far as I am concerned or our corporation is concerned. I have total backing from top management on it. Some days when our wood supply is low, we do not even bother to delimb because we have to move some fiber, and it all makes fiber.

(Moderator Abramson) John, would you comment on that from the engineering research point of view?

(Sturos) As far as I know, no one has researched removing cull trees as such. This has been identified as a problem in the South also. One thing we have looked at is trying to recover fiber from large hardwood sawlog tops--looking at various residue recovery methods. We designed, fabricated, and tested a "topwood harvester" to snip the large limbs of the topwood and bunch them in the bunk of the harvester with the major stem of the top and forward them to roadside. We have collected productivity and cost data on this type of residue recovery operation. We have not studied recovering standing cull trees which should be researched. It would depend on its priority compared to other land management problems.

(Johnson) Initially in our stands we had a sizable number of culls. The ones you are referring to fall apart--they are not even usable for firewood in most cases. We required that they be marked with an "X," cut, and be a part of the sale agreement. Some companies have allowed some adjustment on a per tree basis for felling those trees, and I believe that is the best way to handle the situation. When the contractor is logging, we should give him some incentive--reduction in stumpage, etc.--to remove those trees because some cost is borne in the process.

(Moderator Abramson) One thing we have to keep in mind is the regionality of some of the markets. There may be cases where it is reasonable to require that the trees be cut, removed, and marketed, and there may be

other areas where the hardwood market is so poor and so distant that no matter what requirements you put on the logger, you are going to have trouble getting them to fell or do anything but deaden the trees. There is a certain amount of reasonability that has to be kept in mind.

Q2. In places where there are good saplings and poles underneath the large cull trees, is it better to leave these trees standing rather than cut them down and possibly do extensive damage?

A2. (Erdmann) I think that at some point in time we have to address the question of removing culls. I am in favor of that, except for those that should be left for wildlife habitat. We should decide that first. Leaving a dead tree standing is not going to hurt anything, when it comes down piecemeal. But if you have too many culls in the stand, I would surely drop them and treat those areas so they can produce quality trees. Under uneven-aged management, the cull will take as much space as one of the 53 sawlog trees. It is important to address that situation initially when you enter those stands--drop them now, accept the damage, and mark any poor quality tree that is in that "hole." What we want to develop is the seedling regeneration. There often is a poor quality sugar maple, and at that time, it should be taken out. That is the only thing that we really differ from what Eyre and Zillgit (1953) and Tubbs (1973) have reported; when we make a hole in the stand by removing a large, sawlog-size tree or cull tree, we will do a little TSI job on it at that point. It amounts to only four or five spots like that per acre. On the Argonne Experimental Forest, we mark those trees, and they take them out with the cut at no actual cost to us. Even dead trees, such as dead elm from Dutch elm disease, we mark as dead, and they harvest them for pulpwood if they can use them.

Q3. Damage keeps coming up over and over again. Has any work been done looking particularly at limiting skidding during the slippery bark season?

A3. (Erdmann) I think that is very important. What we would like to do is do all our logging on frozen ground. It limits stem and root damage. In some areas of the U.P., you cannot do that because you really do not get frozen ground, so some of it has to be done. I would say that we would like to do most of our logging in frozen ground conditions. We want no damage on the Argonne Experimental Forest. We have had the third and fourth cuts in our NH-25 cutting method study. We have had almost no damage in the third cut; in the fourth cut, we used Iron Mules and had no root or bole damage. We do hold them to working in frozen ground conditions. We get a little rutting on a few days, but usually they will shut themselves down. A lot of our good work done on the Forest is due to our Forestry Superintendent; he does a very good job of logging supervision. The foresters have to go out and talk to the loggers when unacceptable damage occurs. It is important to have logging supervision and train your operators not to damage trees.

Q4. I have a question that deals with the Spooner case study site. The Spooner site was cut in two different time periods--in the fall and then also with the Timbco in early summer or spring. In the fall cut there was very little visual damage. However, in the spring cut, we had a

significant problem. When you examined damage on that site, did you identify which area was cut in the fall and which was cut in the spring?

(Moderator Abramson) On the Spooner study, is there a difference in damage noted in the areas that were cut in the fall versus the spring?

A4. (Bruhn) I would not say that my study was an afterthought, but I came in after the logging was actually done. John Sturos tells me that I inventoried only on the spring cut.

(Sturos) No comparison was done on that. However, I am sure we could glean something from that comparison and will make every effort to do it.

(Erdmann) For a first thinning in a stand, strip thinning with selection between the 10-foot-wide strips looks like a good treatment from what I have seen. Enough of the initial stand basal area should be removed. You have to get down to about 65 square feet, so you will not damage the good quality, residual trees. In that way you can use mechanized thinning for uneven-aged management. Preparatory to setting up a shelterwood, you can use mechanized thinning and then also take off the shelterwood overstory with bigger equipment, except for what I heard earlier about compaction. It looks like another good option to use big equipment in these stands. There are several good opportunities to use some mechanization in these thinnings.

(Moderator Abramson) Thanks, Gus. Dick, would you comment on restricting logging from an industrial point of view? We seem to be saying that in many higher quality stands, we want to restrict logging to, in one instance, the winter season only.

(Bierlich) We run our crews year round. We are especially cautious during the May and June period. I would not go into a first thinning stand, but we go where we have log diameter trees, etc. and watch our skidder operators. You cannot expect him to pay $50-to $60,000 for equipment and operate it for only 6 months of the year. You must watch his training programs, your stands, and your markings. As Mr. Roberts stated earlier, you must mark your timber to fell it and skid it. You cannot totally restrict the man; he has to operate unless you go back to horses. And they cause damage as Allan Fray's study indicates. We operate year round, and it requires supervision and training in the stand. You must watch the stand you are working in.

(Roberts) I would like to add one thing. One of the main reasons the forest industry is so attractive in Michigan's Upper Peninsula is because we have such a high unemployment rate. Equipment dealers have to make a living, but let us put the people to work, too. People do not tear up the trees; it is the equipment that tears up the trees. One of the panelists just mentioned that 80 percent of all damage was from backing equipment into the trees. If this is so, damage could be reduced if operators were better trained in extension courses.

(Moderator Abramson) Carl Trettin, would you comment on season of logging versus damage in some of these stands?

(Trettin) The critical thing illustrated in a table that we showed--and most of it is common sense--is the seasonal wetness problems that occur on the soils. Naturally, springtime is the worst, during spring breakup and immediately after. If a soil has a tendency for a perched water table or has an inherently high water table, conditions can also be bad during other times of the year.

(Bruhn) There is one other component of damage that I will not even talk about except to mention that we do not know much about it. When you log in the spring, there is no way to evaluate what damage, if any, is done to the submerged root system. There has been no good method devised to study that; any effects on tree growth are hidden.

(Johnson) We have a study in progress; this year we remeasured root damage due to rutting that occurs during the wet season. We will evaluate that during this growing season.

(Erdmann) Some older research shows that as long as damage occurs more than 4 feet away from the bole, it is not likely transmitted to the main stem. I do not know what bearing that has on it, but that is the way we have looked at it. We have told our operators to stay away from the boles of the crop trees. We do not want them damaged at all. Thus far, we have done well with that on sugar maple in particular. That is the main species in most of our stands.

(Bierlich) Quite often when we get very wet periods, our crews will cut out roads. We cut all our roads out first; you can do a lot during extremely wet periods by doing that. The real goal is to make sure our people are employed year round and that we have a continuous supply of wood to the mills. We certainly have to use good judgment from our forest management people--emphasize training and lay the law down. We are not going to damage the boles. There is always a danger in root compaction. I thoroughly understand that. Skidding trails must be dispersed; allow them to make one trip over a trail and move around. That is why you have an Iron Mule going from stump to stump to stump. It offers a lot of versatility. It can be done; we have to do it. It is something we have to work with economically, but we can do it.

Q5. We have a question on the impact of bulk density on tree growth and also how significant this is at varying depths; was this looked at in some of the studies?

A5. (Trettin) Most of the questions raised have not been addressed in the Lake States which points to a gap in our knowledge. The bulk of the rooting mass for the tree species are in the upper portions of the soils. This phenomena can be seen to depths sometimes as much as 6 inches. In very sandy soils, we have seen, in essence, hardpans developed down 9 or 10 inches below the soil surface in areas where large machinery operated on them. In essence, what you have is a sieving action--big machinery sitting there vibrating, sieving out the fines. An artificial pan is created. The values that are critical to root development depend on the size of the roots and the species that you are dealing with. Generally, a bulk density of 1.3 to 1.7 grams per cubic centimeter can limit root

penetration. There is another phenomena associated with the bulk density and that is the root shearing, especially in the surface soils. In the Great Lakes region we have primarily very acid and infertile soil materials. All the nutrients are in the upper surface layer. By drastically disturbing it, you disturb the primary feeding area for the roots. In regard to your question on duration of bulk density, or how long it takes it to get back to a normal or steady state, work has been done. Probably the longest term studies have been conducted in the Pacific Northwest. There have been significant increases in bulk density as a result of machinery, persisting for up to 20 years. It is a very slow process. In the Lake States region where we have the freeze/thaw cycles, this may be ameliorated much more rapidly. Where we do not have soil freezing, it probably will persist longer.

Q6. Has anyone determined what percent of the area is impacted by the equipment in a normal skidding or logging operation?

A6. (Trettin) It depends on the methods of harvesting that are used on the sites. For the selection systems that we are speaking of around here, generally 30 to 35 percent of the area can be impacted. More intensive systems can go anywhere from 60 percent up to 90 percent in some of the real gross sites on clearcutting operations. It is a fairly large area.

What you are saying is that there is a 20 to 50 percent growth loss on 30 percent of the area.

(Trettin) That is correct.

Q7. In our part of the country the majority of the skidders are cable-type skidders, as much as 90 to 95 percent. Has there been any work done using that type of mechanized system--manually felling and skidding with a cable skidder using the strip cut/mark selection method?

A7. (Sturos) As far as I know, there has not been any. As I mentioned in my presentation, we evaluated the radio-controlled winch as a possibility. On the site where it was used, we had almost no damage with this particular semimechanized operation. We are now implementing a study on evaluating low-investment bunching systems to use in hardwood thinning. This certainly has the possibility of limiting the impact of the vehicle on the site. It has some possibilities in improving the overall picture, both economics and damage. Another point could be made. If we are talking of millions of acres that need to be thinned in this area at this time according to the figures Jack Spencer gave us in his presentation, another major concern is how we will get these 3 million acres thinned with the lower productive systems in time to take maximum advantage of what we have. Dr. Webster alluded to the fact that we now have the opportunity. Let us not let the status quo prevail. What can be done to take advantage of the opportunity the Lake States has at this point?

Q8. On ordinary marked sales on public land, the marker does not know what type of equipment will be used. Would you advocate preselecting the cutters for the first thinning or restricting the sale to specific equipment?

(Moderator Abramson) In the case of marking where you do not know the type of equipment that might be used, would you advocate tayloring the marking to the sale or preselecting operators depending on how you have marked a sale?

A8. (Erdmann) With the Forest Service, we have to take the low bidder. We restrict the size of the equipment. We had a restriction on our last cut that the equipment that would be used to do the skidding could be only 8 feet wide. That gives the size of the equipment that you want in the area to do the job and eliminates a lot of the damage.

(Sturos) This actually was the case in one of our case studies on the 1981 Watersmeet, Michigan thinning. That site was actually marked "selective" without any idea that it was going to be mechanically thinned. We had some difficulties there in running the operation. We experienced some inefficiency because the feller/buncher operators had difficulty determining what pattern to follow in this selective-type thinning. It also occurred in the skidding phase of the operation. We followed this study by implementing the 1982 red oak strip selection thinning near Spooner, Wisconsin where the feller/buncher path was predetermined by following the marked strips. This improved the operation considerably.

(Moderator Abramson) Taking into consideration who you are working for is part of the answer to that question. If you are in a situation such as most agencies or small private landowners that are putting their timber up for sale, they have to be concerned about who is going to log it and how the sale will be handled. Preselecting may be one of the answers, or as John said, put qualifications on the kind of equipment that can be used. In many industry cases, we already know who is going to log it before the stand is marked. We have a certain amount of control over who is going to be there, what type of operation he will run, and take that into account in doing the marking ahead of time.

(Bierlich) Too often we hear figures on mechanization that include 10, 11, or 12 cords per man-hour per machine and so forth. When you analyze the equipment, make sure you analyze and include all the mechanics, the foreman, the night mechanics, and the operators and equate them against the power saw man. Too often I have seen that when you go back to the Koehring-Waterous and Arbomatic systems and analyze the system, you find that the power saw man outperforms the mechanized systems in man-day production and man-year production. Everything must be taken into consideration. According to Waterous, it takes about three mechanics to back up their system per shift and about $150,000 worth of parts on hand at all times.

ECONOMICS OF THINNING FROM THE FOREST MANAGEMENT STANDPOINT

Dr. Gerald J. Thiede[1/]

Abstract --Hardwood management can and does pay. Precommercial thinning in hardwoods generally results in low rates of return. Careful selection of opportunities will improve the rates. Commercial thinning almost always improves returns, but at higher discount rates the quantity-quality relationships must be carefully analyzed.

HISTORY OF TSI ON STATE LANDS

To set the stage for the economic discussion to follow, I would like to list briefly the recent history of timber stand improvement (TSI) for northern hardwoods on state forest lands.

In fiscal 1974, the forest cultivation project, which funded a variety of intensive forest management practices, was initiated. In that first year, about 6800 acres were thinned either through reduced stumpage prices on merchantable trees, by direct payment to contractors or by using hired crews. The thinnings cost about $30.00 per acre. In fiscal 1975, 1976, and 1977, approximately 10,000 acres were thinned each year at a cost ranging from $34 to $39 per acre. In 1977 an interesting situation began to develop: costs began to decline. This was the year firewood markets began to expand and hardwood thinnings were becoming commercially valuable. This is well illustrated by the average cost per acre at Baraga versus those in the Cadillac area. At Baraga, thinning costs averaged $37 per acre compared to $16 per acre at Cadillac where a number of thinnings were accomplished at zero cost due to the firewood market. In the period from 1978 to 1984, thinning in northern hardwoods continued, with an increasing portion done commercially each year until nearly all such work was accomplished through timber sales.

As of today, nearly all the acreage of northern hardwoods considered suitable for precommercial thinning has been treated. The original objective of the program was to thin approximately 100,000 acres of the nearly 600,000 acres of northern hardwoods on state lands. The majority of the acreage thinned has a site index equal to or greater than 60. It was estimated that through careful selection of stands receiving treatment, an 8 to 12% rate of return could be achieved.

HARDWOOD MANAGEMENT -- CAN IT PAY?

Now I would like to take you through some case examples of hardwood management and explore the economic returns possible with precommercial and commercial thinnings. But first we need to consider all the assumptions that are used in this analysis. Most of the data used are based on DNR statistics. Others are reasonable estimates provided by knowledgeable people. Finally, some data are simply for illustrative purposes intended to help evaluate the impact of certain factors.

[1/]Planning Leader, Forest Management Division, Michigan Department of Natural Resources

The assumptions are as follows:

Forest land is purchased for $250 per acre, contains a pole timber stand of northern hardwoods which can be thinned, and is sold for $250 at the end of 50 years. A 50 year period is used for all the analyses. This allows enough time to reach similar timber harvests on a selection system regardless of the initial treatments. In the second table, no land purchase costs are included in the analysis. In certain cases land purchase costs are <u>not</u> appropriate. More will be said about this later.

Property taxes are $1.50 per acre per year. This is roughly correct for state lands and forest land entered under the Commercial Forest Act.

Administrative costs are $1.00 per acre per year, slightly higher than what is presently expended by the Department of Natural Resources.

Timber sale administration costs are computed at $1.35 per cord and $22.50 per thousand board foot for sawtimber. Precommercial thinning costs $53 per acre.

Commercial and precommercial thinnings do not result in increased timber volume harvests, rather an improvement in timber quality which is reflected in higher prices.

All costs and prices are in today's dollars and the analysis uses these values throughout except for the simulation of real price increases for stumpage. This means that the rates of return that are reported are real rates of return, i.e., rates of return above the inflation rate. To make them comparable to inflated rates of returns or the interest rate which one can presently get from the bank, credit union, etc., you must add the inflation rate to these rates. If the inflation rate is 6% and the real rate of return is 2%, then the inflated rate is approximately 8% (6+2) and that is what should be compared to bank interest rates. You will have to add the appropriate inflation rate to the internal rates of return (IRR) and to the discount rate for present net worth (PNW) listed in the tables in order to make comparisons to bank, credit union, or interest rates quoted when borrowing funds.

These are before tax IRR's.

Cutting is done on a 10 year cycle for a 50 year period. Stumpage prices for hardwood pulpwood are $4.50 per cord. Sawtimber stumpage starts at $45.00 per thousand board feet for the lower quality trees and increased to $100.00 per M. bd. ft. as thinnings are accomplished and quality improves.

Quite obviously as one changes the assumptions, rates of return will be affected. Although the values utilized in this analysis are fairly conservative, they should provide a fair approximation of what would actually be encountered in Northern Michigan.

ANALYSIS RESULTS

The results of the analysis under various assumptions are displayed in Tables 1 and 2. Before discussing those results, several additional points need elaboration. The question of whether timber can support a land purchase investment is of concern. There are situations where land purchase costs are appropriate to the analysis; others where it is not. If one goes out specifically to buy land or has bought land with the idea that the timber will support the investment, then the land purchase price is a legitimate cost. This is fairly straightforward. If a company buys the land and timber as insurance for mill supply, then the situation becomes more difficult. There are reasons other than an acceptable return on land and timber for the purchase. If the land is purchased for speculative reasons, i.e., for appreciation, then timber production returns should not bear the cost of land purchase. An individual buying land for recreational purposes should not measure all costs against timber returns. Public lands are owned for a number of reasons and provide a variety of outputs. Thus timber alone should not bear the costs of purchase. Because the inclusion of land purchase cost varies by situation and because it is a major expense, two analyses were done; one including land purchase and sale; the other assumes the land is already owned and retained.

The other major concern relates to real price increases for stumpage. The State of Michigan has experienced real price increases in softwood stumpage (this has leveled off recently with the increased supply due to budworm induced salvage offerings) and more recently for aspen stumpage. Hardwoods have not shown the same trend, but there has been little active competition for the overall hardwood resource relative to the large supplies available. As markets improve and competition increases, it is likely we will see some real price increases for hardwoods particularly considering the present low stumpage prices. Therefore, each table contains an analysis which includes a 1.5% real price increase for hardwood stumpage. This provides a reasonable basis for evaluating the impact of a real price increase on hardwood management returns.

As for economic criteria, both present net worth (PNW) and internal rate of return are utilized. In general PNW, which is discounted revenues minus discounted costs, maximizes returns to the land and assumes capital is available at the rates listed. The IRR, which is the rate at which discounted revenues equal discounted costs, maximizes returns to capital and assumes additional lands or investments are available. Both have their place in economic evaluation.

There are four management options listed in the tables. Under the "no thinning" option, no activity occurs in the first 10 years. The first harvests occur in year 10 and then every 10 years thereafter until the land is sold in 50 years. Because no volume is removed immediately, there is additional volume, although of lower average quality, harvested in years 10 and 20. At years 30 and 40,the harvests tend to become similar under all options and they are exactly equal in year 50. At that point, a stable selection system is achieved which provides 2,000 board foot and 5 cords of pulpwood per acre every 10 years or roughly .9 cords per acre per year.

Under the "precommercial thinning" option, volume is harvested at year zero and has no viable market. This is seldom the case now, but is included for illustrative purposes. The harvesting done at year zero reduces the volumes harvested at years 10, 20, and 30, but results in higher prices for the volumes harvested due to improved quality. The cost of the precommercial thinning is $53.00 per acre.

In the "commercial thinning" option, the cost of the thinning at year zero is equal to the value received for the material. The "commercial thinning at profit" option results in a payment at year zero which is twice the cost of the thinning. This progression of options is intended to simulate the importance of the development of markets for hardwood thinnings.

Table 1.-- Land Purchased

	No Price Increase		Real Price Increase (1.5%)	
	PNW Discount Rate (2%)	(4%)	PNW Discount Rate (2%)	(4%)
No Thinning				
PNW	$ 7	$-132	$228	$-25
IRR	2.1%		3.7%	
Precommercial Thinning				
PNW	$ 25	$-151	$301	$-16
IRR	2.2%		3.9%	
Commercial Thinning				
PNW	$ 78	$- 98	$354	$ 37
IRR	2.7%		4.4%	
Commercial Thinning at Profit				
PNW	$131	$- 45	$407	$ 90
IRR	3.3%		5.1%	

Table 2.-- Land Owned

	No Price Increase		Real Price Increase (1.5%)	
	PNW Discount Rate (2%)	(4%)	PNW Discount Rate (2%)	(4%)
No Thinning				
PNW	$165	$ 83	$386	$190
IRR	18.4%		23.8%	
Precommercial Thinning				
PNW	$182	$ 64	$458	$199
IRR	6.4%		9.0%	
Commercial Thinning				
PNW	$235	$117	$511	$252
IRR	15.6%		20.0%	
Commercial Thinning at Profit				
PNW	$288	$170	$564	$305
IRR	25.0%		25.0%	

TABULAR RESULTS

Table 1 lists the IRR and PNW achieved with land purchase and sale included; Table 2 with no land transactions included. Discount rates used for PNW are 2% and 4%. Although this may seem low, recall that these are real rates and if a 6% inflation rate is used, compare to 8 and 10% returns from a bank. Also this is the range where PNW moves from positive to negative values and is thus of greater interest.

It is noteworthy that in Table 1 all IRR's are positive, although somewhat low. The rates of return improve consistently from top to bottom reflecting opportunities through intensified management. When real price increases of 1.5% per year (doubles real prices in slightly less than 50 years) are considered, the real rates of return increase by about 2%. PNW's are now positive above 4% (10% inflated rates) when thinnings are accomplished commercially. However, it is also noteworthy that these IRR's are relatively low. Large upfront costs, in this case land purchase, make it difficult to achieve high rates of return from hardwood land management based solely on timber revenues.

In Table 2, where land purchase is not considered part of the investment process, the rates of return and present net worths are much higher. With these higher rates, precommercial thinning now reduces the overall rate of return because it has a fairly low, although positive, rate. If 2 to 4% real rates (8 to 10% inflated rates) are acceptable, then the investment would still be justified. This is reflected in the increased PNW attained for all except the 4% discount rate with no real price increase.

An interesting result occurs in Table 2 in comparing the commercial thinning to the no thinning option. It would seem that a thinning that covers cost should be attractive. However, recall that the early thinning results in lower volume harvests in years 10, 20, and 30, but increased prices due to quality improvement. At these high rates of return (15 to 20%), the improved quality is not enough to offset the decreased volumes which occur early in the management regime. This is not the case at lower interest rates as reflected in the higher PNW which occur at the 2 and 4% discount rate. As would be expected, the commercial thinning at a profit gives high returns and stresses the importance of strong commercial markets for such timber.

CONCLUSIONS

In general, hardwood management does pay. Returns from timber are quite high if the timber alone is not required to cover land purchase costs. If the timber must cover such costs, then the rates of return are equivalent to those paid by banking institutions. Real price increases for timber improve the rates of returns, although not dramatically. As previously stated, some real price increases appear reasonable for this previously surplus resource which is now and should continue to attract new markets.

Precommercial thinning can give returns equal to those available from banking institutions. Careful selection of opportunities can improve the rates somewhat, but even then they are likely to remain in the lower ranges unless quality differences are substantial. This has made the development of commercial markets for hardwood thinnings quite important to the increased production of high quality sawlogs.

Finally, although extremely important to the improved profitability of hardwood management, commercial thinning is not always automatically desirable. It depends on the quality-quantity relationships and the rates of return acceptable to the decision-maker.

This last caveat reminds me of the story about Harry Truman who was always looking for an one-armed economist for his staff. He decided that that was the only way he could get one who wouldn't be able to say "On the other hand." Unfortunately, you have a two-armed economist who says hardwood management pays, but . . .

EXISTING AND FUTURE PRODUCTS FROM HARDWOOD THINNINGS

Edwin Kallio[1/]

Abstract.--Changes in technology will continue to encourage the use of hardwoods for pulp and paper, waferboard, medium density fiberboard, lumber, and energy fuels in the Lake States during the next 10 years. Incentives for export trade will encourage shipments of more hardwood products from the Lake States through the St. Lawrence Seaway.

A recent study by the Office of Technology Assessment (OTA) indicates that the forest products industry is the world's most productive and among the most efficient. The OTA believes that changing technology will continue to make greater and more efficient use of the forest resource than past assessments have assumed (OTA 1983).

Technology has made possible a greater use of timber through utilization of cull trees, limbs, tops, and slash. Technology has made it possible to use species once considered noncommercial. Technology has permitted more efficient end use of many wood products. Presently, more than 95 percent of the wood entering primary processing mills is converted to products, including energy. All this has had a dramatic impact on the use of our hardwood resources. Let's examine some hardwood use trends, product by product, with emphasis on the future potential for hardwood thinnings in the Lake States area.

PULPWOOD

About 5½ million cords of pulpwood were produced for the Lake State's 38 pulpmills and for the region's 10 waferboard and particleboard mills in 1982; about half a million cord equivalents were in the form of whole-tree chips (Blyth and Smith 1984). Use of all hardwoods for pulpwood has increased by about 90 percent during the past 20 years, from 2 million cords in 1962 to 3.8 million cords in 1982.

The use of hardwood pulp has probably increased because of both technological and economic reasons. Technology has permitted increased use of hardwood fiber in bleached pulps for printing and writing grades of paper and in semi-chemical pulp used for corrugating medium. Economically, there may also have been an increase in relative demand for those grades of paper that make use of lower cost hardwood-based pulps (Ince 1984).

The big news today is the construction of a new pulp and paper mill at Quinnesec, Michigan, by Champion International Corporation. The mill will be designed to use hardwood volume in the furnish to utilize the region's abundant

---

[1/] Principal Market Analyst, North Central Forest Experiment Station, USDA Forest Service, Duluth, Minnesota.

hardwood timber resource. It is estimated that about 450 thousand cords of dense hardwoods will be used each year. Champion International plans to have the mill in operation by 1986. Other existing pulp mills are also investing in some expanded pulping capacity throughout the Lake States. For instance, the Mead Corporation in Escanaba increased its annual pulpwood requirements by 100 thousand cords in 1982; Consolidated Papers, Inc. will expand pulping capacity at the company's Kraft Division in Wisconsin Rapids in 1984; and Owens-Illinois in Tomahawk, Wisconsin, is studying the feasibility of expanding capacity in the future.

However, the lack of suitable technology has limited the use of dense hardwood fiber in some pulp grades such as unbleached sulphate and in paper grades such as kraft linerboard. One new and exciting development that may solve this problem is called press drying (Setterholm 1979). Press drying, developed by the Forest Products Laboratory in Madison, is a method of drying stiff pulp fibers under a compressive force. It offers a means of getting the highest specific strength and stiffness possible from any pulp furnish and can reduce the energy requirements of paper making. It eliminates the need for excessive pulp refining and results in paper products with superior dimensional stability. It allows for use of hardwood pulp to make paper that has higher compression strength than now attainable, thus giving the hardwood resource a new competitive economic advantage.

A pulpmill equipment firm is now experimenting with a commercial press dry unit and private companies are also doing their own research. Some forest product researchers predict that the first commercial application(s) to produce linerboard and corrugating medium may take place as early as 1986. When fully accepted by the industry, the rate of conversion to hardwoods should be dramatic. If hardwoods such as birch, oak, and maple could be used to supplement by one-third the softwood and aspen currently used in the Lake States, the forest resources could accommodate an enormous expansion in pulping capacity - about a million cords - and provide an industrial base for many more jobs and investment dollars.

WAFERBOARD AND ORIENTED STRAND BOARD

Waferboard and orierted strand board (OSB) are rigid, flat, and dimensionally stable boards produced by compressing particles of wood while simultaneously bonding them with an adhesive. They are usually available in sheets from 4 by 8 to 8 by 28 feet. They are commonly used for sheathing, roofing, and subflooring in houses as a substitute for CDX plywood. A basic difference between waferboard and OSB is that OSB is manufactured with alternate layers of particles oriented at 90 degrees to each other, similar to plywood. It is stronger and stiffer in the oriented direction of the face layers than in the 90 degree or cross direction to the face layers. Waferboard and OSB are manufactured with a waterproof and durable adhesive, generally phenol formaldehyde resin (Borchgrevink 1980).

There are about 18 waferboard plants and 5 OSB plants in the United States, most built since 1980. Six of these plants are located in the Lake States; one additional plant is being built. Other firms are considering the construction of additional waferboard or OSB plants in the United States; one firm intends to erect 10 more before 1987. Undoubtedly, some of these plants will be built in

the Lake States. About 1,250,000 cords of round wood were used in 1983 for OSB, waferboard, and particleboard. Although aspen is the principal species used, waferboard and OSB producers expect to be using more birch and other hardwoods in the future. A new OSB plant in Louisiana will be using medium and high density hardwoods, and this approach is being watched with interest by the rest of the industry.

MEDIUM DENSITY FIBERBOARD (MDF)

Medium density fiberboard (MDF) is one of the most exciting products to come into the market in a long time. It is rapidly being utilized in furniture and woodworking, as well as in applications ranging from interior paneling to doors, jambs, shelves, cabinets, mouldings, and interior stair treads.

MDF is made in much the same manner as particleboard, with a few important exceptions. Before refining, the wood furnish is heated or "cooked"; the semi-plastic wood is rubbed apart into fiber bundles, a resin binder is added, the treated fiber is formed into a mat, and the mat is hot pressed. Further mill treatments include sanding and sawing before shipment. Systems are available to orient fibers as well.

MDF has a combination of qualities that give the user a flat, smooth surface combined with a tight edge that can be painted or finished easily without filling. MDF has excellent impact strength, is free from knots and voids, and has exceptional screw holding capability. It saws cleanly, drills easily, and does not splinter or chip out. Although a relatively new product, its sales have soared as users have found it ideal for their needs.

MDF has grown rapidly in the United States since 1975. In that year, the MDF industry shipped a scant 177 million square feet(3/4-in. basis); by 1983, shipments were up almost 3½ times to 605 million square feet, and the number of customers for MDF had risen dramatically.

Most users agree that the future is bright for MDF and that it will continue its recent growth pattern. The Stanford Research Institute's International Forest Products Planning Service projects consumption of an additional 480 million square feet of MDF nationally by 1990. One MDF plant utilizing 80 thousand cords of paper birch and dense hardwoods will be completed at Newberry, Michigan in 1985. We expect other MDF plants to be built in the Lake States because of the readily available hardwood supplies and closeness to furniture and other MDF markets in the upper Midwest.

FUELWOOD

Currently, between 5 and 6 million cords of fuelwood are being produced for residential use in the Lake States each year. Fuelwood production has been increasing at the rate of about 10 percent each year. Most of the fuelwood is still obtained from nonforest and noncommercial forest land; from nongrowing stock on commercial forest land such as dead trees, cull trees, and sections; from tops and limbs of growing-stock trees; and from saplings. One study by the North Central Forest Experiment Station showed that in 1981, only 15 percent of the fuelwood came from growing stock on commercial forest land (Blyth and others

1984). This proportion is expected to increase in the future. Hardwoods are the preferred species for residential fuels. Thinning of hardwood stands offers an outstanding opportunity to supply this growing demand.

In addition to residential fuels, an increasing volume of wood is being utilized by the pulp and paper industry for energy. Electrical power plants in the Lake States are also interested in converting a part of their boiler capacity to use wood.

Two recent innovations for using wood for fuel are wood pellets and chunkwood. Pellets are made by grinding or hogging wood to small particle size, drying, and extruding the pellets under heat and pressure. Wood pellets are a feasible replacement for fossil fuels normally used in heating homes, small businesses, schools, and other institutions. Many gas- and oil-fired package boilers can be modified for pellet use fairly easily, and several new burning devices on the market are well suited for pellets. Pellet use is well established in domestic, commercial, and institutional northern Minnesota--and these markets are growing.

The NCFES Engineering Research Unit at Houghton, Michigan, designed, constructed, and tested a wood "chunker" that reduces roundwood bolts up to about 9 inches in diameter into chunks. Chunkwood makes better fuelwood than chips for industrial use because it dries faster, burns cleaner, and requires much less energy to produce. Chunks can also be used as raw material for structural flakeboard and composite wood products (Arola and others 1983). The chunker is ideal for processing thinnings and small trees removed in timber stand improvement operations. We can expect to hear more about this new development for a number of different uses in the near future.

SAW LOGS

About 1 billion board feet of lumber are produced by about a 1,000 sawmills each year in the Lake States. About 600 thousand board feet of this volume is sawed from hardwoods other than aspen.

Most of the saw logs produced from hardwood thinnings are relatively low in overall quality. The objective of thinning is, of course, to produce stands with high-quality saw logs and veneer logs. Many of the lower quality saw logs are sawn into lumber for the pallet and container industry. That industry in the United States consumes a volume of sawn wood equivalent to nearly 60 percent of total hardwood lumber production. The pallet and container industry is projected to grow normally at a 4-percent rate from 1985 to 2000 (Anderson and others 1984).

Some of the hardwood lumber is also used for dimension parts for furniture and cabinets. There is much interest in applying a process for cutting, drying, edging, and gluing lumber from low-quality hardwood bolts into high-quality hardwood panels for furniture and cabinets. This "System 6" process, developed by the Northeast Forest Experiment Station's Forestry Sciences Laboratory in Princeton, West Virginia, will be covered in the next session.

INTERNATIONAL TRADE

Hardwood exports from the U.S. now average about half a billion dollars annually. The period of most rapid growth during the last 20 years was from 1973 to 1980, when the value of exports increased by 400 percent. However, exports declined rapidly in 1982. Lumber accounts for more than half of the total value of hardwood exports, followed by logs (22 percent), veneer (19 percent), and plywood (2 percent). About one-fourth of all hardwood exports are shipped out of southern ports. Most of the remainder is shipped out of the North (Wisdom 1984).

The U.S. Department of Commerce, the Seaway ports, the State Departments of Business and Industry, and other agencies are busily promoting exports of both raw materials and manufactured products. The International Trade Administration (ITA) provides assistance to potential exporters in regard to trade promotion, finance, insurance, negotiations, and trade analysis. One impetus for increasing export trade is the recent Export Trading Company (ETC) Act of 1982. This act allows a group of competing firms to combine in export ventures if their conduct does not have substantial anti-competitive effects inside the United States. An ETC can enjoy economies of scale not usually available to small and medium-sized companies operating individually because it exports large volumes of products from many sources at lower per-unit costs.

Very few timber products are currently shipped through the Seaway from the Lake States area. However, there is much interest in developing the export markets for Lake States hardwoods. One example is a continuing study of the possibility of shipping wood fuel pellets from the Port of Duluth, Minnesota, to African nations that suffer from a serious shortage of wood fuel for homes and factories.

CONCLUSION

Based on the best available information on changing technology and increasing demands (and assuming a relatively stable economy), the following is an estimate of the increasing consumption of hardwoods (not including aspen) that will be cut from growing stock on commercial forest land in the Lake States.

	1982	1987	1992
pulpwood (million cords)	1.0	2.1	3.0
fuelwood (million cords)	1.0	1.7	3.5
particleboard/MDF (million cords)	-	.3	.7
saw logs (million board feet)	600	750	900

These are truly exciting times for forestry in the Lake States. Waferboard and OSB have tremendously expanded the aspen market. New technology will allow the use of material from hardwood thinnings and help foresters manage this valuable resource to restore the forest products industry as a major contributor to the economic well being of the Lake States.

At the same time, never in the history of the Lake States have there been more dedicated, enthusiastic, and knowledgeable people working on wood product industrial development than there are today. Research and promotion by the State Departments of Natural Resources, various governor's councils and task forces, regional development groups, the State Departments of Business and Commerce, and the wood-using industries will certainly have a positive impact on the future use of our hardwood resource.

LITERATURE CITED

Anderson, R. B.; Luppold, W. G.; Wallin, W. B. The economic potential for utilizing low-grade southern hardwoods. (Accepted for publication in the proceedings of the Southern Forest Economists meeting, Memphis, TN; 1984).

Arola, R. A.; Winsauer, S. A.; Radcliffe, R. C.; Smith, M. R. Chunkwood production: a new concept. For. Prod. J. 33(7/8): 43-51; 1983.

Blyth, J. E.; Smith, W. B. Pulpwood production in the North Central Region by county, 1982. Res. Bull. NC-79. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1984. 21 p.

Blyth, J. E.; Bailey, E. M.; Smith, W. B. An analysis of fuelwood production and sources in Wisconsin. Res. Bull. NC-75. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1984. 20 p.

Borchgrevink, G. Fabricating and using MDF. In: Proceedings, 14th International Particleboard Symposium; Pullman, WA: Washington State University Press; 1980: 291-311.

Ince, P. Pulp and paper science may change to technology and increase use of southern hardwoods. (Accepted for publication in the proceedings of the Southern Forest Economists Meeting, Memphis, TN; 1984).

Office of Technology Assessment, U.S. Congress. Wood use: U.S. competitiveness and technology. OTA-ITA-210. Washington, DC: Superintendent of Documents, U.S. Government Printing Office; August 1983. 20 p.

Setterholm, V. C. An overview of press drying. TAPPI 62(3): 45-46; 1979.

Wisdom, H. W. Hardwood exports: trends and prospects. (Accepted for publication in the proceedings of the Southern Forest Economists Meeting, Memphis, TN; 1984).

APPLICATION OF THE SYSTEM 6 PROCESS TO HARDWOOD THINNINGS

Hugh W. Reynolds[1/] and Edwin Kallio[2/]

Abstract.--Additional revenues to support the best silvicultural practices can be gained by selling logs and bolts from commercial cuts to producers of high-valued products. System 6 is a new technology to convert small-diameter, low-grade timber from hardwood thinnings to a new, high-valued product called blanks. This new technology can provide jobs at low investment levels per job while improving the hardwood forest.

Thinning cuts, timber stand improvement (TSI) cuts, precommercial cuts; call them what you will, one fact is common to all: Costs to make the cuts are more than the revenues from the timber removed. These cuts are investments to be realized from the increased stumpage values in future commercial cuts.

Investments in thinning cuts, etc., are difficult to justify when inflation rates exceed the rates of return on such investments. The value of the timber products from these cuts must be increased and the costs incurred in making these cuts must be decreased. In this paper we describe ways that the value of the timber produced can be increased.

There is no way that the timber manager can convert the small-diameter, low-grade timber to produce Factory Grades 1 and 2 sawlogs. The Grades 1 and 2 sawlogs are valuable because a sawmiller can make No. 1 Common and Better hardwood lumber from these sawlogs. In turn, the No. 1 Common and Better lumber is valuable because furniture, dimension, or kitchen cabinet companies can make rough-dimension parts from this lumber.

But, if the rough-dimension parts can be produced from the small-diameter, low-grade timber, then this timber will become more valuable. And if the No. 2 Common and poorer lumber produced when sawing Factory Grades 1, 2, and 3 logs can be used to make rough-dimension parts, then these logs will become more valuable. Using conventional cut-up technology to make rough-dimension parts from low-grade logs and lumber is too costly. Too much waste is produced. Not enough long rough-dimension parts are produced.

What we need is a new solid hardwood product that can be substituted for high-quality hardwood lumber. This new product should be made from (1) small-diameter, low-grade timber; or (2) No. 2 Common and poorer lumber made during the sawing of high-quality logs; or (3) all the lumber, No. 2 Common and Better, called log-run lumber, made from medium-quality sawlogs.

1/ Forest Products Technologist, Northeastern Forest Experiment Station, USDA Forest Service, Princeton, West Virginia.

2/ Principal Market Analyst, North Central Forest Experiment Station, USDA Forest Service, Duluth, Minnesota.

Research by the USDA Forest Service, together with university cooperation, has solved these needs. The new solid hardwood product is called blanks, which can be made by gang ripping No. 2 Common lumber or log-run lumber. Blanks can also be made from small-diameter, log-grade sawbolts.

Blanks

Furniture and kitchen cabinet parts are made in thousands of sizes. We at the Forest Sciences Laboratory, USDA Forest Service, Princeton, West Virginia, have completed a parts study of 20 furniture and 12 kitchen cabinet companies (Araman 1982). We found that all the required parts could be made from edge-glued panels made in four quality classes, six thickness classes, and in no more than 13 lengths per class (Araman 1983; Araman and others 1982). We call these edge-glued panels "blanks." Recommended standard sizes for furniture and cabinets were established (Araman 1983). A furniture or cabinet company will buy blanks, rip and crosscut the parts from these blanks, and have no more than ten percent end-trim loss (Araman 1983). Making parts from blanks will cost no more, sometimes less, than making parts from high-quality hardwood lumber.

System 6

Blanks can be made from small-diameter, low-grade hardwood timber using System 6 (Reynolds and Gatchell 1979, 1982, 1983). The tree stem is bucked into 6- or 8-foot bolt lengths. The bolts are sawed into two cants. The cants are resawed into boards, and the boards are kiln dried. The boards are then cut up into defect-free pieces in the standard-size blank lengths. The pieces are then edge-glued into standard-size blank widths. Final planing completes the process.

A System 6 research pilot plant has been built at the Forestry Sciences Laboratory in Princeton. We also designed a hypothetical but typical System 6 mill. This $2 million mill has a 21 percent rate of return, after taxes, over a ten year investment period (Hansen and Reynolds 1983). Studies on such a mill using oak bolts from West Virginia and Virginia to make frame blanks for a Tennessee upholstery furniture company and clear blanks for a Kentucky kitchen cabinet company were successful (Reynolds and Araman 1983; Reynolds and others 1983).

We have made System 6 studies using white oak, red oak, cherry, white birch, and yellow-poplar. The low-grade, small-diameter timber came from West Virginia, Virginia, Maryland, Pennsylvania, Massachusetts, and Minnesota. The blanks have been put to commercial test use in furniture and kitchen cabinet companies in North Carolina, Virginia, Pennsylvania, Massachusetts, New York, Minnesota, Wisconsin, and Iowa. System 6 commercial mills are being designed or are under consideration in Minnesota, Wisconsin, New York, West Virginia, and South Carolina.

Gang-Rip Rough Mills

Blanks can be made from the No. 2 Common and No. 3A Common hardwood lumber. This lumber accumulates as No. 1 Common and Better lumber is sawed from high-quality logs. The No. 2 Common and No. 3A Common boards are air dried, kiln dried, hit-and-miss planed, gang ripped into strips, and the strips are crosscut to blank length pieces while removing defects. Pieces with edge defects are edged. Pieces are edge-glued to make blanks.

Gang-rip rough mills are operating presently. The only new requirement for making blanks is that the gang ripsaw must produce glue-joint quality cuts. Both American and foreign machines are available. The gang-rip rough mill lends itself to automation.

Research at the Princeton Lab has shown that a gang-rip rough mill will provide the long pieces necessary for blanks production (Gatchell 1982; Gatchell and others 1983).

Conventional Rough Mills

Crosscut-first rough mills can be used to produce blanks profitably. No. 2 Common and Better hardwood lumber is air dried, kiln dried, crosscut to blank lengths, hit-and-miss planed, and selectively ripped to random-width pieces to remove defects. Pieces with end defects are trimmed to shorter blank lengths. Pieces are edge-glued to make blanks.

Research at the Princeton Lab has shown that conventional rough mills can be practical blanks producers (Araman and Hansen 1983). A completely new conventional rough mill, a $3 million investment, would return 26 percent after taxes on a one-shift basis or 40 percent after taxes on a two-shift basis (Araman and Hansen 1983).

Marketing Blanks

Blanks sell well when the cost of blanks to the furniture and kitchen cabinet maker results in parts that cost as much as or less than parts they produce themselves (Araman 1982). In our research studies, the blanks that we have made have been used by furniture and cabinet makers. Our economic analyses have been made with blanks priced at the low point of the hardwood lumber market (Reynolds 1983). When business is good, high-quality hardwood lumber prices rise sharply. But blanks can be made from low-quality lumber and logs, so blank prices will not rise sharply giving blanks a competitive edge.

A marketing survey in the spring of 1983 was made at eight furniture plants in the New England area. Seven of the eight plants would have bought red oak blanks if they had been available. The eighth and smallest company had its own lumber supply.

The University of Minnesota in cooperation with the North Central Forest Experiment Station, USDA Forest Service, determined markets for white birch blanks. Based on contacts with company executives, the furniture industry in the Upper Midwest is receptive to the concept of wood blanks and to birch blanks in particular (Monson and Bowyer 1982).

The market for blanks to home craftsmen is large. These blanks can carry a much higher price than blanks sold wholesale to furniture and cabinet makers. (Araman and Reynolds 1983). Results of a study in the Upper Midwest and test marketing by distributors in the Minneapolis - St. Paul area indicated a widespread interest in standard size hardwood panels for retail consumption (Michaels and Bowyer 1983).

Blanks have also been shown at the International Woodworking and Furniture Supply Fair-USA (IWF) in 1978, 1980, and 1982. Blanks will be shown again at

the IWF-84, in Atlanta, Georgia, August 25-28, by both research and industry representatives. Prospective blank purchasers and suppliers will be contacted.

SUMMARY

The small-diameter, low-grade hardwood timber removed during thinning cuts does not cover the costs incurred. This timber can be increased in value when it is converted to a high-valued product such as rough-dimension furniture parts. This increase in timber value will not cover all the thinning costs but will reduce the investment necessary to do the work.

Rough-dimension parts can be made from standard-size furniture blanks. Blanks can be made from the small-diameter low-grade timber, using System 6, removed during thinning cuts. When better logs are removed during thinning operations, blanks can be made by gang ripping the lower grades of lumber. Blanks can also be made from mill-run lumber using conventional-type rough mills.

White birch from Minnesota has been made to blanks successfully using System 6. Commercial System 6 mills are being designed for use with white birch. Other species of Lake States' hardwoods can also be used to make blanks using System 6.

LITERATURE CITED

Araman, P. A. Rough-part sizes needed from lumber for manufacturing furniture and kitchen cabinets. Res. Pap. NE-503. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1982. 8 p.

Araman, P. A. Standard-size hardwood blanks (edge-glued panels)--an opportunity for hardwood producers. Natl. Hardwood Mag. 56(8): 36-37, 41, 45-46; 1982.

Araman, P. A. BLANKS: a computer program for analyzing furniture rough-part needs in standard-sized blanks. Res. Pap. NE-521. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 8 p.

Araman, P. A. Program BLANKS analyzes rough-part needs in standard size blanks. Res. Inf. NE 44-83. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 6 p.

Araman, P. A. Standard-size blanks for furniture and cabinets. Res. Inf. NE-45-83. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 6 p.

Araman, P. A.; Gatchell, C. J.; Reynolds, H. W. Meeting the solid wood needs of the furniture and cabinet industries: standard-size hardwood blanks. Res. Pap. NE-494. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1982. 27 p.

Araman, P. A.; Hansen, B. G. Conventional processing of standard-size, edge-glued blanks for furniture and cabinet parts: a feasibility study. Res. Pap.

NE-524. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 11 p.

Araman, P. A.; Hansen, B. G. The dollars and cents of conventional processing of standard-size blanks. Res. Inf. 43-83. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 6 p.

Araman, P. A.; Reynolds, H. W. Crafts offer new market for edge-glued panels. Wood & Wood Prod. 88(6): 86, 88, 90; 1983.

Araman, P. A.; Reynolds, H. W. Craftsmen say "We want edge-glued standard-size panels." Res. Note NE-312. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 4 p.

Gatchell, C. J. Get long lengths from No. 2 Common by gang ripping. South. Lumberman 243(3028): 68-69; 1982.

Gatchell, C. J.; Anderson, R. B.; Araman, P. A. Effect of gang ripping width on C1F yields from No. 2 Common oak lumber. For. Prod. J. 33(6): 43-48; 1983.

Hansen, B. G.; Reynolds, H. W. The economics of System 6 processing of standard-sized blanks. Res. Inf. NE-47-83. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 6 p.

Monson, C. A.; Bowyer, J. L. Evaluation of suitability and market potential of white birch furniture dimension produced in northern Minnesota. Final Rep. 23-81-19. St. Paul: Department of Forest Products, College of Forestry, University of Minnesota; 1982. 278 p.

Nicholls, D.; Bowyer, J. L. Panels from birch for final wood working - an evaluation of market potential. Final Rep. 23-82-28. St. Paul: Department of Forest Products, College of Forestry, University of Minnesota; 1983. 140 p.

Reynolds, H. W. When times are good again for furniture and kitchen cabinet makers. Res. Inf. NE-51-83. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 6 p.

Reynolds, H. W.; Araman, P. A. System 6: Making frame-quality blanks from white oak thinnings. Res. Pap. NE-520. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 9 p.

Reynolds, H. W.; Araman, P. A.; Gatchell, C. J. [and others]. System 6 used to make kitchen cabinet C2F blanks from small-diameter, low-grade red oak. Res. Pap. NE-525. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 11 p.

Reynolds, H. W.; Gatchell, C. J. Marketing low-grade hardwoods for furniture stock--a new approach. Res. Pap. NE-444. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1979. 7 p.

Reynolds, H. W.; Gatchell, C. J. New Technology for low-grade hardwood

utilization: System 6. Res. Pap. NE-504. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1982. 8 p.

Reynolds, H. W.; Gatchell, C. J. New technology for using low-grade hardwoods: System 6. Res. Inf. NE 50-83. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 6 p.

SESSION III - DISCUSSION

Q1. Gerry, do economists ever agree on one particular discount rate for the forest industry as a whole?

A1. (Thiede) No, in fact, the industries themselves do not agree on one discount rate, so it obviously is going to vary considerably. Some can get money cheaper than others; there is no agreement on that. There is always a discussion about what discount rate will be used. Normally what you would do is say. "At what rate can I borrow money?" That may be a key for a number of the industries to determine what their discount rate might be.

Q2. So when you are using 2 percent, you are saying that they can borrow money at 8 percent, and you subtract 6 percent for inflation?

A2. (Thiede) That is correct. In that particular instance, you are saying, "I can borrow money at 8 percent. Or if I have some money, that is my alternative--I can invest it in the bank at 8 percent." That is what you are really comparing. If I am using a 4 percent discount rate for present net worth and inflation is 6, I would make 10 percent. If I can get only 8 percent from the bank, it would be worthwhile for me to invest it in hardwood management in that particular case.

Q3. What were the volume tables used for the hardwoods?

A3. (Thiede) The volume tables are those that I obtained from our silviculturist. They are his best estimates of what we have been able to attain in our 10 years of history. So there are historical records that we have used in our own situation in the State Forest System. They are his best estimates, so they were not any specific volume tables. He agreed that they are fairly conservative. If we erred, I think we probably erred on the low end as to what you can get.

Q4. What is the historical real rate of return for northern hardwoods above and beyond inflation?

A4. (Thiede) I do not know that there is a historical rate; I have not seen one developed anywhere. Our people were saying that they could get 8 to 12 percent in certain instances, but it depends on all the assumptions made. These could include, among other things, whether or not land is purchased, what kind of activity takes place, and what is done in those particular instances on those lands.

Q5. That is not the rate of return I was looking for, but what was the real rate of increase for stumpage?

A5. (Thiede) I do not have a figure on that; he did not give it to me. The real rate of increase that I used--1.5 percent--seems to be very conservative given that you are increasing your market opportunities in these three Lake States, and that we now have a decidedly excess or surplus resource. As markets improve and competition increases, one would expect

that it would be in excess of 1.5 percent--the real rate of increase. I think that is a quite conservative assumption.

(Kallio) I might add a little to that question. In our study of hardwood stumpage rates from 1950 to 1980, we found that it was a flat and sometimes a little downward sloping curve after correcting it for inflation.

PANEL ON FOREST MANAGEMENT PROSPECTIVES: HARDWOOD THINNING OPPORTUNITIES ON NATIONAL FOREST LANDS IN THE LAKE STATES

Myron L. Smith[1]

Abstract.--Five of the National Forests in the Lake States have great opportunities for producing quality hardwoods by thinning pole timber stands now. There are some controls needed on equipment size, skid road layout and time of year for entry.

There are great opportunities for forest management on the Lake States National Forests and hardwoods will play an important role in the overall management program. The States of Michigan, Minnesota and Wisconsin all have recognized the importance of this renewable resource we call timber. My comments apply specifically to the dense hardwoods generally referred to as the northern hardwood timber type as well as oak, paper birch, lowland hardwoods.

In general, the Lake States National Forests will be managing for quality hardwoods on sites capable of growing them. I say generally because as you well know, we manage under the multiple use concept and sometimes over-riding needs from another resource will prevail. Diversity for wildlife habitat is a prime example.

I feel that despite the technical ability to chip, grind, flake and otherwise break wood down and reconstitute it into boards, panels and dimension material, the demand for quality hardwoods will remain. To reach quality product size, there will be a sizable volume of low quality and small size products from thinnings.

There are some concerns and/or limiting factors which need to be addressed if we are to reach full management of all the available acres.

1. Markets for low quality material.--Most National Forests in the Lake States are marketing only half of what could be sold and in many cases, less than half in dense hardwoods.

2. While markets are picking up, the National Forests in the Lake States must compete nationwide for dollars and people to prepare and offer for sale additional timber. Thinning hardwoods is more costly per unit to prepare and administer than many other types which can be clearcut or row thinned such as plantations. This more costly work is coming at a time when the money to prepare and offer sales are shrinking.

---

[1]Timber, Wildlife and Fisheries Staff Officer, Nicolet National Forest, USDA, Forest Service, Rhinelander, Wisconsin.

3. Control of harvest operations in hardwood thinnings needs close attention to insure a quality job.

   a. Time of year which operations take place is important as damage potential to residual trees is much greater during the growing season. Also, the soils on which we can expect to grow quality hardwoods are heavier and more susceptible to rutting which can cause root damage and erosion. It is unlikely that all harvesting can take place under frozen conditions so--

   b. Equipment size and type may need to be carefully selected for thinning cuts. Operator skill may have to be demonstrated before one is allowed to operate machinery in the stands.

   c. Skid roads will need to be laid out prior to when the sale is sold. Equipment will be required to stay on them to reduce soil compaction. Some studies indicate that as much as 80 percent of the soil compaction is done in two passes, so by staying on the same skid road will not cause much additional compaction.

   d. Proper residual stand density is necessary to ensure we move toward quality. Too dense a stand reduces growth while over cutting will provide opportunities for loss in quality by sunscald, epicormic branching, forking caused by the maple bud minor and wind firmness.

Thus, while we have a tremendous opportunity to grow quality hardwoods through thinning stands, we must remember that quality control of intermediate cuts is necessary to have quality sawtimber in the future. Without quality control of operations in intermediate cuts, the future never arrives.

Thank you.

LARGE INDUSTRIAL FOREST MANAGEMENT PERSPECTIVE OF HARDWOOD THINNING

Ermine J. Venuto[1]

Abstract.--Land ownership size, long-term objectives, and income alternatives all play a role in how northern hardwood stands should be managed. Foresters have the responsibility to make stand prescriptions that combine silviculture and cash generation for the landowner.

In attempting to present part of the industrial side of forestry, we have earlier heard a number of industrial foresters. As much as we believe in the continued multiple use on our properties throughout the whole forestry center of the Great Lakes, we operate forests as a business. We grow trees to make money; corporate timberland ownership is predicated on this. The Mead Corporation, Owen-Illinois, Champion--none of them would own timberlands if there wasn't a payoff. Sometimes the payoff is in a combination with a facility--a pulp mill, a liner-board mill, whatever alternate uses they might have for it; but obviously, as foresters, we have to show that there is a payoff in terms of our growing trees on these acres.

Mead owns approximately 677,000 acres in the Upper Peninsula. Almost half of it, 380,000 acres, is in the northern hardwood types. We are quite concerned with hardwood management, and we practice a number of different types of forestry in the hardwood types. In Escanaba, Mead anually buys a little over 700,000 cords of pulpwood every year. Some of it is hardwood, some softwood, and some aspen which we use in a specialty process for making pulp. In addition to pulpwood, we purchase and/or harvest from our own timberlands about 20 million board feet of sawlogs a year, primarily dense hardwoods. This gives you some idea of the variety of products that we produce.

Each year we harvest about 6,000 acres on Mead land through clearcutting. Depending on the year and the markets, we also thin anywhere from 12 to 18,000 acres per year on a selective basis. Presently, we plant about 3,000 acres a year to conifers on the 6,000 acres that we clearcut. We let the remaining acreage regenerate back primarily to aspen, spruce-fir, or white birch types. The ongoing selective systems that we use for harvesting are quite conventional. Typically, we thin down to a basal area of 75 to 90 square feet and then revisit the stand, depending on the site index of that particular area and the components of the stand, somewhere in the neighborhood of 8 to 12 years. This is very normal for northern hardwoods, especially with a large component of hard maple type. The reason we return to these stands in the range of 8 to 12 years versus other options is that the trees are growing into new size categories, and the variable sometimes overlooked is that we can afford to return and log these areas because the volume that we can remove after an 8- to 12-year growing period is sufficient to be able to justify a logging operation.

In the beginning, I said the key to the whole thing is being able to economically and cost effectively manage the forest and the timber harvest process,

---

[1]Woodlands Manager, Mead Corporation, Escanaba, Michigan.

which is what we sometimes call "silviculture." We need to make that an integral part of the way we put the stand back together and design the long-term needs for it.

However, I don't want to emphasize only company lands because the majority of our purchased material comes through state, federal, and private lands. On those operations, the nice feature about being in the pulpwood business is that we can help in the management of northern hardwood stands. We can manage a small landowner's acreage and remove not only the grade sawlogs that need to be thinned during that particular harvest, but we also can harvest the cull poletimber that would effectively not make anything more valuable in 8, 10, or 40 years from that time. Thus, the complete thinning of a stand is a very important ingredient of it. Only thinning a stand by what has been historically known as hygrading obviously does not help in the long-term development of the stand.

The key in thinning depends on three or four conditions. The first is the ownership objective of the individual. The Mead Corporation, Champion International, large industrial users, Cleveland Cliffs Forest Products, and others all have perhaps a little different type of ownership objective than the small private landowner. Their objectives, their time horizon, which is another factor, are almost infinite. A corporation is formed to go on in perpetuity, so when we manage our lands we manage 677,000 acres; we don't necessarily manage just 1 acre at a time. Therefore it is done on a little different basis compared to a private, small landowner who may have a 40-acre parcel, 10 acres of which are northern hardwoods. He has to put his objectives into a much more localized sense in being able to pinpoint how he would like to take care of the stand.

One of the critical variables is the income source. We can regulate stands of timber on a fairly continuous basis because we have large land holdings. The private landowner, who may have 40 or 80 acres or even a section, won't necessarily have the alternative of regularly being in that stand on a continuing basis. In other words, his income flows are the reason that he frequently harvests that stand. Most private landowners don't like to practice good forestry at all times. Their sons or daughters need to go to college or there is a wedding or some other alternative which has pressed him into cutting the timber. Whenever we or anyone else manage those types of stands, those are the types of situations you are either fighting or you have to agree upon with the landowner--his objectives for income may be the way you have to direct the harvest of that stand. It doesn't mean you have to do a bad job of management, but you certainly have to listen to ownership objectives.

Another critical variable which I continue to emphasize is the size of the ownership. It is difficult for Mead sometimes to leave a 5-acre parcel of northen hardwoods in the middle of a clearcut that we are ultimately going to site convert. The private landowner might take the same 80 acres and manage it on a 5-acre basis rather than manage it on an 80-acre basis.

I want to include a quotation from a publication by Jim Johnson of the Ford Forestry Center which says, "The management goal of the selective harvest system is to maximize volume and value growth while perpetuating a sustained yield forest." One can say the same thing of a clearcut (and I'm not saying it to be facetious), but sustained yield hardwood forests in perpetuity is the underlying theme of this symposium. There are a number of different ways to

evaluate this which is important. Silviculture, including thinning, individual selection, etc., is a tool that the practicing forester has to use and use judiciously. It is just like any other timber harvesting practice. As well as making a decision to thin, there are times when thinning might be an inappropriate practice. You must look at the stands. Some stands may have a negative payback if you begin to thin. I am sure you have all come upon stands of what I would call "clump red maple" with some hard maple in them; you look at the stand and try to decide what to do with these areas. In some cases, it might not be silviculturally appropriate to recommend thinning on those particular areas. It doesn't matter whether it is a private large ownership or the small woodlot, but the initial appraisal the forester makes when he evaluates that stand sets the consequence and the payback for that stand over the future of it. It is important when guidance is given or the timber harvesting process is put into effect that you look at that stand and say not only, "What can we do to it today?" but "What is the potential in 40 years, and what are the options and the pathways that we could use on managing the stand?"

There are a number of other tools that we have, but ultimately everyone in this room realizes that the idea of practicing forestry is somehow profoundly tied to economics--keep the two together. Whenever the prescriptions are made on a stand, you do it in a format that allows that to occur.

HARDWOOD OPPORTUNITIES ON WISCONSIN'S STATE AND COUNTY FOREST

By

James E. Halvorson 1/

Abstract. --Over the next ten years, 3.5 million cord equivalent of hardwoods will be ready for cutting on Wisconsin's public forest. Presently, the majority of available hardwoods fall within the 5-10 inch, pole size class. The marking technique chosen will have an impact on how well the land manager addresses:

- Silvicultural Needs
- Damage Potential
- Logging Chance, and
- Forester Productivity

The goal is to arrive at an adaptable system. One that optimizes the needs of the stand, but allows flexibility in the types of equipment used.

RESOURCE AVAILABILITY

The public ownership in Wisconsin is broken into three catagories: two national forests, six state forests, and twenty-eight county forests which total approximately 3.8 million acres (Fig. 1). The majority of these public forest lands lie in the northern one-half of the state. The hardwood surplus on the state and county forests alone is projected at 230,000 cord equivalent annually. Expanded over the next ten-year period this will be 2.3 million cord equivalent. This is above and beyond the harvest that we have today, and does not include private and federal lands (Table 1).

Table 1. -- County and State Hardwood Surplus.

	*Forcast	*Harvest	*Surplus
County	309,000 cd. equiv.	105,000 cd. equiv.	204,000 cd. equiv.
State	40,000 cd. equiv.	14,000 cd. equiv.	26,000 cd. equiv.

* Annual average (cord equivalent)

Current availability of Wisconsin wood can be found in a recent publication entitled (Timber Forecast: Wisconsin Public Forest 1984/1983) which was published by the Northwest Regional Planning Commission and the Wisconsin Department of Natural Resources. The publication describes in detail each of the individual county forests, national forests, and state forests. Each property has three tables associated with it. An example using Washburn County Forest will be used to show the forecasting information.

Table 1a, describes timber availability. Specifically estimated volumes of timber available for harvest by year and species group over the next ten years are as follows:

1/ Assistant Area Forester, Wisconsin Department of Natural Resources, Spooner, WI.

Figure 1. --

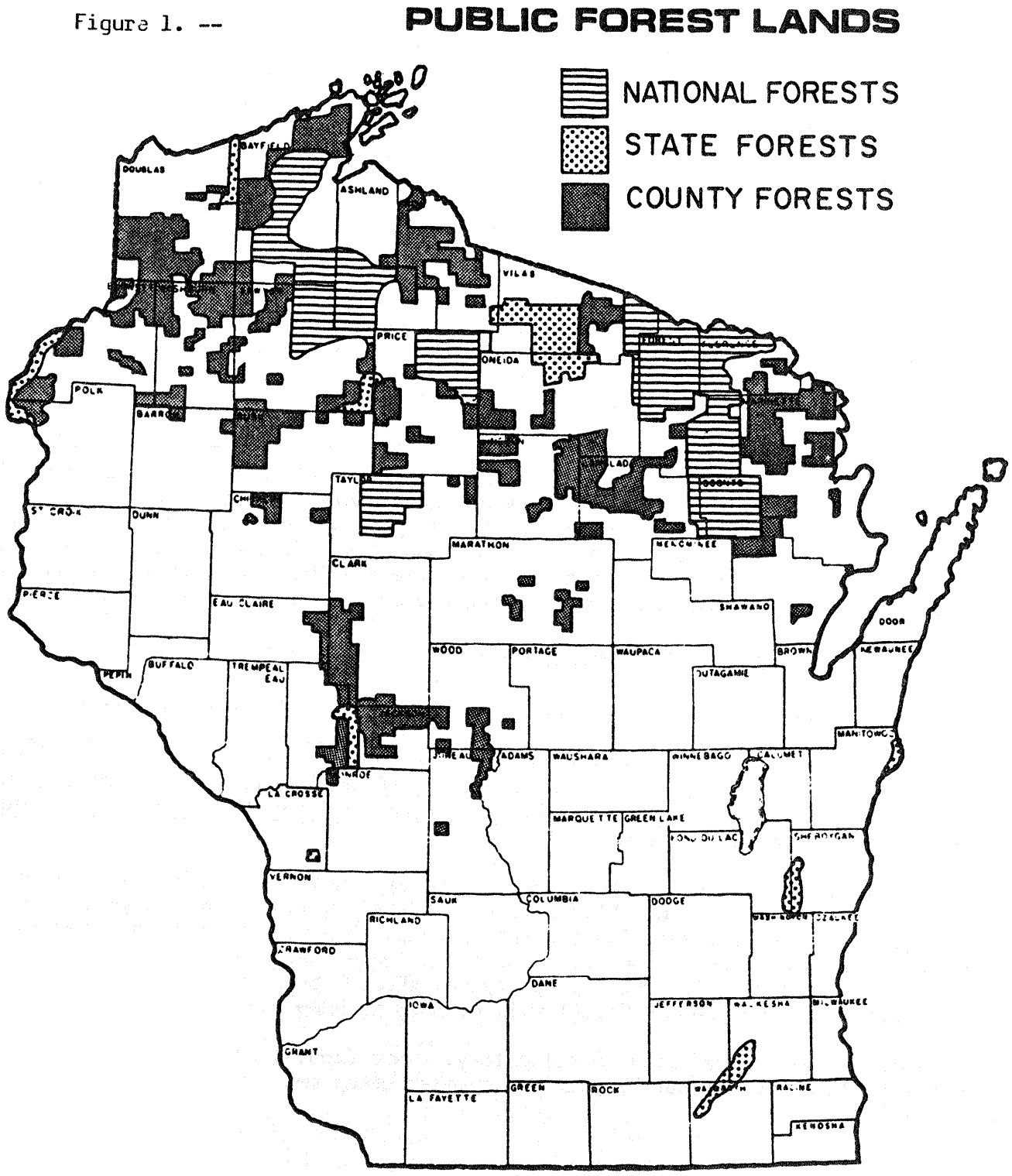

PUBLIC FOREST LANDS
NATIONAL FORESTS
STATE FORESTS
COUNTY FORESTS
DOUGLAS
ASHLAND
VILAS
PRICE
ONEIDA
POLK
DUNN
CLARK
MARATHON
MENOMINEE
SHAWANO
DOOR
PIERCE
EAU CLAIRE
WOOD
PORTAGE
WAUPACA
BROWN
OUTAGAMIE
BUFFALO
ADAMS
WAUSHARA
WINNEBAGO
CALUMET
MANITOWOC
LA CROSSE
MARQUETTE
GREEN LAKE
VERNON
SAUK
COLUMBIA
DODGE
RICHLAND
CRAWFORD
DANE
JEFFERSON
IOWA
GRANT
LA FAYETTE
GREEN
ROCK
RACINE
KENOSHA

Table 1a. --Estimated Volume of Timber Available For Harvest by Year and Species Groups (1984-1993), (Cord Equivalents).

	Pine	Fir-Spruce	Other Conifer	Hardwoods	White Birch	Aspen	Yearly Total
1984	6,650	6,260	2,680	33,440	4,240	18,120	71,390
1985	6,050	2,280	850	15,790	2,830	13,280	41,080
1986	6,640	1,910	700	14,560	2,870	13,230	39,910
1987	6,020	2,000	610	13,830	2,830	13,230	38,520
1988	6,290	1,690	440	14,010	2,740	13,170	38,340
1989	6,280	1,500	500	12,940	2,670	13,020	36,910
1990	6,170	1,440	440	12,810	2,690	13,030	36,580
1991	6,820	1,360	380	12,640	2,660	13,030	36,890
1992	7,360	1,340	330	12,700	2,670	13,060	37,460
1993	8,080	1,690	480	12,200	2,770	13,240	38,460
TEN YEAR TOTAL	66,360	21,470	7,410	154,920	28,970	136,410	415,540

Table 2a, gives you a timber sale summary over the past 10 years. This is useful in that it gives you the level of activity for each individual species group. It also can be compared to Table 1a to determine surplus above the historical harvest.

Table 2a. -- Timber Sales Summary (1973-1982).

Fiscal Year	Sawlogs (M Bd Ft)	Pine Tamarack (Cords)	Balsam-Hemlock (Cords)	Spruce (Cords)	Aspen Birch (Cords)	Other Species (Cords)	Total All Products (Cord Eqv.)
1973	316.9	7,510	92	-	8,071	481	16,788
1974	155.3	5,288	-	8	10,913	448	16,968
1975	32.9	5,309	209	-	2,537	-	8,121
1976	62.0	4,126	1,050	-	22,815	2,141	30,256
1977	267.7	5,428	-	155	22,218	2,147	30,483
1978	127.7	6,165	42	-	15,373	101	21,936
1979	165.0	8,680	43	-	10,244	1,050	20,347
1980	736.0	7,056	705	214	8,834	2,662	20,943
1981	298.6	6,265	141	75	8,444	3,422	19,036
1982	560.5	3,956	276	90	25,792	5,993	37,398
						TEN YEAR TOTAL..	222,276

Source: WDNR Bureau of Forestry Madison, WI
Northwest Regional Planning, Spooner, WI

Table 3a, shows the commercial forest composition and scheduled harvest by timber type.

Table 3a. --Commercial Forest Composition by Type. 1984-1993 Scheduled Harvest by Timber Type (Acres).

	(Acres)	(%)	Rotation Harvest	Thinning Saw	Thinning Pole
White Pine	444	.3	14	-	197
Red Pine	6,148	4.5	12	-	3,058
Jack Pine ***	13,984	10.3	2,330	-	-
Fir-Spruce	1,821	1.3	721	-	-
Swamp Conifer	1,876	1.4	693	-	-
Black Spruce	2,732	2.0	*	*	*
Cedar	501	.4	*	*	*
Tamarack	1,550	1.1	*	*	*
Hemlock-Hardwoods	37	.	**	**	**
Northern Hdwds	20,510	15.2	-	-	9,906
Oak	11,510	8.4	-	1,900	3,694
Scrub Oak	1,185	.9	688	-	-
Swamp Hardwood	6,983	5.2	2,917	-	-
White Birch	817	.6	175	-	-
Aspen	53,832	39.8	12,300	-	-
Grass, brush, shrubs, etc.	11,464	8.5			
TOTAL COMMERCIAL FOREST	135,278	100.0%			
TOTAL COUNTY FOREST LAND ENTRY	148,216				

* SC, SB, C, T combined in this schedule under SC.
** HH and NH combined in this schedule under NH.
*** Pj regeneration questionable on 5000 acres due to Oak Lake Fire (1980).

THINNING TECHNIQUES FOR POLE SIZE HARDWOODS

Management of pole size hardwood stands have taken a back seat in most areas. Poor markets, high logging costs, and being labor intensive are a few of the reasons loggers and foresters alike have used to avoid these stands. Markets are changing, however, along with the development of new machinery and logging systems. I will be discussing three of these systems: mark selection, strip selection and the strip mark selection. The following are my views on marking and silvicultural considerations, and damage potential from past experience with specialized equipment and labor intensive operations.

First, what kinds of stand are we talking about? The size class is predominately 5-10 inches averaging 9 inches. These are predominately second growth stands, commonly even aged. The basal area is anywhere from 90-200 square ft/acre. The number of stems per acre is running anywhere from 500-700 trees per acre. This would be in the diameter class of 3" and above. The age of the stands run from 45 to 60 years. Most of them originating back in the early 1900's, dating back to the fire and logging era.

Marked Selection.

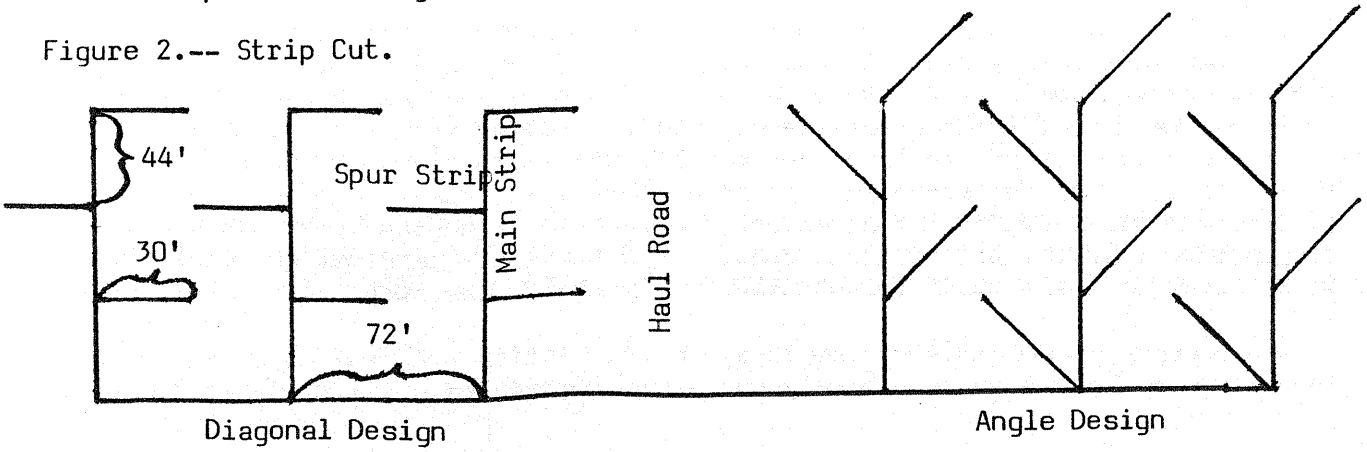
The first system we will discuss is the marked selection method. We all are familiar with how a marked selection works within a saw timber stand. Let us see how it works when it is applied to a pole size situation. The marking considerations are the same. The selection is based on risk, cull, form, species, crown position and size class. A forester in a pole size stand can normally mark one to one and a half acres per hour. This is marking out approximately 6-7 cords per acre.

When you look at the silvicultural aspects of a marked selection in a pole stand, it is one of the best. It is the most adopted or widely used practice when we discuss hardwood marking. However, when one looks at damage, this is where the system has a high potential of failing, particularly when there is poor supervision. It becomes very difficult for a logger to go into a pole size stand with 600-700 stems to the acre without doing damage to the residual crop trees. Damage can be minimized, however, by considering a few contract restrictions. These being: 1) Put a seasonal skidding restriction on the sales. Do not allow skidding operations during the slippery bark period. Particularly during May and June and possibly July. 2) Limiting stringer lengths. A commonly used stringer length for saw timber stands is 16 feet. Practicality of this restriction on pole size stands is doubtful. Many of the trees here being harvested are only 2-3 sticks. 3) Limit skidder size particularly width. A specific width should be determined by the local land manager by reviewing the available machinery in the area. 4) The fourth restriction and probably the most important, is close sales administration followed by penalities. The operator must have a clear understanding of what is expected of him before he begins a sale. I guarantee if you put all four of these restrictions on a sale, you won't have any damage, but you may not have any loggers cutting your sales, either!

Strip Cut.

The next system, the strip selection or strip cut is also a method that can be used in pole sized hardwoods. The design we have used is similar to a wish bone pattern. (Fig. 2).

Figure 2.-- Strip Cut.



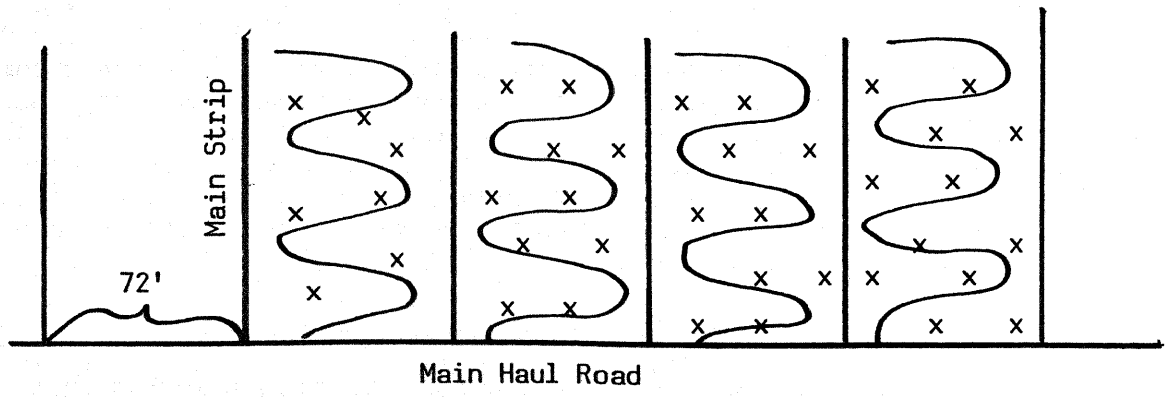
It was felt this system would best facilitate our loggers present degree of mechanization. This is manually felling followed by a cable skidding. Marking considerations are based on the main strips being cut to a 10-foot width and spaced approximately 72 feet apart. Spur strips are then marked and set at a diagonal or angle to the main strip. The spur strips are 44 feet apart and are 30 feet long. Cutting width of the spur strip is approximately 2-3 feet wide. This type of marking requires minimal skills as trees are being marked strickly by a compass line. Spacing and width of strips are dependant on final stocking levels desired and vary with individual stands marked.

Silvicultural aspects on this type of cutting scheme are the poorest. Trees marked are based strictly on your compass heading. There is no consideration to any of the other factors I mentioned earlier in the marked selection to improve quality. However, this type of cut may have possibilities if you are working within a low-site hardwood stand where quality is not important, but are more concerned with fiber production. Damage potential was the least in this design. It was limited mainly to the pivot trees associated with the spur and main strips. Foresters marking productivity in this type of marking system is approximately 2½ acres per hour.

Strip, Marked Selection

The final cutting scheme is a strip, marked selection. (Fig. 3).

Figure 3.-- Strip, Marked Selection.



It is similar to the strip selection with the operation of the machinery being limited to your main strip. Strips are put in 72 feet apart, but may vary with the type of equipment used. A distance of 72 feet apart was chosen in our cuts anticipating manual felling followed by cable skidding from the main strips. After your main strips are layed out the forester selectively marks between these strips. The foresters marking productivity in this type of marking scheme is the fastest averaging 3.7 acres per hour. This is a good scheme to use in conjunction with the private land owner. The owner can mark out the strips with a compass while the forester selectively marks the stand within the interior.

Silviculturally this system is a good compromise. Access is provided into the stand, and you also selectively mark and improve the quality within the strips.

Damage associated with this system was variable, dependent on the type of equipment used and the season it was logged. Here I would like to stress again season. Even a good operator with a small tractor and jammer can do considerable damage during your loose bark period.

I had the opportunity to see the Timco Feller Buncher followed with the grapple skidder working in this particular cutting scheme. Identical stands were cut but during different seasons, spring versus fall. The spring cut site had moderate to heavy logging damage while the fall cut showed very little damage and was confined mainly to your major pivot trees. Because of this and other spring cuts we have seen, we normally put on as a minimum a no skidding restriction during May, June and July.

One additional point associated with both strip methods of cutting is the road cost. It has not yet been discussed, but is a substantial cost when considering a highly mechanized logging system. When laying out the main haul road systems for your strip method cuts we attempt to stay within a 1/8 to 1/3 mile maximum skid.

CONCLUSIONS

There are three points I want to stress with you before leaving. 1) Be adaptable. Listen to the logger and the researchers. Take the best of both and fuse their ideas together. 2) Minimize damage. Stem damage to our pole stands today will be with us for the next 50 to 100 years. 3) Develop a cutting system on your forest that can be used with a variety of different pieces of equipment. Very seldom does the forester know before hand the exact piece of machinery or operation that will be used in a particular stand.

The strip cut with the mark selection between has the potential of addressing these points. One can go in with a fully mechanized system (Feller Buncher with Grapple Skidding) or with a small ma and pa operation. Both operations will come out fairly good.

LITERATURE CITED

Arend, John L., and Scholz, Harold F.
Oak forests of the Lake States and their management. N. Cent. Forest Exp. Sta., St. Paul, Minn. 36 p., illus. (U.S.D.A. Forest Serv. Res. Pap. NC-31) 1969.

Arola, R. A., Hillstrom W. A. Mechanical Thinning of Northern Hardwood: Proceedings, IUFRO P. 402 Symposium; Corvallis, Oregon: 1977, 25P.

Biltonen, Frank E., William A. Hillstrom, Helmuth M. Steinhilb, and Richard M. Godman. 1976. Mechanized thinning of northern hardwood pole stands: methods and economics. USDA For. Serv. Res. Pap. NC-137, 17p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Northwest Regional Planning Commission (Mike Luedeke) & Wisconsin Department of Natural Resources (Dick Beri). Timber Forcast: Wisconsin's Public Forests 1984-1993: Northwest Regional Planning Commission, Spooner, WI: 1983. 80 p.

Tubbs, Carl H. Manager's handbook for northern hardwoods in the north central States. USDA For. Serv. Gen. Tech. Rep. NC-39, 29 p. North Cent. For. Exp. Stn., St. Paul, Minnesota. 1977.

SAWMILL INDUSTRY VIEWPOINT

Richard Connor, Jr.[1]

Abstract.--A number of concerns are listed in regard to hardwood thinning. They include a concern for the public agencies to emphasize hardwood thinnings in their timber sales at the expense of sawtimber stands, lack of markets for basswood, the abandonment of railroad transportation, over-thinning, conventional skidding versus the strip method, and the need to acquaint our elected officials with the fact that the hardwood forest can support increased harvests.

Since 1969, Pine River Lumber Company has purchased approximately 10,000 acres of northern hardwood timberland. These lands are basically pole stands. Being close enough to the Wisconsin pulpwood market, we have been able to operate them using the conventional small forwarder and pole skidder operations. We believe these lands are in good shape, and we have marketed most all the products that we would want to develop from them.

Goodman Forest Industries, which we took over from Louisiana-Pacific on October 1, 1983, is a veneer mill and a sawmill which operates a cutting license on 70,000 acres of lands owned by Universal Oil Products, Inc. in Florence and Marinette Counties. In the past, these lands have been logged basically for the 6.2 million feet of sustained yield sawlog and veneer log production that is available off that acreage.

Little attention has been given to the tremendous pulpwood production. We are starting this year to operate the pulpwood acreage, and with continued improvement in pulpwood consumption, we will be able to develop this resource and properly manage this heretofore idle pulpwood resource. At present, on these lands, we are using conventional forwarder-type skidding equipment. Universal Oil Products has allowed us to use John Deere and Gafner Iron Mule forwarders in place of the old D-2 Caterpillars, which they favored for years.

I personally own approximately 3,000 acres of hardwood timber that are being selectively cut using forwarder and pole skidder-type operations, so you can see that I do have a commitment to the management of northern hardwood forests.

I have some concerns in the thinning of our hardwood forests. My first concern is the anxiety of our public agencies to thin hardwood pole stands now that hardwood markets seem to be coming available. I caution them not to forget the sawmills that are dependent on log production off our Federal, State,

---

[1]President, Pine River Lumber Company, Long Lake, Wisconsin.

and County forest lands. These mills need 10-inch and larger sawtimber and cannot operate on box bolt-type thinnings. Many of these mills do not have timberlands of their own to fall back on. Mills like this include Steiger Lumber Company at Bessemer, Michigan; Wenos Lumber Company at Iron River, Michigan; and my own company, Pine River Lumber Company at Long Lake, Wisconsin.

Point number two--we need new markets for basswood. Many of the pole stands in my area contain as much as 50 percent of their volume in basswood. The debarking problem prevents it from being used for waferboard production where it would make an ideal raw material. It seems to me that we can fix the satellite in space, but we cannot debark basswood. There is room for research in that area.

Point three--transportation. We cannot continue to let our railroads abandon right-of-way at will and place more burden on truck transport and our already neglected state highway systems in Wisconsin and in the Northern Peninsula of Michigan. It is my belief that Michigan will be forced to adopt the Federal standard of 80,000 pounds. Just think for a minute, if you will, the added traffic that will put on our highway system.

Point four--I do not know how many of you are privileged to know Bob Colby. Bob was a forester with Connor Forest Industries, and I think he worked for the company about 35 or 40 years. Bob often mentioned that some of the best pole stands he had ever seen had never seen a power saw. They have been thinned by Mother Nature and have achieved the necessary height by reaching for sunlight. We, in the sawmill business, know that height is important to the production of quality sawtimber, and I caution that thinning too early can give us diameter growth at the expense of height and epicormic branching.

Point five--I tend to favor conventional skidding in hardwood timber over the strip method. Especially in my area, the high percentage of basswood creates a high volume of unsalable product.

Point six--I understand the Forest Service, in fiscal 1985, proposed funding that will support a cut of 11.2 billion feet. In talking with Jim Berlin, the supervisor of the Nicolet National Forst, he felt it is time to acquaint our elected officials with the fact that the hardwood forest in the Lake States has the potential to support increased harvest opportunities.

Point seven--I believe in the intensive multiple use management of our hardwood forests. I do not think we should thin these forests to the point of conversion. I have seen too many good hardwood forests slashed and converted to aspen and red pine, and I am certainly not in favor of that on our public forests nor on our forest croplands in Wisconsin and Michigan.

RESEARCH NEEDS FOR HARDWOODS IN THE LAKE STATES

David F. Karnosky [1]

Abstract.-- Significant progress has been made in the management and utilization of hardwoods in the Lake States over the past thirty years. However, there is much room to improve on the current growth and use of hardwoods in the Great Lakes Region. For example, the substantial hardwood resource in the Upper Penninsula of Michigan is greatly underutilized. Additional research accompanied by transfer of information to the forest products industry is needed in order to more effectively use our hardwood resource. Seven research priorities are presented in this paper.

I am a forest geneticist -- not a hardwood manager. However, in examining research priorties at Michigan Technological University, I have had the opportunity to discuss research needs for both conifers and hardwoods with representatives from industry, university, and government in the Lake States. Thus, it seems appropriate that I summarize some of what I perceive as the most important research needs for hardwoods in the Lake States. To put this paper in perspective, let me first say that this is an extremely complex topic, because research needs vary from agency to agency and from company to company within a given industry. It is a good one for a geneticist to discuss as we are accustomed to dealing with variation. I will present seven research areas, and I will outline some open questions for each area.

First, there is much we still need to know about site evaluation. What species and what stocking levels are optimum for a given site? Often times in the Lake States, we are faced with mixed hardwood sites or hardwood/conifer combinations which have been cut over once or twice. Thus, it is generally difficult to determine what are the best uses for those sites by looking only at the existing trees. Coffman et al. (1983) have developed a site evaluation system that is proving very useful in determining the best uses of a given site but this system needs additional testing, especially outside of the Upper Peninsula of Michigan.

In contrast to the opinions of some of the other speakers at this meeting, I think we still do not know all we need to about all-age hardwood management. For example, what are the best ways to move a stand to an all-age system? What are the most cost effective ways of doing this, and what are the best ways to maximize returns? How fast should we bring existing unmanaged stands into the all-age management system? In my opinion, these are still open questions. We have certainly gained a lot of experience over the last 30 to 40 years through the extensive efforts by Arbogast (1957), Crow et al.(1981), Erdmann (1983), Tubbs, (1977) and others, but there is

---

[1] Professor, School of Forestry and Wood Products, Michigan Technological University, Houghton, Michigan, 49931.

still considerable refining to be done.

The area of growth and yield modeling still is an exciting area for research, especially to include in-growth, mortality, and changes in log quality in these models (Buchman and Shifley, 1983, Reed et al. 1985). Growth models are also needed for mixed species forest stands so that interspecific as well as intraspecific competition is accounted for (Lynch and Moses, 1983).

Michael Thompson of the Forestry Sciences Laboratory, North Central Forest Experiment Station at Houghton, Michigan gave a very intriguing talk on harvesting equipment and techniques at a recent Xi Sigma Pi Forestry Symposium at Michigan Technological University. It was exciting to see some of the new machines that are being developed used to harvest, delimb, and process trees. It was pointed out, however, that we still do not have a machine to delimb hardwoods. Such a machine could greatly improve logging efficiency with small hardwood trees and so engineering research is warranted here. Additional research and demonstration of the chunkwood production system described by Arola et al. (1983) is neccesary to document the great potential of this system for processing fuel wood from low quality hardwoods or from hardwood thinnings or for producing materials for composite wood products.

As Johann Bruhn, Carl Trettin, and others at this symposium have pointed out, there is a need for additional study of ways to minimize damage to the residual stand and also to the site with harvesting, skidding, bunching, and loading equipment. Few thorough studies have been done to detail logging-related damage to either the remaining trees or to the site. And even less information is available on colonization of selectively-logged stands by pathogenic fungi.

Perhaps the most important research area is in developing ways to increase utilization of low-quality hardwoods and hardwood residues. Development of new composite wood products, finding ways to combine wood with plastics, and exploring ways to decrease the weights of composite wood products are important research areas. One of the areas that is currently being studied at Michigan Technological University's Institute of Wood Research is a way to decrease needs for synthetic glues in composite wood products. Researchers are examining various microorganisms that can break down bonds in wood and open up natural bonding sites. Methods for marketing our Lake States hardwood products in and beyond our region are also needed.

Hardwood management has been shown to yield some favorable rates of return on investment as has been shown by Jim Johnson at this meeting. However, additional economic studies of this type must be done on more sites in the Great Lakes region. McLintock (1979) also pointed out the need for economic studies for hardwood management by small private land owners.

SUMMARY AND CONCLUSIONS

I have described seven research priorities for harwoods in the Lake States. Five of the seven (site evaluation, growth and yield information, economics, equipment for converting and preparing woods residue for use as fuel, and increasing utilization of low quality hardwoods) were listed among the highest research priorities for eastern hardwoods by the Hardwood Research Council (McLintock, 1979).

LITERATURE CITED

Arbogast, C., Jr. 1957. Marking guides for northern hardwoods under the selection system. USDA Forest Service Lake States Forest Exp. Stn. Pap. 56. 20 pp.

Arola, R.A.; Winsauer, S.A.; Radcliffe, R.C. and Smith, M.R. 1983. Chunkwood production: A new concept. Forest Products Journal 33 (7/8): 43-51.

Buchman, R.G.; and Shifley, S.R. 1983. Essentials for forecasting mortality trends and changes. In: Bell, J.F.; and Atterbury, T. (Eds.) Proc. International Conf. on Renewable Resources Inventories for Monitoring Changes and Trends. Corvallis, Oregon, pp. 141-144.

Coffman, M.S.; Alyanak, E.; Kotar, J.; and Ferris, J.E. 1983. Field guide habitant classification system. CROFS, Michigan Technological University. 139 pp.

Crow, T.R.; Tubbs, C.H.; Jacobs, R.D.; and Oberg, R.R. 1981. Stocking and structure for maximum growth in sugar maple selection stands. USDA Forest Service North Central Forest Exp. Stn. Res. Pap. NC-199. 16 pp.

Erdmann, G.G. 1983. Tending valuable young northern and central hardwoods in natural stands. In: Stier, J.C. (Ed.) Silviculture of established stands in North Central forests. SAF Publication 83-11, pp. 76-94.

Lynch, T.B., and Moser, J.W., Jr. 1983. Modeling mixed species forest stands. In: Bell, J.F.; and Atterbury, T. (Eds.) Proc. International Conf. on Renewable Resource Inventories for Monitoring Changes and Trends. Corvallis, Oregon. pp. 573-576.

McLintock, T. 1979. Research priorities for eastern hardwoods. Hardwood Research Council. 70 pp.

Reed, D.D.; Jones, E.A.; Leary, R.A.; and Lyon, G.W. 1985. Projection of stem quality distribution in sugar maple stands. Abstract accepted for Fifth Central Hardwoods Conference (In Press).

Tubbs, C.H. 1977. Manager's handbook for northern hardwoods in the North Central states. USDA Forest Service North Central Forest Exp. Stn. Gen. Tech. Rep. NC-39. 29 pp.

CONVERTING TIMBER STAND IMPROVEMENT AREAS TO COMMERCIAL THINNING IN THE NORTHEASTERN AREA

Lloyd R. Casey[1]

Abstract.--Since 1979, fewer acres of timber stand improvement have been completed. Better markets for fuelwood and chips have enabled the thinning to be completed commercially. Problems associated with completing the needed thinning include: local restrictive cutting ordinances; limited markets in localized areas; small size tract per average woodland owner; and lack of available professional forestry advice. Solutions to these problems come from all foresters, both public and private, working together as a team.

The 20 Northeastern States contain approximately 157 million acres of commercial timberland. Of this figure, 35 percent or 55 million acres are in the pole-size class. Although some of these stands have been thinned and there are older stands that could be thinned, these 55 million acres provide a good representation of the potential acres needing thinning (table 1) U.S. Department of Agriculture, Forest Service 1978).

Table 1.--Pole-size stands in the eastern U.S.

State	Thousand acres	Million cubic feet	Cubic feet/acre
Connecticut	600.1	1131.8	1,886.019
Delaware	83.3	214.4	2,573.830
Illinois	944.7	1,700.5	1,800.042
Indiana	818.1	1,472.6	1,800.024
Iowa	356.6	641.9	1,800.056
Massachusetts	947.2	1729.2	1,825.591
Maryland	665.5	1,171.1	1,759.730
Maine	5,339.6	12,193.8	2,283.654
Michigan	8,271.5	14,888.7	1,800.000
Minnesota	8,032.6	14,458.7	1,800.002
Missouri	4,927.5	8,869.5	1,800.000
New Hampshire	1,555.6	3,338.3	2,145.989
New Jersey	388.1	687.7	1,771.966
New York	4,375.3	6,531.9	1,492.903
Ohio	1,537.9	2,267.7	1,474.543
Pennsylvania	5,008.1	9,865.2	1,969.849
Rhode Island	133.0	199.2	1,497.744
Vermont	954.5	744.7	780.199
West Virginia	3,959.6	5,466.3	1,380.518
Wisconsin	6,584.2	11,851.6	1,800.006
	55,483.0	99,424.8	35,442.670

[1]Rural Forestry Assistance Specialist, Northeastern Area, State and Private Forestry, USDA Forest Service, Broomall, Pennsylvania.

Conservatively speaking, about one-third of the stocking should be removed in order to bring these stands into optimum growing conditions. This means that there are presently 33,141 billion cubic feet or 414 million cords available for harvesting. This does not count those stands that should be clearcut for various management purposes.

OPPORTUNITIES

Until recently, all markets for roundwood required clearcutting if the timber was purchased. However, several changes have occurred in the marketplace.

New equipment has been developed that has made thinning existing stands more profitable. Increased markets for soft hardwood for the manufacture of formulated board products have made thinning of hardwood stands more profitable. The increases in the cost of fuel oil have brought on an unprecedented demand for fuelwood.

Only six states in the area do not have sufficient demand for fuelwood to have a ready market for stumpage; i.e., Illinois, Indiana, Iowa, Missouri, Ohio, and West Virginia. We have witnessed the rise in the value of fuelwood stumpage from nothing to $20.00 per cord in a matter of a few years. In 1979, while employed with the Navy Department, I offered a fuelwood sale of over 100 cords of red maple. The offers varied from, "How much will you pay me to clear the area?" to, "I'll take it off your hands at no charge." Today this area in Massachusetts is buying fuelwood stumpage at $10.00 per cord. New Jersey has seen stumpage prices rise to $30.00 per cord in some areas. The States of New Jersey and Connecticut have had to institute a lottery system in order to allow residents to purchase fuelwood from the States' forest land.

In the last five years, timber stand improvement (T.S.I.) operations supervised by State Forestry organizations on private land in the 20 Northeastern States have dropped from 100,000 acres in 1979 to 67,000 acres in 1983 as shown in the following tabulation.

Year	Acres	Percent of 1979
1979	99,854	
1980	101,225	102
1981	90,410	91
1982	78,507	79
1983	67,290	68

Most of this has come about because of the increased use of fuelwood.

As I see it, all this demand has been generated because of the high cost of energy. People have turned to wood as the main source of heat. Some areas in New England report that over 40 percent of the residents use wood as a primary source of heat.

Even though the trucking industry has been de-regulated, transporting lumber and other forest products from the West Coast has become a very expensive business. Corporations are seeking manufacturing locations close to the resource and near the market. Over 58 percent of the population of the United States lives within the Northeastern Area.

All this activity has concerned many conservation organizations. One New York government official has warned that the State of New York could be stripped of its wood resource, while others are concerned that high quality timber will be burned for fuel rather than being made into high quality furniture and other products.

During a recent public hearing, a Sierra Club official requested an expansion of the State's service forestry programs because so many people were being persuaded to harvest their timber at low stumpage prices and then clear-cutting these young stands.

The demand for forest products has been high enough to keep stumpage prices stabilized throughout the recent recession, although over the 20-state area they did not keep up with inflation.

PROBLEMS

With all these good markets, high prices, and adequate supply, why isn't all the thinning being done? Loggers now have to contend with many new regulations. Local cutting ordinances have effectively stopped many logging operations. The State Forestry organizations of Massachusetts, Connecticut, and New Jersey have written model ordinances in order to be sure that owners can manage their forests for timber products.

Localized market areas and small acreages are also problems in certain localities. The average size ownership in the Northeastern Area varies from 10 acres in Connecticut to over 90 acres in Maine. Seventy-two percent of the owners own less than 10 acres (Birch et al. 1982). Many owners have acreages too small to manage economically, unless they join with neighbors in order to have holdings of sufficient size. Some of these lands are managed only for the owner's fuelwood.

Another problem that prevents the proper thinning of forest stands is the lack of professional assistance. Of all the timber that is harvested within the Northeastern Area, less than 11 percent of the owners have the assistance of a forester of any kind. The State Forestry organizations service about 3 percent of these harvesters.

At the present time, there are approximately 300 State Service Foresters (down from 495 in 1980) available for assistance to landowners, and there are over 600 private consultant foresters assisting in this effort. This means that there are less than 1,000 foresters for 157 million acres of forest or one forester for every 157,000 acres. This does not take into consideration the number of industrial foresters that are available because the figure is not available. If we guessed that there were 500 industry foresters, the forester to forestland ratio would be 1:112,142, which is unacceptable for proper forest management.

The last major reason that landowners do not thin their forests is that they have a bias against cutting. Landowners' studies conducted by the Northeastern Forest Experiment Station show that less than 50 percent of the owners surveyed would be harvesting in the next 10 years. When queried as to the main reason for owning timberland, aesthetics and wildlife were stated far more often than timber production.

CONCLUSIONS

In summary, the markets for hardwood thinnings are available in many areas. There are sufficient acreages of pole-size stands in need of thinning, and prices have risen for fuelwood in many areas to encourage landowner participation in more intensive forest management. Logging equipment has become more sophisticated, and they can operate in the woods more efficiently and economically than in the past. However, there is a need to determine the proper mix of equipment for an efficient thinning operation.

However, there are many stumbling blocks in the way of getting the job done. Local cutting ordinances are in need of monitoring and changing in order to meet the needs of the landowners, loggers, and the township taxpayers.

There are still areas that need markets. These states are also the same states that have been blamed for acid rain production. If the coal burning utilities would burn a coal-wood mixture, one benefit is a major reduction in the sulfide emissions, and in turn, a market for the thinning material would be available to the landowners.

The formation of forest management districts or landowner cooperatives for the management of small parcels would bring more timberland under proper forest management in economical units.

The last two problems may be the most difficult to overcome. But I believe that the cooperation of all foresters, including industrial, government, and private consultants, can solve the problems. More foresters are needed in the field. I propose that the Federal government provide assistance to new consultants coming into practice. State foresters provide those services that cannot be financed from the proceeds, such as the development of management plans and education of landowners and the general public as well. The consultants in turn would follow the management plan as a referral. In other words, there would be teams of foresters--the public foresters providing umbrella services with specific on-the-ground work being done by the consultant. With the increased activity within a community, I am sure that more timber management will take place. I predict that, within a few years, commercial thinning will increase to the point of possibly eliminating TSI operations as a major forest management practice. Thinning will no longer cost; it will pay and, hopefully, be done on a large scale.

TIMBER SUPPLY AND HARDWOOD THINNING OPPORTUNITIES ON MICHIGAN'S NONINDUSTRIAL PRIVATE FORESTS

Eugene M. Carpenter[1/]

Abstract.--Nonindustrial private forest landowners control 58 percent of the hardwood forest resource in Michigan and provide 70 percent of the annual removals of hardwood growing stock. Though timber production is not an important objective for NIPFL's, most of their timber will be available in the long run. Whole-tree thinning may encourage these owners to harvest. Thirty-one percent of the owners who said they never planned to harvest indicated they would consider a whole-tree thinning. Owners' attitudes towards timber harvest often change over time.

In the brief time I have, I'd like to talk about nonindustrial private forest landowners (NIPFL) as timber suppliers; their control of the hardwood forest resource in Michigan; how timber harvesting intentions and actions change; and how this is influenced by tenure, size class of ownership, and residency.

First, I'd like to tell you where I think NIPFLs stand as timber suppliers, and how thinning--especially a whole-tree improvement cut--could increase short run timber supplies from these ownerships.

In a recent statewide study of nonindustrial private forest landowners in Michigan, we asked owners if they intended to harvest timber in the next 5 years, 5 to 10 years, sometime in the future, or never (table 1).

Table 1.--Estimated number of private owners and acres of commercial forest land owned, according to time of future harvest, Michigan, 1981[a/]

Time of Future Harvest	Private Owners		Acres Owned	
	Number	Percent	Number	Percent
In next 10 years	84,350	22	3,092,350	35
Sometime in future	101,550	26	3,224,550	37
Never	153,200	40	1,832,950	21
No answer	44,600	12	648,550	7
Total	384,700	100	8,798,400	100

a/ Includes all private owners of 1 to 9,999 acres of commercial forest land. Excludes forest industry owners.

1/ Market Analyst, North Central Forest Experiment Station, USDA Forest Service, Duluth, MN.

Statewide, we estimated 48 percent of the owners plan to harvest sometime, 40 percent never intend to harvest, and 12 percent did not answer the question. Forest land owned by these groups were 72 percent, 21 percent, and 7 percent, respectively, of the commercial forest acreage owned by small nonindustrial private forest landowners in Michigan.

Later, we asked owners if they would consider a whole tree thinning to improve the growth and quality of the residual stand and possibly improve wildlife habitat and woodlot appearance. We indicated this might be possible if markets were available for small and low quality material such as fuelwood. Thirty-nine percent of the owners holding 63 percent of the forest land said they would be interested. Not quite as many were interested in thinning as in harvesting.

But, let's look at the 21 percent of the owners who said they never intend to harvest to find out how they felt about an improvement cut. They own over 1.8 million acres of commercial forest land. To begin with, 47 percent of these owners (holding 42 percent of the 1.8 million acres) said they would not consider an improvement cut (table 2). These owners represent 19 percent of all owners and hold 9 percent of all forest land in Michigan.

Table 2.--Estimated number of private owners who never intend to harvest timber and the acres of commercial forest land they own by their interest in a whole-tree thinning, Michigan, 1981[a/]

Interest in Whole Tree Thinning	Private Owners		Acres Owned	
	Number	Percent	Number	Percent
No	71,950	47	782,850	42
Yes	47,150	31	817,500	45
No answer	34,100	22	232,550	13
Total	153,200	100	1,832,900	100

a/ Includes all private owners of 1 to 9,999 acres of commercial forest land. Excludes forest industry owners.

However, 31 percent of these owners holding over 817,500 acres--these are owners who said they have no intention to harvest timber--said they would consider a whole tree improvement thinning. I maintain that this indicates slash or clearcutting are deterrents to harvest in the minds of some NIPF owners. And, that, if needed, more fiber can be available from the NIPF source by using whole-tree thinning.

Tying this to the theme of the symposium--hardwood thinning--we find that NIPFL's in Michigan:

Own 53 percent of the commercial forest acreage
Own 58 percent of the hardwood forest type
Own 55 percent of the hardwood poletimber acreage

Own 58 percent of the hardwood growing stock volume
Own 60 percent of the hardwood sawtimber volume

Generate 60 percent of the hardwood growing stock growth
Generate 60 percent of the hardwood sawtimber growth

Provide 70 percent of the removals of hardwood growing stock
Provide 76 percent of the removals of hardwood sawtimber

Cut only 54 percent of the total growth of hardwood growing stock on their lands annually
Cut 55 percent of total growth of hardwood sawtimber on NIPF lands annually

Thus, NIPFL's control a major share of the hardwood forest resource in Michigan. And these statistics reinforce the position of NIPFL's as important timber suppliers. Relative to their share of owning the hardwood resource they are providing their share or more of the timber cut. Yet, they are removing only slightly over half of their annual growth.

Bob Stone, in 1967, first realized the seeming inconsistency between case studies showing that a significant proportion of nonindustrial forest landowners would reserve their timber from harvest and forest survey statistics showing that NIPFL's provide a proportion of timber harvest consistent with their share of timber volume and growth--and equal in proportion to other owner classes (Stone 1970).

Now, for those who are concerned about nonresident owners as timber suppliers, our study showed that 53 percent of these absentee owners holding 28 percent of the nonresident held forest land (or about 8 percent of all forest land) said they had no intention to harvest timber (table 3). This compares to 38 percent of resident owners holding 18 percent of the resident held land (about 11 percent of all forest land). Fifty-two percent of these nonresidents with no intention to harvest (holding 58 percent of the land) said they would think about an improvement cut. Nonresidents appeared to be somewhat more receptive to whole tree thinning than residents.

Similarly, owners of half the land in the 1- to 49-acre size class, that have no harvest plans, showed an interest, especially those who own larger tracts in the class. Webster and Stoltenberg (1959) were among the first to report that size class of ownership had a direct influence in predicting response to forestry programs. We demonstrate somewhat the same thing here. The average size of ownership is 36 acres for those with positive harvest plans, 32 acres for those with indefinite harvest plans and 12 acres for those who never plan to harvest. The average ownership expressing an interest in an improvement cut is 37 acres. The average size holding for owners who never plan to harvest but would consider a whole-tree thinning is 18 acres and only 11 acres for those who would not.

Table 3.--Estimated acres of commercial forest land owned by residents and non-residents who never plan to harvest timber, by their interest in a whole-tree thinning, Michigan, 1981[a/]

Harvest Decision	Acres Owned by Residents		Acres Owned by Non-residents	
	Number	Percent	Number	Percent
Never plan to harvest	947,100	18	693,650	28
Interest in whole tree thinning				
No	468,100	49	234,900	34
Yes	370,700	39	401,300	58
No answer	108,300	12	57,450	8
Total	947,100	100	693,650	100

a/ "Residents" live within 25 miles and "non-residents" live 50 miles or more from their nearest forest tract. Owners with nearest tracts from 25 to 49 miles own 69,250 acres and are omitted here.

Consequently, if one feels more fiber may be needed, whole-tree improvement thinning may be the key that unlocks the door to nonresident and smaller sized ownerships. Because immediate returns to the landowner may not cover costs of thinning, consideration should be given to promoting improved wildlife habitat, improved appearance of the woodlot, improved quality, value, and growth of the residual stand.

Now, we've been talking about the short run. And there are those who are fed up to here with statistics relating intentions, attitudes, and characteristics of NIPF owners. We characterize these owners as being completely disinterested in timber production as an objective for owning forest land. And that's what they tell us for the most part. But, we should recognize that they have been holding their own as timber suppliers.

And one possible reason is highlighted in a recent study of NIPF landowners in the Upper Peninsula that included an analysis of change during three time periods (Quinney 1960, Stone 1970, Carpenter, in preparation). We found that the proportion of owners holding a particular intention does not change much. But for a particular ownership (piece of forest land) intentions held by the current owner often have changed--mostly because different owners have different intentions and partly because the same owners change their minds.

In comparing ownership information beginning with a base forest acreage of about 20,300 acres in 1960, we found that 46 percent of the owners of forest land from the original 1960 base were different in 1967. Fifty-five percent of the owners of the 1967 base were different in 1979. And 72 percent of the owners in 1979 were different than those in 1960. (To be an "owner" in 1967 and 1979 each had to own at least a piece of the original 1969 forest acreage).

However, some stability is apparent. From 1960 to 1979, 28 percent of the original ownerships were still held by one original owner, though the forest acreage reported may have changed. About half the owners had within a few acres of the same amount as in 1960, one-quarter had more, and one-quarter had less. (These original ownerships amount to 21 percent of all 1979 ownerships).

Furthermore, from 1960 to 1979, an additional 38 percent of the original owners still own at least a part of the original 1960 forest land. (These original owners amount to 28 percent of all the 1979 owners).

What we have seen, however, is a tremendous change in owners and it is not surprising that this impacts on attitudes, intentions, and actions.

In documenting changing attitudes toward timber harvest we found that thirty-five percent of the responding resident owners had a change in attitude from 1967 to 1979.

--43 percent changed to positive and half of these were different resident owners of property formerly held by a resident

--57 percent of the residents changed to a negative attitude and 63 percent were different resident owners.

Forty-five percent of the responding nonresident owners had a change in attitude from 1967 to 1979.

--60 percent of the shift was to a positive intent to harvest. This was evenly divided between different nonresident owners of property formerly held by a nonresident and different nonresident owners of property formerly owned by a resident. This is an indication that when resident-held property shifts to a nonresident status, the timber may still be available for harvest.

Attitudes and intentions are one thing, positive actions are something else. We found that eleven ownerships whose owners said harvesting was definitely incompatible with other objectives in 1967 had harvested timber by 1979. Two were the same owners, the rest were different. Five said they cut because they needed the money. In addition, three inactive ownerships (unsettled estates), whose owners indicated their timber was unavailable in 1967, had different owners in 1979 who had harvested. Quite obviously from this sample different owners are important as timber harveting prospects and perhaps in making timber available for harvest.

In analyzing the period between 1960 and 1967, Stone also reported that a significant proportion of owners who had no commercial timber objectives in 1960 subsequently had timber sales by 1967. The proportion increased as size of ownership increased.

Turner, Finley, and Kingsley (1977) found a similar situation in Delaware--that there was considerable change in attitude or action after only four years. They concluded that owners of small tracts--often too small for practical harvesting--are the ones who consistently oppose harvesting and they control a relatively small proportion of the State's timber.

We conclude, as did Stone in 1970, that most timber on NIPF owernships will likely be available in the long run. Certainly all indications are that whole tree thinning could assure this availability and provide increased growth, quality, and value of the hardwood forest resource as well.

We feel that the results of these studies have important implications for timber supply in the Lake States if not for the Nation. Certainly, when an assessment for industrial development projects include an estimate of timber available from NIPF ownerships, the amount available may be much larger, especially in the long run, than previously thought.

REFERENCES

Carpenter, Eugene M. The dynamics of forest ownership change and the consequences for timber supply on nonindustrial private lands. Res. Pap. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; (In preparation).

Carpenter, Eugene M. The private forest land owners of Michigan. Res. Pap. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; (In preparation).

Quinney, Dean N. Small private landowners in Michigan's Upper Peninsula. Sta. Pap. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1962. 20 p.

Stone, Robert N. A comparison of woodland owner intent with woodland practice in Michigan's Upper Peninsula. St. Paul, MN: University of Minnesota; 1970. 115 p. PhD thesis.

Turner, Brian J.; Finley, James C.; Kingsley, Neal P. How reliable are woodland owners intentions? Journal of Forestry. 75(8): 498-499; 1977.

Webster, H.H., Stoltenberg, C.H. What ownership characteristics are useful in predicting response to forestry programs? Land Economics. 35(3): 292-295; 1959.

SUMMARY OF HARDWOOD THINNING SYMPOSIUM

Craig Locey[1/]

We have seen examples of what Hank Webster discussed in terms of increased attention on hardwoods in the Lake States, so it is more than fantasizing. We are beginning to see some of these things take place.

The overview we had on some of the pros and cons of silviculture and the comparison of even-age and all-age management, the importance of residual stand density in maintaining quality, and some of the thinning systems are all viable options. We can all relate to our own individual experiences and see where they are beginning to pay off. The fascinating part is that we now are beginning to see economic opportunities to accomplish cultural activities that we all knew should be done, but were economically very difficult to accomplish in the past. To me, it is seeing the light at the end of the tunnel; I believe we are on the threshold of some dramatic changes.

In relation to the discussions we had on damage to residual stands, I have concerns. When we are trying to assess the damage from mechanized processes, I would like to put more emphasis on Alex Shigo's work and see if it is feasible or practical to be able to tolerate a slightly higher percentage of damage of small-diameter stems. Shigo, through his work on compartmentalization of decay and damage to larger diameter stems, really focused on the high economic impact this potential damage may have on the stand. This may be a subject area that needs much more attention.

Relating to Carl Trettin's presentation on soil compaction, it made me question somewhat some of the recommendations we have talked about. One was to encourage skidding operations to spread out over the entire sale area and not concentrate in skid trails. The reason for that was to increase scarification, but with the dramatic impact on soil compaction and its slow recovery rate, I question if that is a wise decision. It is something we must think about.

I appreciate Dick Bierlich's industrial perspective. I work for a public agency, and I am envious of a person who can follow the entire process through from beginning to end and have "total control." That is a real opportunity!

Regarding the economics of early thinning, I will have to admit that I am somewhat skeptical. We have heard profitable statements come from many different directions, so I am inclined to think that Gerald Thiede's opinion is right regarding early thinning as a good investment.

I have a low budget woodworking hobby at home. I didn't realize it, but after listening to Ed Kallio, I found that I have been using the "System 6 process" for quite a few years!

1/Timber Management Specialist, Wisconsin Department of Natural Resources, Tomahawk, Wisconsin.

I appreciate all of the viewpoints of the members of the panel on forest management perspectives. It is interesting to compare these and the problems that are unique to each viewpoint. We are involved in managing public land in terms of multiple use and integrated resource management, and we share Myron Smith's concern. In reality, we should apply the same logic to private ownership. We have just heard about the high percentage of our hardwoods that are in small private ownership and as professional foresters, I believe we can increase management on these lands through intelligent integrated resource management. Many small landowners place more value on wildlife habitat, recreation, etc., than timber production. It is our responsibility to show how silvicultural practices can be the tool to accomplish their goal. Plant succession continues in these stands, and if they aren't managed, they may succession into a habitat stage that may not provide the landowner's management objective. It is a sales program on our part.

Jim Halvorson mentioned some things on contract specifications. That is another basic criteria to accomplish desired objectives.

To get back to Dick Bierlich, you could see there is very tight sales administration on their company lands.

With reference to Lloyd Casey and the fuelwood situation alone, that was the beginning of quite a dramatic change in making TSI operations economical. It will allow us to accomplish activities that were economically impractical in the past. We have a State Forest just a few miles west of Milwaukee. Intense competition for fuelwood in such areas has generated unusually high fuelwood prices.

From the size of the turnout for this program and the fact that attendance and attention has remained high right through the last session, I think we can conclude that it has been a timely and well presented agenda.

CTL:nll

SESSION IV - DISCUSSION

Q1. I believe Jim Halvorson brought up a question for Jerry Thiede when he talked about the very labor intensive nature of TSI marking. Jim indicated that a forester can mark an acre to an acre-and-a-half per hour or 10 acres per day. If manpower is all benefits and transportation is worth $200 a day, you are looking at a cost of $20 an acre. Thinking back to what Jerry said about the State being a no-cost effort now on TSI, I wonder if that included roughly $20 an acre just to mark the stand, much less to have it cut? Would someone on the panel wish to comment on this--Jim Halvorson or anybody that might speak for the State of Michigan?

(Moderator Gaffney) The question refers to an earlier speaker who indicated that the cost of marking is approximately $20 an acre, and he is asking the panel for comments on it. Jim, would you have any idea of what your cost per acre is on marking?

A1. (Halvorson) The cost is actually paid by the taxpayers; it is not passed on to the private landowner or to the County forests, per se. I really do not know. Twenty dollars per acre, that's what you're saying, right?

(Locke) You followed my example, didn't you? If you can mark only 10 acres in a TSI-type marking in a day, then personnel time, whether it is $150 or $200, will amount to $15 to $20 per acre for marking. I am assuming it costs about $20 an acre to do the cutting. I do not think it is exactly a no-cost deal. I do not know if Jerry Thiede is still here to defend himself on that subject. But to me it is not a no-cost deal. There are tremendous costs just in marking.

Q2. Jim, you had some forester productivity data, didn't you, in your earlier trials of marking hardwood thinning sales?

A2. (Halvorson) Those are the figures I quoted. For marked selection, it came out to about an acre or an acre-and-a-half per hour that could be marked. For the strip selection or the strip cut, that came to about 2-1/2 acres per hour--again, based on six to seven cords to the acre. The marked selection between the strips was the most productive from a forestry standpoint; one forester could mark about 3-1/2 to 4 acres per hour. There is a cost there, but I do not really know how to answer your question. We do not figure it in.

(Moderator Gaffney) Jerry Thiede is not here to defend the statistics, so we cannot sufficiently answer that question.

Q3. Most of us are familiar with the work that Dr. Shigo did, which indicated that a good share of our defect, degrade, and discoloration in hardwoods comes from an injury to the tree. A good share of the injury on these trees is from logging. We have been talking in terms of anywhere from 7, 10, or 12 years as a cutting cycle. Why don't we lengthen the cutting cycle? We know how far down in basal area we can go and still maintain quality in the stems. If we can lengthen our cutting cycle to 15 years and assume 90 years as the rotation age of the tree, we would decrease

the number of times we enter that stand by about 33 percent. In addition to saving time for marking and preparing the sales, we could cut out a little more basal area and give more room for skidding and therefore cause less damage.

(Moderator Gaffney) Would anyone care to comment on the feasibility of reducing defects by lengthening the cutting cycle?

A3. (Halvorson) That is a very good point. I agree with you 100 percent. Normally, foresters mark too light rather than too heavy. It is something to consider.

(Moderator Gaffney) Any other comments? I believe marking is most often governed by the growth rate, and much of the work that I have done in the past has shown that 15 to 20 years will give sufficient growth to be able to continue the cutting cycle. It varies by area, the stocking there is to work with, and the economics of the time.

Q4. Mr. Carpenter, has any research been done to determine how much of the wood coming from these private lands is from lands that are being mined rather than managed?

A4. (Carpenter) No, I am sorry, we do not. The study that we did, which is tied in with the statewide forest survey on a plot basis, does not give us those answers. One would guess, though, that if they are cutting--if their tendency is to maintain a low volume of material or a low timber capital because of their high time preference for money--that some of this could occur, but I do not know how much.

Q5. A question to Mr. Connor. I do not know how much basswood you have in that part of the State, but you indicate a considerable amount. I do not know if anybody has ever tried this before, but it is a thought. Basswood holds its taper very well and dries out probably light. If treated, could it possibly be used for cabin logs?

A5. (Connor) I cannot answer that question. I do not think that it would make a good cabin log, although I think we have to try to find some way to get the bark off in the woods. What you are suggesting is that we take it off in the woods in some way. We do not seem to be able to get it off at the plant. Either it comes off in one big piece which plugs all our conveyors, or if it does come off in small pieces, it threads up in the conveyor or the debarking heads. We recently had a situation at Goodman where we finally had to discontinue debarking the basswood sawlogs. It just throttled the debarker head down to the point where it could not operate. So what you suggest may be feasible--some method to get the bark off in the woods.

(Halvorson) In answering that question, it is not rumor that there is a very good possibility that basswood can be cut into cants and used as landscape timber. I believe there is a fellow who has done research on this. I cannot remember where he is located. In fact, he has approached our County and questioned what our supply could possibly be.

☆U.S. GOVERNMENT PRINTING OFFICE: 1986 655-313/40034

Q6. Mr. Connor, do you have any comments on the viability of the System 6 method for utilizing small hardwood logs?

A6. (Connor) Unfortunately, I was not here for that presentation, and I know very little about System 6 techniques. I will have to turn this over to somebody else on the panel who was here for that discussion.

(Moderator Gaffney) Does anyone else wish to comment on this? The question was directed to Mr. Connor asking him, as a sawmill owner, whether he thinks the System 6 method could benefit him in his operation.

(Smith) I suspect you will find that is a specialty type thing. You would have to set up a mill for that based on what we heard this morning, and it probably would not fit in with the system that most sawmillers have today. I think it would take a fairly good investment to set up for it.

(Connor) In the old Conner Forest Industries mill in Laona, they had a technique that utilized the slabs and edgings that developed from the production of high-grade sawlogs. The slabs and edgings were ripped and put through a "pony" resaw, ripped to width, and used very successfully in the furniture production at Laona. I think Steiger Lumber Company also developed a system similar to this System 6. I am referring to a pamphlet on the System 6 that Myron Smith just gave me. They did not take the trim nor debark their low-grade lumber in the mill; they used the low-grade lumber that was undebarked to produce dimension. Paul Steiger always felt that the only profit he ever made making dimension was in making it from the edgings that would have normally been thrown away, which is very similar to this system.

Q7. Mr. Carpenter, do I understand that you feel that the private land will contribute to the long-range timber supply? Do you have studies in other states that verify the same things that you found in Michigan?

A7. (Carpenter) I think our study is the only one that looks at three time periods. The other studies that I mentioned, Bob Stone's study and the Thurner, Fingley, Kingsley study in Delaware, looked at two time periods. I do not think anyone else has addressed that specific problem. I do know that more and more people are accepting it. There was a fellow from Texas who addressed an audience at a meeting in Duluth a couple years ago. He had drawn the same conclusion that this volatile ownership and change generally means that, over a rotation, a great deal of this nonindustrial private forest land will be available for harvest.

When you consider that 72 percent of the land in the Northeast Area is owned by private ownership, and only 6 percent is National Forests, it has to come from there.

U.S. Department of Agriculture, Forest Service. Sturos, John A., comp. Hardwood thinning opportunities in the Lake States. Gen. Tech. Rep. NC-113. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1986. 153 p.

The symposium presents and discusses new information on the hardwood resource, silviculture, harvesting, economics, and product potential from hardwood thinnings in the Lake States. Included are forest management perspectives from the logger, private industry, and state and federal forest managers.

KEY WORDS: Hardwood resource, silviculture, harvesting, economics, wood products, forest management.

1966-86
NORTH CENTRAL
FOREST
EXPERIMENT STATION
20th Anniversary