U. S. FOREST SERVICE

RESEARCH NOTE NC-1

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

A Silvicultural Evaluation of Four Methods of Marking Second-growth Northern Hardwood Stands

Second-growth northern hardwood stands occupy an important segment of the commercial forest land of Upper Michigan and northern Wisconsin. The size- and age-class distributions and species composition of these stands vary considerably, but under all conditions most of the trees are highly defective or poorly formed or of an undesirable species. Forest managers recognize the need for early thinning and improvement cuttings but have hitherto been reluctant to do noncommercial cutting. Now, however, not only are there active noncommercial operations on the National Forests of the region, but also the use of dense hardwoods for pulpwood is making cuttings economically feasible at a much earlier age than was previously possible.

In the Lake States the cut of northern hardwood stands has generally been controlled by marking the individual trees to be removed. In old-growth and regulated stands this management expense is offset by current income. In young second-growth stands, however, the return from the first cutting tends to be submarginal because of the low value of the products removed and the greater expense of examining and marking a large number of trees. On large ownerships, moreover, the time requirements could conceivably place an impossible demand on the technical manpower available.

There are other possibilities for preparing these stands for cutting. The simplest and cheapest would be a diameter-limit designation; but in northern hardwood stands the dollar yield is governed more by species and quality than by fiber production. Other suggested methods involve variable diameter limits for different species, the retention of set numbers of trees within broad diameter classes, mechanically applied spacing factors, and similar rules which the logger is expected to follow. Taylor (1946) analyzed and compared the tree-selection method with three other marking procedures in second-growth Allegheny hardwoods. He concluded that the rules were a makeshift means of preventing destructive cutting and that the rules must be relatively complicated to obtain results comparable with silvicultural marking.

This Note compares four methods of marking or designating the trees to be cut or to be left in the first commercial thinning and improvement cuttings of second-growth northern hardwood stands in the Lake States. Because of the few trees with potential high quality (Eyre and Zillgitt 1953, Hurd 1960), any efficient stand improvement measure should favor the growth and development of these trees. It should also yield adequate returns to cover the costs of cutting and marking.

The study.—In all four techniques described below, the residual density aimed for was 80 square feet of basal area per acre in trees of intermediate crown class and above.

1. *Marking by individual tree selection.* The trees to be removed were selected and paint marked.

2. *Setting a diameter limit from above.* All trees larger than the minimum diameter needed to leave 80 square feet of basal area were designated for cutting.

3. *Setting a diameter limit from above with good growing stock marked to leave.* All trees which met the specifications as good growing stock (adapted from Arbogast 1957) were paint marked to leave. As in Treatment 2, trees larger than the minimum diameter were designated for cutting.

4. *Setting a diameter limit from below with good growing stock marked to leave.* This technique is similar to Treatment 3 except that the trees smaller than a maximum diameter were designated for cutting.

Test areas were established in four widely separated second-growth stands in Upper Michigan. Each stand was typical of its geographical location and needed a thinning and improvement cut. Without markets for hardwood pulpwood the returns would not have covered the cost of the cuttings.

Three of the stands were essentially uneven-aged and had densities between 101 and 112 square feet of basal area per acre. These were stocked with a scattering of large and highly defective sawtimber trees left on the area at the time of the original cuttings, some small sawtimber trees that developed from the poles of the original stand, and smaller trees that became established following the cutting. The fourth stand (136 square feet per acre) originated after a clear cut for charcoal wood and was heavily stocked to poles; 88 percent of the trees were between 5 and 9 inches in d.b.h.

The tests involved no cutting, and all techniques were applied in the same 4-acre plot. The plots were first marked on the individual tree-selection method by a crew of two foresters experienced in northern hardwood marking for that particular area.[1] Next, the good growing stock was marked to leave; the same 2-man crew of research foresters did this on all areas because foresters experienced in this type of marking were not available in all locations. The diameter limits were then set to leave the desired residual density. These were based on a 100-percent cruise of all trees of intermediate crown class and better.

Under the selection method the three uneven-aged stands were marked to 71, 75, and 77 square feet of basal area per acre and the dense pole stand to 100 square feet. The latter residual density is considerably higher than recommended, but it was considered desirable because of the diameter distribution and generally vigorous crowns.

Item	*Basal area (square feet) in study area—* 1	2	3	4
Before marking	112	116	101	136
After marking by:				
Selection	77	75	71	100
DBH limit from above	82	80	74	92
DBH limit from above plus crop trees	78	80	74	94
DBH limit from below plus crop trees	79	82	75	94

[1] *The author is indebted to the following for their assistance in locating, cruising, and marking the study areas: Clark Lebo and John Walstrom, Calumet-Hecla, Inc.; Goodman Lumber Division, Calumet, Mich.; and Leon Anderson, Phillip Jaquith, Malcolm McIver, and Richard Ruppenthal, U.S. Forest Service.*

The residual densities for the diameter-limit techniques differed by as much as 8 square feet per acre from those resulting from the selection markings. The differences are not considered critical for the silvicultural evaluation.

Results and evaluation.—The number of crop trees ranged from 8 to 28 per acre and averaged 17. This is similar to the results obtained by Hurd (1960) in Wisconsin. The species distribution of the crop trees closely followed that of the stand as a whole. Of the 288 crop trees, 45 percent were sugar maple, 42 percent were red maple, and 13 percent were yellow birch, basswood, or beech. Their diameters ranged from 4 to 14 inches, with 94 percent less than 9.6 inches d.b.h. Five percent were in the intermediate crown class, 75 percent were codominants, and 20 percent were dominants.

Treatment effectiveness was judged mainly by the degree of release that would have been given the good growing stock. The degree of release was estimated by the number of adjacent trees of intermediate crown class or better marked around each crop tree by each cutting method. These data are shown in table 1.

The basis for comparing results is this: Judicious thinning of northern hardwood poles generally calls for the removal of one or two, and occasionally three, competitors. Further release increases the likelihood of persistent epicormic shoots and sunscald injury. On the other hand, no release means no alteration of the growth of the desirable trees. (Some trees, of course, need no release—for example, those with full and vigorous crowns.)

This method of evaluation has some obvious weaknesses. Mainly, *which* trees are cut is often more important than *how many*. Nevertheless, the results were so clear that a complicated evaluation seemed unnecessary. We think that, upon studying the data, most hardwood managers will agree with the conclusions.

The diameter-limit designations left the crop trees in highly contrasting environments. In both of the diameter-limit-from-above methods, more than 50 percent of the crop trees would have had no release (table 1). On the other hand, in the diameter-limit-from-below method 54 percent had four or more adjacent trees designated for cutting. This release would have been far too severe for quality increment.

When marking from above, it made little difference whether the crop trees were marked. Most of them were less than 9 inches d.b.h. and therefore had little effect on limits which were 10 inches or above. Actually, it would have been impractical to mark the crop trees because only 5.2 percent would have

Table 1.—Degree of release of crop trees by marking technique

Marking technique	Number of adjacent trees marked for cutting				
	0	1	2	3	4+
	(Percent of crop trees)				
Selection	15	29	33	16	7
DBH limit from above	51	34	12	3	0
DBH limit from above plus crop trees	53	35	10	2	0
DBH limit from below plus crop trees	2	10	14	20	54

been cut. On the other hand, if the crop trees had not been marked in the diameter-limit-from-below, more than half of them would have been cut.

The basic reason for the results in the diameter-limit marking is that trees of like size tended to grow in groups. Thus, either most of the group would have been cut or few or none would have been cut. Moreover, the good growing stock also tended to be in a group of like-size trees. This environment may be a necessity for the development of trees of good quality in unregulated northern hardwood stands. Trees that become dominant early generally develop coarse branching characteristics. On the other hand, trees not reasonably free to grow in height will set low crowns. In both cases, natural pruning will be slow.

Another objection to the diameter-limit cuttings is illustrated by the diameter distribution of the cut and leave trees. In the cuttings from below, the maximum diameter of the trees to be cut varied from 6.0 to 7.6 inches. This size tree is not likely to attract competent cutters. In the diameter-limit-from-above, on the other hand, only sawtimber trees would have been cut. In the stand heavily stocked to poles, 100 percent of the trees above 9.6 inches would have been removed whereas the selection cut would have removed only 21 percent. Although many of the larger trees in the other stands were marked in the selection method, skillful manipulation of the harvesting of the remainder would help finance the series of cuttings required to develop a productive forest.

The selection marking clearly created the best environment for the future growth and development of the good growing stock. Of the crop trees 78 percent had between one and three adjacent trees cut. For the four study areas, the crop trees released in this manner ranged from 76 to 82 percent even though the marking was done by four different crews and previous to the marking of the good growing stock.

Time requirements.—The time required to prepare the stands for cutting was recorded on three of the study areas. The small sample and the study conditions rule out absolute time requirements, but the results indicate that crop tree marking (0.48 man-hours per acre) can be almost as time consuming as marking the trees to cut by the selection technique (0.61 man-hours).

In both methods all trees in the stand must be examined; apparently this tends to offset the advantage of marking the much smaller number of trees classified as good growing stock.

The diameter-limit designations also require a cruise to establish the cutting diameters that would leave the desired residual stand density. The evaluation here was based on 100-percent samples, but a partial-cruise technique was also tested. The technique employed systematically spaced point samples for estimating total basal area per acre, and a transect tally between points for estimating the diameter and species distribution. The sample points gave good estimates of the average stand density (the largest discrepancy was 6 square feet per acre), but the transect tally gave generally unsatisfactory estimates of the diameter distributions. Undoubtedly more efficient cruising techniques could be devised, but a fairly intensive sample probably would be required.

The diameter-limit-from-above without marking crop trees would naturally be the most economical method of preparing the stand for cutting. The only task would be a cruise to establish the cutting diameter. However, the land manager would have to accept the release of only half the crop trees and the other unfavorable features of this system.

In summary.—Considering the silvicultural aspects and the physical application of the techniques, any control other than marking the individual trees to be cut would be hard to justify if the management goal is the production of high-quality saw logs. The forester must evaluate the requirements of each tree rather than those of the stand as a whole.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-2

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Pulpwood Chip Production and Markets in the Lake States

As a major pulp and paper production area, the Lake States is a potential market for pulpwood chips. As a producer of solid wood products, it has a considerable potential for the production of pulpwood chips from coarse sawmill residues (slabs, edgings, and trim) and other sources. Only a small amount of the available residues, however, is now being utilized. In response to numerous inquiries about pulp chips and sawmill residues, a study was begun on their production and marketing as well as any problem aspects that might require additional research. This Note is a preliminary report.

Utilization of wood chips from sawmills for the manufacture of pulp and paper requires that they be relatively free of bark.[1] Barking equipment is now at a cost level that justifies its use at many Lake States sawmills. Under some circumstances and in some locations, the cost of chipping equipment and accessories has declined enough to make their use feasible. This situation is responsible for a relatively recent increase in chip production. Even so, sawmill residues still supply only 5 percent of pulpwood requirements in the Lake States compared with 17 percent in the South.

Present Status of Chip Production

In mid 1965, sawmills with chipping equipment numbered 35 in the Lake States—18 in Michigan, 15 in Wisconsin, and 2 in Minnesota (fig. 1). Four chippers not at sawmills also produce pulp chips from residues of pallet, box, and veneer manufacturers. In addition, two nonintegrated chipping operations concentrate sawmill residues and roundwood. A few of the sawmills concentrate and chip bark-free residues from other mills as well as from their own. Bark removal equipment is used by 87 sawmills in the Lake States.

Railroad and trucking facilities are available to most sawmills. Sawmill residues, however, must be in sufficient volumes to make their transportation as chips or coarse residue to a pulpmill economically feasible. Although most residue is being transported less than 100 miles, some is moving as far as 300 miles.

Marketing

Sawmill residues are sold to pulpmills, other sawmills, or other plants with chipping facilities. Nine pulpmills in the Lake States purchased chips or slabs in 1965. A small volume of chips, including some chips with bark which are used to make roofing felt or similar products, is shipped to mills in adjacent States.

Although some chips and slabs are purchased by volume, most purchases are made on a weight basis using the ton (2,000 pounds) as the pricing unit. This may be either a green ton or its moisture-free equivalent, but the trend appears to be toward the latter. Occasionally chips are also purchased by the unit, which may be 2,400 pounds (1.2 tons) or some other weight specified by the purchaser.

The relationship of green and "dry" chip prices at various moisture contents is shown in figure 2. As an example, a green ton price of $7.00 at a moisture content of 35 percent of total weight is equivalent to a dry-ton price of $10.77. Using a lumberman's moisture measurement basis (dry wood equals 100 percent), this same material would have a moisture content of 54 percent. If a sawmill operator's moisture meter indicates his slabs have 25-percent moisture, this is equivalent to 20 percent based on the total weight used by pulpmills.

[1] *Allowable percent of bark depends upon the type of paper or pulp produced. It is generally 1 to 3 percent but may be 5 percent or more for products such as roofing felt.*

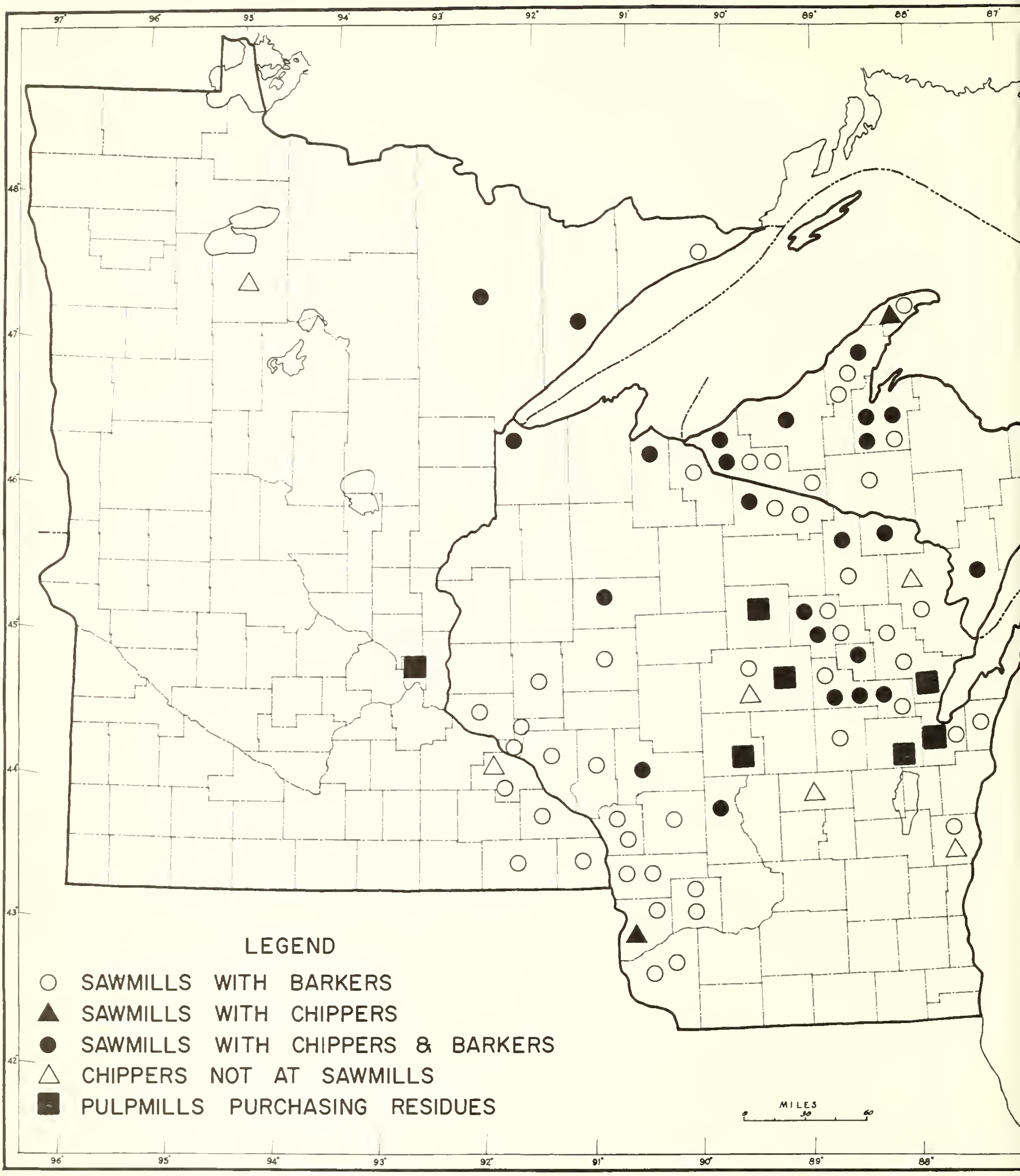

Figure 1.—Location of (1) plants converting residues to chips for pulpm
mills purchasing pulpable residues, 1965.

Delivered prices (1965) in the Lake States for hardwood slabs vary from about $3.50 to $4.50 per green ton and $7.00 to $7.50 per dry ton. Hardwood and aspen chip prices vary from $7.00 to $9.00 per green ton and $14.50 to $16.80 per dry ton. Softwood prices are slightly higher and vary according to species.

Wood Recovery

The yield of chippable residue produced by sawmills is influenced by many factors including the nature of raw materials, end product sawn, equipment used, and management policy. Variations in these factors result in yields ranging from approximately 0.95 to 1.75 green tons per 1,000 board feet of lumber produced.

The amount of chips produced at sawmills can be increased by bringing in or purchasing top bolts, logs below lumber grade, or pulpwood. At this time, however, data are insufficient to permit generalizing on economic conditions favoring or limiting this practice. Major factors to be considered are raw material costs, distance to market, processing costs, and market price.

On the basis of the 1964 lumber production in the Lake States, it is estimated that sawmill residues probably could supply up to about three times the current production of chips. Residues from veneer plants, pallet plants, and related industries could increase this volume. Average annual unused residues between 1958 and 1962 at plants in the Lake States are shown in table 1, and average annual volumes produced in that same period are shown in table 2. Some of the residues shown as used and unused at the time of the survey in 1962 are currently being used for pulp chips.

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(See next page for fig. 2 and tables)

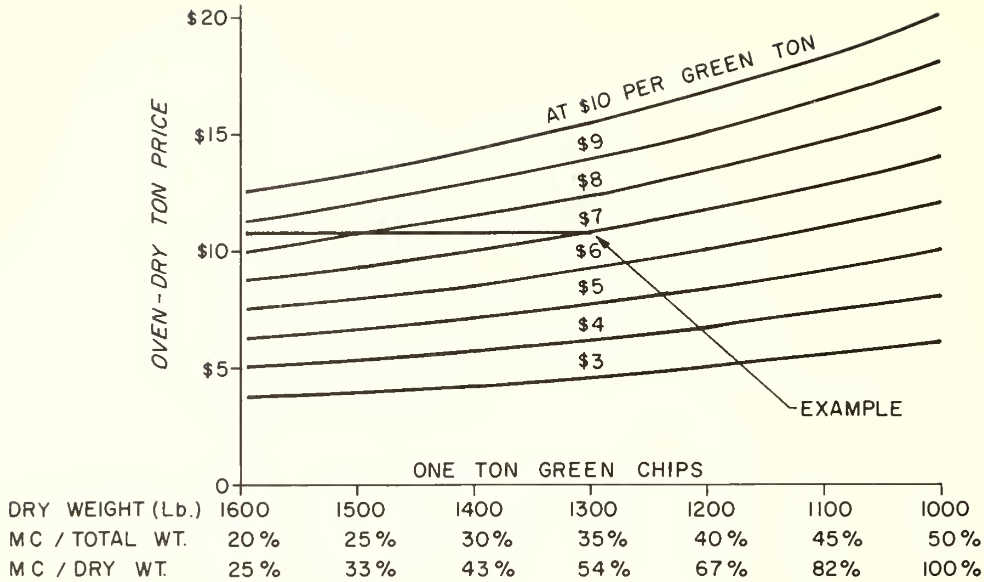

Figure 2.—Comparison of the prices of green wood vs. oven-dry wood. The dry weight of a ton of green wood varies according to species and length of storage. MC=moisture content. MC/total wt. is the pulpmills' moisture measurement basis. MC/dry wt. is the lumberman's moisture measurement basis.

Table 1.—Average annual volume of unused plant residues of softwoods and hardwoods by industrial source and type of residue, Lake States, 1958-62
(In thousand cubic feet)

Species and character of residues	Industrial source			
	Lumber	Veneer	Other primary industries	All industries
All species	28,490	130	445	29,065
Coarse[1/]	10,980	20	160	11,160
Fine[2/]	17,510	110	285	17,905
Softwoods	9,900	--	70	9,970
Coarse[1/]	4,070	--	45	4,115
Fine[2/]	5,830	--	25	5,855
Hardwoods	18,590	130	375	19,095
Coarse[1/]	6,910	20	115	7,045
Fine[2/]	11,680	110	260	12,050

Source: Unpublished data on file at the North Central Forest Experiment Station.

[1/]Slabs, edgings, veneer cores, etc.
[2/]Sawdust, shavings, veneer clippings, etc.

Table 2.—Average annual volume of all plant residues of softwoods and hardwoods by industrial source and type of residue, Lake States, 1958-62.
(In thousand cubic feet)

Species and character of residues	Industrial source			
	Lumber	Veneer	Other primary industries	All industries
All species	56,300	5,550	2,250	64,100
Coarse[1/]	29,900	2,190	1,110	33,200
Fine[2/]	26,400	3,360	1,140	30,900
Softwoods	16,750	--	200	16,950
Coarse[1/]	9,000	--	110	9,110
Fine[2/]	7,750	--	90	7,840
Hardwoods	39,550	5,550	2,050	47,150
Coarse[1/]	20,900	2,190	1,000	24,090
Fine[2/]	18,650	3,360	1,050	23,060

Source: Unpublished data on file at the North Central Forest Experiment Station

[1/]Slabs, edgings, veneer cores, etc.
[2/]Sawdust, shavings, veneer clippings, etc.

U. S. FOREST SERVICE

RESEARCH NOTE NC-3

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Lake States Pulpwood Production Hampered by Adverse Weather and Labor Shortage, 1965

Demand for Lake States pulpwood gained strength in 1965, but production failed to rise. Adverse weather during part of the year and a general shortage of woods labor were deterrents to a larger harvest. The total pulpwood cut was 3,636,000 cords in 1965, representing very little change over the level of the 2 previous years (table 2 on back of page). The tempo of pulpwood activities started leveling off in 1964; until then the pulpwood cut in the Lake States had been increasing about 10 percent annually.

Of the three States, Michigan's production held up the best, registering a 3-percent gain over 1964; aspen and pine were cut more heavily than ever before. Wisconsin production registered only a slight increase. Although the pine pulpwood harvest was the largest ever recorded in the State, the cut of most other species fell below that of 1964. Minnesota's pulpwood harvest, on the other hand, was down by 4 percent, primarily because of smaller cuts of the softwood species.

Logs and bolts cut for pulpwood in 1965 amounted to 3½ million cords, about 96 percent of the total regional output. Roundwood production has remained firm, hardly fluctuating during the past 3 or 4 years. Quantities of wood chips, slabs, and veneer cores for pulping amounted to 4 percent of the total and continued to increase. Local primary wood-using firms shipped 144,000 cords of such material to local and Central States pulpmills in 1965, an increase of 13 percent over 1964.

Total 1965 pulpwood receipts at Lake States mills were approximately 4 million cords, about the same as in 1964. Michigan and Wisconsin receipts were up 4 percent and 1 percent respectively, while those of Minnesota were down 3 percent. Lake States forests supplied 90 percent of the pulpwood bolts received, Canada 8 percent, and western States 2 percent (table 1). Eight Lake States mills received approximately 210,000 cords of wood chips, slabs, and veneer cores for pulping. Lake States wood-using establishments supplied about 63 percent of such wood materials; the remaining 37 percent was received from South Dakota, Montana, Colorado, Idaho, and Wyoming.

Table 1.—Geographic origin and destination of pulpwood received by Lake States mills, 1965

Species	Percent of pulpwood originating from:					Percent of pulpwood received by mills in:		
	Minn.	Wis.	Mich.	Canada	Other U. S.	Minn.	Wis.	Mich.
Aspen	26	34	39	1	-	26	50	24
Balsam fir	35	24	35	6	-	29	54	17
Birch	*	43	57	-	-	*	48	52
Hemlock	-	48	52	-	-	-	97	3
Pine	25	28	31	8	8	28	56	16
Spruce	44	3	12	41	*	27	59	14
Tamarack	65	22	13	-	-	1	99	-
Misc. hardwoods 1/	10	50	40	-	*	11	58	31
Residues	2	38	23	-	37	4	87	9
All wood material	25	31	34	7	3	23	57	20
Previous year (1964)	26	31	33	7	3	23	57	20

1/ Mostly dense hardwoods.
* Less than 1/2 of one percent.

Table 2.—Production and imports of pulpwood, Lake States, 1965
(In standard cords, unpeeled)

Species and destination	Production by states 1/				Imports			Total receipts
	Minnesota	Wisconsin	Michigan	Region	Other U. S. 2/	Canada	Total imports	
Aspen								
Minn.	452,036	1,607	-	453,643	-	8,068	8,068	461,711
Wis.	15,687	605,348	278,348	899,383	-	32	32	899,415
Mich.	-	534	426,019	426,553	-	9,780	9,780	436,333
Total	467,723	607,489	704,367	1,779,579	-	17,880	17,880	1,797,459
Balsam fir								
Minn.	56,907	-	-	56,907	-	2,810	2,810	59,717
Wis.	16,596	50,003	47,534	114,133	-	-	-	114,133
Mich.	-	-	25,346	25,346	-	9,833	9,833	35,179
Exported 3/	115	-	555	670	-	-	-	-
Total	73,618	50,003	73,435	197,056	-	12,643	12,643	209,029
Birch, white								
Minn.	73	-	-	73	-	-	-	73
Wis.	-	23,776	2,517	26,293	-	-	-	26,293
Mich.	-	-	28,993	28,993	-	-	-	28,993
Total	73	23,776	31,510	55,359	-	-	-	55,359
Hemlock								
Minn.	-	-	-	-	-	-	-	-
Wis.	-	60,149	60,332	120,481	-	-	-	120,481
Mich.	-	-	3,721	3,721	-	-	-	3,721
Total	-	60,149	64,053	124,202	-	-	-	124,202
Pine								
Minn.	156,439	300	-	156,739	-	47,904	47,904	204,643
Wis.	24,888	206,319	109,974	341,181	57,902	10,761	68,663	409,844
Mich.	-	-	113,674	113,674	-	-	-	113,674
Total	181,327	206,619	223,648	611,594	57,902	58,665	116,567	728,161
Spruce								
Minn.	134,816	-	-	134,816	1,423	1,919	3,342	138,158
Wis.	87,177	15,240	44,844	147,261	416	152,067	152,483	299,744
Mich.	-	36	16,635	16,671	-	54,251	54,251	70,922
Exported 3/	15,623	-	3,855	19,478	-	-	-	-
Total	237,616	15,276	65,334	318,226	1,839	208,237	210,076	508,824
Tamarack								
Minn.	168	-	-	168	-	-	-	168
Wis.	11,976	4,026	2,412	18,414	-	-	-	18,414
Mich.	-	-	-	-	-	-	-	-
Total	12,144	4,026	2,412	18,582	-	-	-	18,582
Misc.dense hdwds.								
Minn.	39,229	-	-	39,229	-	-	-	39,229
Wis.	-	187,166	31,337	218,503	82	-	82	218,585
Mich.	-	-	118,037	118,037	-	-	-	118,037
Exported 3/	1,713	10,281	-	11,994	-	-	-	-
Total	40,942	197,447	149,374	387,763	82	-	82	375,851
Total roundwood								
Minn.	839,668	1,907	-	841,575	1,423	60,701	62,124	903,699
Wis.	156,324	1,152,027	577,298	1,885,649	58,400	162,860	221,260	2,106,909
Mich.	-	570	732,425	732,995	-	73,864	73,864	806,859
Exported 3/	17,451	10,281	4,410	32,142	-	-	-	-
Total	1,013,443	1,164,785	1,314,133	3,492,361	59,823	297,425	357,248	3,817,467
Residues, softwood								
Minn.	-	-	-	-	-	-	-	-
Wis.	883	9,723	3,175	13,781	76,753	-	76,753	90,534
Mich.	-	-	-	-	-	-	-	-
Exported 3/	-	3,884	2,038	5,922	-	-	-	-
Total	883	13,607	5,213	19,703	76,753	-	76,753	90,534
Residues, hardwood								
Minn.	2,098	6,293	-	8,391	-	-	-	8,391
Wis.	1,553	63,395	27,354	92,302	-	-	-	92,302
Mich.	-	-	18,435	18,435	-	-	-	18,435
Exported 3/	-	4,859	-	4,859	-	-	-	-
Total	3,651	74,547	45,789	123,987	-	-	-	119,128
All wood material								
Minn.	841,766	8,200	-	849,966	1,423	60,701	62,124	912,090
Wis.	158,760	1,225,145	607,827	1,991,732	135,153	162,860	298,013	2,289,745
Mich.	-	570	750,860	751,430	-	73,864	73,864	825,294
Exported 3/	17,451	19,024	6,448	42,923	-	-	-	-
Total	1,017,977	1,252,939	1,365,135	3,636,051	136,576	297,425	434,001	4,027,129

1/ Vertical columns of figures under box heading "Production by states" present the amount of pulpwood cut in each state.
2/ Mostly western states.
3/ Pulpwood shipped to mills outside of Region.
4/ Some balsam poplar and dense hardwoods in Minnesota, mostly dense hardwoods in other states.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-4

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Minnesota's Aspen and Its Projected Supply

Aspen, Minnesota's largest forest type,[1] covers nearly one-third of the commercial forest land in the State. Its major components are bigtooth aspen, *Populus grandidentata,* and quaking aspen, *P. tremuloides,* both fast-growing, generally short-lived, aggressive pioneer species that readily become established in burns and clear cuttings. They cannot be "stored on the stump," as they become decadent rapidly after reaching maturity. Their wood is technically identical.

The Present Stand

Based on the most recent Minnesota Forest Survey estimates (1962), the 5,451,000 acres of commercial forest land in the aspen type are distributed by size, age, and site classes as shown in table 1. Poletimber, the dominant size class, comprises almost three-fourths of the type. More than one-half of the type is in stands 30 to 50 years old—rapidly approaching maturity. Sites of three-fourths of the land supporting aspen are classed as medium and better (site index 56+).

The table also shows the distribution by the relatively new concept of area condition class. Under this concept, commercial forest land is classified according to the amount of growing space occupied by desirable trees compared to the area not occupied by desirable trees. The amount of growing space not occupied by desirable trees is further classified according to the potential difficulty in establishing desirable trees. Thus, an area without a desirable tree but without a serious inhibiting factor is rated higher than one in which undesirable factors, such as brush or cull trees, reduce the opportunity of obtaining desirable stocking on that area.

Almost half of the type is in area condition classes 1 and 2—at least 40-percent stocked

Table 1.—Area of aspen type on commercial forest land, Minnesota, 1962

Item	Thousand acres	Percent of total
Stand-size class:		
Sawtimber	293	5.4
Poletimber	3,833	70.3
Sapling and seedling	1,325	24.3
Stand age class (years):		
Less than 9	321	5.9
10 - 19	559	10.3
20 - 29	1,005	18.4
30 - 39	1,642	30.1
40 - 49	1,202	22.1
50 - 59	409	7.5
60 - 79	260	4.8
80 - 99	52	.9
100 - 119	1	<.1
Site class:		
Excellent (SI 76+)	650	11.9
Good (SI 66-75)	1,591	29.2
Medium (SI 56-65)	1,874	34.4
Poor (SI 45-55)	1,336	24.5
Area condition class:		
1- Desirable	1,310	24.0
2- Moderate and favorable	1,226	22.5
3- Moderate and unfavorable	898	16.5
4- Poor but favorable	690	12.7
5- Poor and unfavorable	1,327	24.3

[1] *See end of Note for definitions of terms used here.*

with desirable trees *and* with conditions favorable for a potentially denser desirable stocking. More than 2 million acres (37 percent) are less than 40-percent stocked with desirable trees—about two-thirds of this having conditions unfavorable for natural regeneration.

Eighty-six percent of the growing-stock volume of 38 million cords is in trees less than 11 inches d.b.h.—that is, in pole-sized trees (table 2). More than half of the sawtimber volume is in trees in the 12-inch d.b.h. class.

Table 2.—Volume of aspen growing stock and sawtimber on commercial forest land by diameter class, Minnesota, 1962, and totals from the 1953 Survey

D.b.h. class (inches)	Growing stock		Sawtimber	
	Thousand cords	Percent of total	Million board feet	Percent of total
6	12,706	33.2	-	-
8	12,363	32.4	-	-
10	7,659	20.0	-	-
12	3,110	8.1	1,315	55.1
14	1,524	4.0	680	28.5
16	554	1.5	273	11.4
18	179	.5	70	2.9
19.0+	110	.3	50	2.1
Total	38,205	100.0	2,388	100.0
1953 totals	22,937		1,716	

Between 1953 and 1962, Minnesota's aspen increased 67 percent in growing-stock volume and 39 percent in sawtimber volume (table 2). In 1962, the growing-stock volume of aspen comprised 31 percent of the total for all species compared to 25 percent in 1953. Aspen sawtimber volume increased from 14 percent in 1953 to about 15½ percent of the total for all species in 1962.

The Future Stand

Two important questions arise concerning the future of aspen. What will the resource be in 10 or 20 years? Could heavier cutting be sustained without depleting the growing stock?

To answer these questions, three resource projections were prepared, each controlled by a different timber cut (*A, B, C*) for the selected output years of 1970 and 1980. Starting with the number of trees by 2-inch d.b.h. classes for the beginning of 1962 (year of survey), and adding the net inventory change (net change is obtained by subtracting timber cut, mortality, and the growth on cut and mortality from the expected gross growth) during each year, an updated or projected stand was obtained for the specified output years; the numbers of trees were then converted to volume.

The three timber cut estimates (*A, B, C*) for 1970 and 1980 came from two sources. The estimate *A* is based on historical trends and is the most conservative of the three. The other two came from *Timber Trends in the United States.*[2] *B* is based on the estimated cut of hardwood growing stock in the North,[3] while *C* is based on the estimated hardwood-roundwood-pulpwood production in the United States. The estimated aspen timber cuts for 1970 and 1980 (projection controls) compared to the 1962 actual cut of 549,000 cords are:

	Control *A*	Control *B*	Control *C*
1970			
Estimated cut, thousand cords	607	747	813
Percent of 1962 cut	110	136	148
1980			
Estimated cut, thousand cords	689	1,000	1,258
Percent of 1962 cut	125	182	229

Under all three cutting levels, the volumes of standing timber show increases for both 1970 and 1980 (table 3). These increases,

[2] *U.S. Forest Service. Timber Trends in the United States. U.S. Forest Serv. Forest Resource Rep. 17, 235 pp., illus. 1965.*

[3] *North region comprises 26 States from a line between the southern borders of Virginia and Kansas north to the Canadian border—the northeast quarter of the Nation.*

Table 3.—Minnesota aspen; projected volume of growing-stock trees in 1970 and 1980 for three timber cut controls[1]
(In million cords)

Diameter class (inches)	1962	1970			1980		
		A	B	C	A	B	C
6	12.7	11.9	11.8	11.9	10.0	9.9	9.9
8	12.3	17.8	17.8	17.7	20.5	20.3	20.1
10	7.7	13.3	13.2	13.2	21.3	20.8	20.5
12	3.1	5.6	5.4	5.4	11.4	10.6	10.0
14	1.5	2.0	1.9	1.8	4.4	3.5	3.1
16	.6	.7	.7	.6	1.4	1.1	.9
18	.2	.3	.3	.3	.7	.5	.4
20	.1	.1	.1	.1	.3	.2	.2
22+	.0	.1	.1	.1	.1	.1	.1
Total	38.2	51.8	51.3	51.1	70.1	67.0	65.2

1/ Timber cut controls for projections A, B, and C are described in the text.

then, lead to the answers to the two questions about the future of aspen. Apparently, the present resource can sustain a heavier cutting and at the same time increase in volume.

For the three projections, some significant changes in volume distribution by size class can be noted (table 3). Large numbers of trees (volume) are moving into larger diameters. These stands originated in a relatively short period after the extensive cutting and burning of about 50 years ago. As the stands mature and trees continue to move into larger diameters, the average tree will become bigger in both height and diameter; therefore, the volume per acre will be greater. Harvesting should then be more efficient, and one of aspen's marketing problems—its use limitations due to small size—will be at least partially alleviated.

As might be expected with a relatively short-lived species like aspen, the projections show no significant increases in the number of larger trees (16 inches d.b.h. and over). Similarly, with a rapidly growing, early maturing resource the proportion of the total volume in small trees (6 inches d.b.h. and under) declines as the resource ages.

What does this mean to wood-using industries depending upon aspen for their major source of raw material? Substantially larger harvests of aspen could probably be made from the Minnesota aspen resource over the next several decades. However, because of the inherent biological characteristics of the species, the bulk of the resource will be in pole-size or, at best, small sawtimber-size trees (8 to 12 inches d.b.h.). Thus, this resource will afford opportunities for those products that can be manufactured from these size classes. The necessity for efficiencies in logging, transporting, and manufacturing relatively small-size materials will continue.

The projected growth of our national economy is sharply upward. The factors used to measure this growth—population, new household formation, gross national product, disposable personal income, and construction activity—also influence consumption of forest products. Forest industry planners seeking additional sources of timber supply to meet increasing demand for forest products should consider Minnesota aspen — an available resource.

Definitions of Terms

Aspen type.—A stand in which a mixture of quaking or bigtooth aspen, balsam poplar (balm-of-Gilead), and paper birch predominate, with the aspen the most common.

Commercial forest land.—Forest land which is producing or capable of producing crops of industrial wood and not withdrawn from timber utilization.

Sawtimber stands.—Stands at least 10 percent stocked with growing-stock trees and with a plurality of stocking by live sawtimber trees (at least 11.0 inches d.b.h.).

Poletimber stands.—Stands at least 10 percent stocked with growing-stock trees with a plurality of stocking by poletimber trees (5.0 to 10.9 inches d.b.h.).

Sapling and seedling stands.—Stands at least 10 percent stocked with growing-stock trees and with a plurality of stocking by saplings and seedlings (less than 5.0 inches d.b.h.).

Site classes.—These classifications are used to measure quality of forest land for raising timber products. Site index (SI) is the expected height of a free-growing tree at age 50.

Area condition class.—

1—Areas 70 percent or more stocked with desirable trees.

2—Areas 40-70 percent stocked with desirable trees and with less than 30 percent of area controlled by inhibiting vegetation or surface conditions that will prevent occupancy by desirable trees.

3—Areas 40-70 percent stocked with desirable trees and with more than 30 percent of the area controlled by inhibiting vegetation or surface conditions that will prevent occupancy by desirable trees.

4—Areas less than 40 percent stocked with desirable trees and with adequate seed source and seed bed favorable to natural restocking.

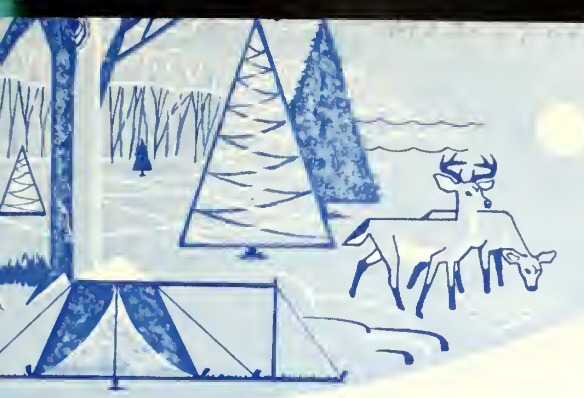
5—Areas less than 40 percent stocked with desirable trees and with inadequate seed source and/or seed bed unfavorable to natural regeneration.

Growing-stock volume.—Net volume of live merchantable sawtimber and poletimber trees from the stump to a variable 4-inch top diameter outside bark of the central stem. Does not include limbs or cull-tree volume. (There are 79 cubic feet of solid wood in a standard cord.)

Sawtimber volume.—Net volume, International ¼-inch rule, of live merchantable sawtimber trees (11.0 inches d.b.h. and larger) from the stump to a point in the central stem at which utilization for sawn products is limited by large branches, forks, or other defects, or by a diameter outside bark of 8.0 inches.

July 1966

Richard W. Groff
Associate Mensurationist



U. S. FOREST SERVICE

RESEARCH NOTE NC-5

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Performance of Seven Seed Sources of Blue Spruce in Central North Dakota

Blue spruce (*Picea pungens* Engelm.) has been planted quite extensively in North Dakota shelterbelts and farmstead windbreaks. Generally survival and growth have been promising, but there is considerable variation in the performance of individual trees or plantations. Poorly adapted seed sources have been suspected as one cause for poor performance. There should be interest, therefore, in the results of a study designed to test the growth, survival, and resistance to climatic agents of seven known seed sources of blue spruce after 5 years in the field.

The Study

Seed collections were assembled by Professor Donald Duncan of the University of Minnesota Forestry Department. The seedlings were produced in the nursery at the University of Minnesota Forest Research Center near Cloquet, and in 1958 were transferred as small 3-0, 4-0, and 5-0 stock to the Hugo Sauer Nursery at Rhinelander, Wis. Three years later, when the stock was ready for field planting, it was unusually small for its age, probably because of crowded conditions in the seedbed and some rust infection in the transplant bed.

The trees were planted May 8, 1961, on a level area in the Denbigh Experimental Forest in north-central North Dakota The soil there is a Valentine loamy sand and had been covered by a native grass sod. The site had been plowed and disked during the 1960 growing season and disked again just prior to planting.

The trees were set out 6 feet apart in a single row, which consisted of 25 replications of 7-tree blocks. Each block contained in random order one tree (a single-tree plot) of each seed source. The row was bordered on the west by a row of 2-0 Siberian peashrub (*Caragana arborescens* Lam.) and on the east by a row of green ash (*Fraxinus pennsylvanica* Marsh.).

The origins of all the seed sources are south of the planting site at Denbigh by 5° to 13° of latitude (250 to 850 miles) and west of the planting site by 5° to 12° of longitude (fig. 1). The elevation at Denbigh is 1,486 feet; the elevations of the sources (see table 1) vary from 6,000 to 9,000 feet.

Results

Survival for the period between the second and the fifth years[1] after planting varied among the seed sources from 22 percent for the Targhee National Forest source in Wyoming to 96 percent for the Ashley National Forest source (number 1834) from the north

[1] *A severe drought the first summer was primarily responsible for initial losses ranging from 8 to 76 percent. Dead trees were replaced, but there was not enough stock of all lots to permit complete replanting. Hence survivals discussed here are based on the number of trees alive in the spring of 1962, after replanting.*

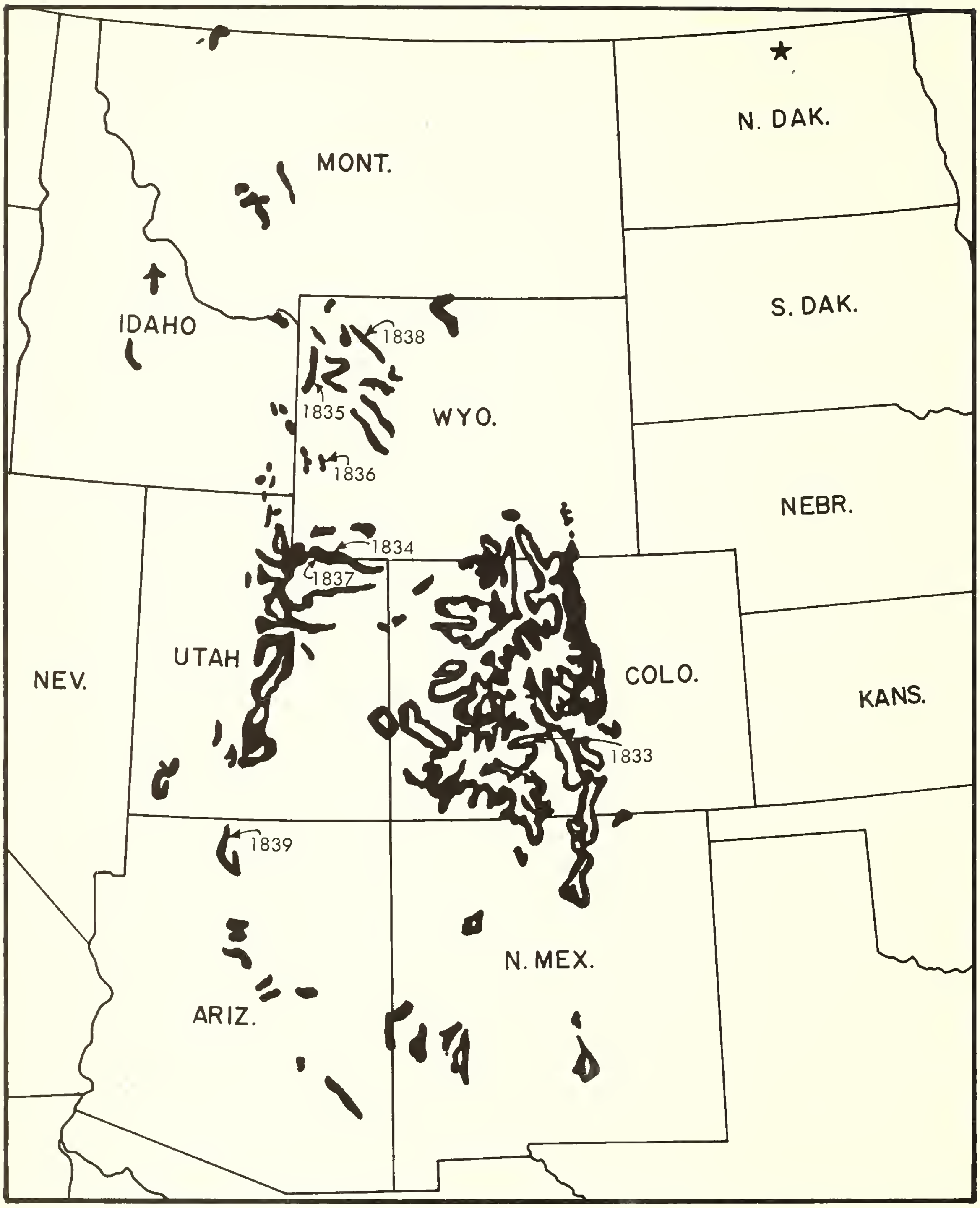


Figure 1.—Botanical range of blue spruce showing locations of the tested seed sources. (From Munns, E. N. The distribution of important forest trees of the United States. U.S. Dep. Agr. Public. 287, 176 pp., illus. 1938.)

Table 1.—Seed origin and 5-year results of seven sources of blue spruce growing in the Denbigh Experimental Forest, Denbigh, N. Dak.[1]

Source of seed				Five-year results				
Source number	Class of stock May 1961	Location of native stand	Elevation of native stand	Survival (2-5 years)	1965 age from seed	Mean height2/	Average3/ frost damage in new growth 1964 & 1965	Average crown diameter
			Feet	Percent	Years	Feet		Feet
1834	5-3	Ashley Nat. Forest, Wyoming-Utah	7,000-7,500 (north slope)	96	13	1.88	1.9	1.1
1838	5-3	Shoshone Nat. Forest, Wyoming	8,000	69	13	1.77	2.2	.9
1835	5-3	Teton Nat. Forest, Wyoming	7,000	60	13	1.56	2.2	1.0
1833	3-3	Chaffee County, Colorado	8,000 +	72	11	1.46	2.2	.9
1836	5-3	Targhee Nat. Forest, Wyoming	6,000	22	13	1.40	2.5	.6
1839	4-3	Kaibab Nat. Forest, Arizona	9,000	52	12	1.32	2.3	.8
1837	5-3	Ashley Nat. Forest, Utah	7,000-8,000 (south slope)	68	13	1.23	2.0	.7

1/ The elevation of the planting site was 1,486 feet.
2/ Vertical bars bracket sources not significantly different in height according to Duncan's Multiple Range Test at the .05 level.
3/ Classification:

4 = Severe damage; more than 75% of shoots damaged.
3 = Medium damage; 25% to 75% of shoots damaged.
2 = Light damage; less than 25% of shoots damaged.
1 = No visible damage.

Shoot damage was scored according to the percentage of elongating buds on each tree blackened as a result of frost. The figure is an average for 1964 and 1965.

slope of the Uinta Mountain Range. The major causes of loss appeared to be drought and winter killing.

At the end of 5 years in the field, variation between average heights for the blue spruce lots was significant at the 5-percent level according to Duncan's Multiple Range Test.[2] Again the Ashley National Forest source (number 1834), from the northern mountain slopes was better than all other sources. Surprisingly, the source from the southern slopes of the Uinta Mountains in the Ashley National Forest (number 1837) had the shortest average height of the group.

Damage to new growth from severe late spring frosts occurring after flushing of buds was evaluated subjectively in 1964 and 1965 as severe, medium, light, or no damage. Although there appears to be but little correlation between susceptibility to late spring frost and other factors, the Ashley Forest source (1834) from the northern slopes of the mountains, was superior to others both in height growth and frost resistance.

There was also considerable variation in crown diameter, ranging from a low of 0.6 foot for the average of the Targhee National Forest source to almost twice as great (1.1 feet) for source number 1834 from the northern slopes of the mountains in the Ashley National Forest.

After 5 years in the field and on the basis of the four factors of survival, height, relative freedom from late spring frost damage, and crown diameter, it appears that the source from the north slopes of the Ashley

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2 *Steel, Robert G. D., and Torrie, James H. Principles and procedures of statistics. 481 pp., illus. New York: McGraw Hill Book Co. 1960.*

National Forest is the best adapted to the test site of the seven sources planted. The fact that the shortest source (number 1837), from the southern slopes of the Uinta Mountains in the Ashley National Forest, has made only 65 percent of the height growth of the fastest growing source (1834), from the northern slopes of the range in the Ashley National Forest, indicates that seed source response data for blue spruce can be interpreted only for very limited—rather than broad—collection zones, when planting programs in the northern Prairie-Plains are being considered. We must remember, too, that the relative responses of the various seed sources may change as the plants become older.

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July 1966

[3] *When this study was made, Mr. Dawson was on the staff of the North Central Forest Experiment Station.*

U. S. FOREST SERVICE

RESEARCH NOTE NC-6

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Growth Response of Seedling Yellow Birch to Humus-Mineral Soil Mixtures

Previous observers of the establishment of yellow birch have cited the importance of mixed humus-mineral soil seedbeds.[1,2] Godman and Krefting pointed out that both germination and growth were enhanced.[1] Subsequent studies[3] have shown that while germination in the absence of competition is adequate on mineral soil of a Podzol A_2 under a wide variety of light and moisture conditions, growth is uniformly poor. On humus, good growth was obtained but adequate germination occurred only in part of the environments tested. This Note reports the growth response of yellow birch seedlings grown on various mixtures of mineral soil and humus.

Procedure

Humus and mineral soil were collected from the same profile of a well podzolized soil underneath a hemlock-hardwood stand near Marquette, Mich., and six volumetric mixtures were made up: (1) humus, (2) ¼ A_2, ¾ humus, (3) ½ humus, ½ A_2, (4) ¾ A_2, ¼ humus, (5) A_2, and (6) A_2 with a cold water extract of the humus added periodically. Seed stored from a single tree collection made in 1962 were scattered on pots of the various mixtures.

The pots were arranged in five blocks in randomized block style on a greenhouse bench under a bank of fluorescent and incandescent lights with a daylength of 16 hours. After germination, all but five of the tallest seedlings were removed from each pot. Pots were watered from below.

Seedlings were measured every 2 weeks. After 80 days, plants were removed and roots were washed, dried, and weighed. Leaves and stems were weighed separately. Root-shoot ratios were calculated from dry weights.

One block germinated poorly; this was discarded from the experiment. Significance was tested with standard analysis of variance and regression techniques.

Results

Both height growth and dry weight increased as the amount of humus in the mixture increased (fig. 1). Treatment differences are significant at the 1-percent level. The addition of the humus extract (data not shown in fig. 1) appeared to depress growth slightly but not significantly in comparison to the 100-percent mineral soil treatment.

Dry weight increment of all major plant parts was decreased by the addition of mineral soil to humus but leaves responded most (fig. 2). On a percentage basis (fig. 3) the distribution of dry matter was relatively unchanged in stems; root weight increased and leaf weight decreased as mineral soil content increased. This disproportionate change in dry matter resulted in an increasing root-shoot ratio as the mineral soil content of the mixture increased:

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[1] *Godman, Richard M., and Laurits W. Krefting. Factors important to yellow birch establishment in Upper Michigan. Ecology 41: 18-28, illus. 1960.*

[2] *Jarvis, J. Cutting and seedbed preparation to regenerate yellow birch in Haliburton County, Ontario. Can. Dep. Northern Affairs and Natur. Resources, Forest Res. Div. Tech. Note 53, 17 pp., illus. 1957.*

[3] *Data on file at the Northern Hardwoods Laboratory, North Central Forest Experiment Station, Marquette, Mich.*

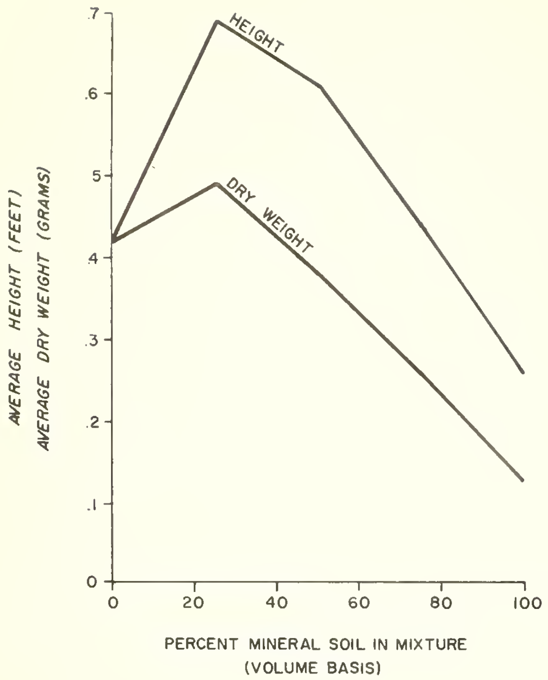

Figure 1.—Average height and dry weight of seedlings grown in varying mixtures of humus and mineral soil.

Percent mineral soil	*Root/leaf ratio*[1]	*Root/stem ratio*[2]	*Root/shoot ratio*[3]
100	.62	1.03	.40
75	.60	1.03	.37
50	.39	.65	.23
25	.27	.52	.17
0	.27	.47	.17

[1] Root-leaf ratios were computed from leaf and root weights.

[2] Root-stem ratios were computed from stem and root weights (leaves were not included).

[3] Root-shoot ratios were computed from stem plus leaf weights and root weights.

Discussion

In the environment in which the plants were grown, mineral soil additions to the humus depressed growth generally but root growth decreased less than did that of leaves, thus increasing root-shoot ratios. In the field, survival should be enhanced as a result of the more favorable moisture relations usually ascribed to better balance between absorbing and transpiring organs. However, good height growth is necessary to keep yellow birch above other species competing for light.

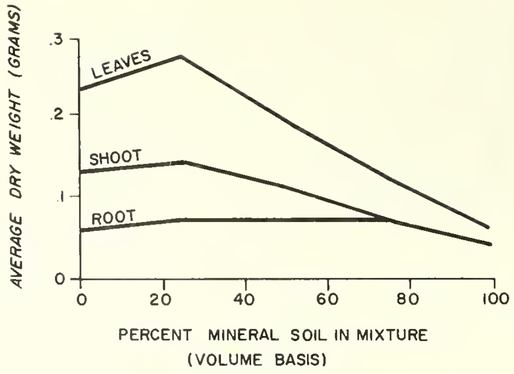

Figure 2.—Distribution of average dry weight of seedlings by plant part of seedlings grown in varying mixtures of humus and mineral soil.

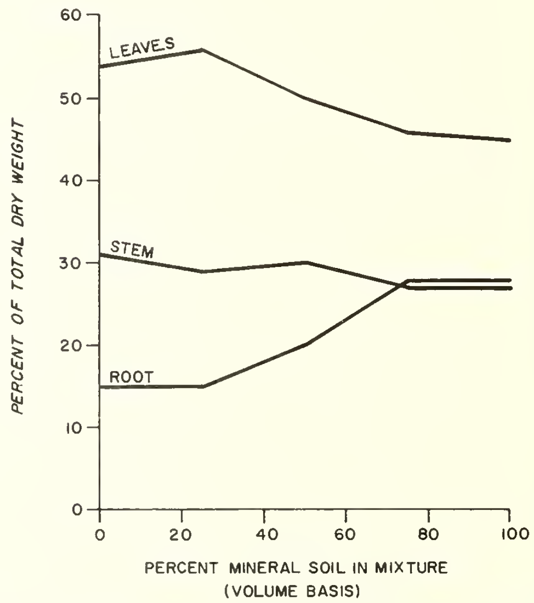

Figure 3.—Percentage of total dry weight by plant part of seedlings grown in varying mixtures of humus and mineral soil.

A 50-50 mixture seems to be the best compromise since height growth does not increase greatly with humus proportions of more than 50 percent and root-shoot ratios are still relatively good.

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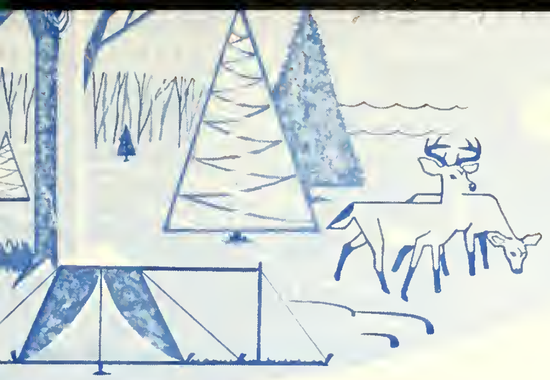
July 1966



U. S. FOREST SERVICE

RESEARCH NOTE NC-7

RTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Forest-Product Imports and Exports Via the Great Lakes-St. Lawrence Seaway Through Upper Lakes Ports

The expanded Great Lakes-St. Lawrence Seaway ystem was opened in the early spring of 1959, and or the first time deep-draft ocean-going vessels could isit inland Great Lakes ports. In 1963 the Station ublished a Research Note reporting what effect his expansion may have had on the volume of forest roducts moving through Minnesota, Wisconsin, and Michigan ports; data were shown for overseas comnerce for 1957 to 1961.[1] The current Note presents nformation on all overseas imports and exports of orest products moving through Upper Lakes ports, ncluding the port of Chicago, for 1954 to 1964.[2]

Definite trends developing for some product groups. —Eleven years' data indicate that trends are developng for many product groups. Those showing signifiant increases include: log exports; plywood, veneer, nd cooperage imports; wood manufactures imports; aperboard exports: and paper and related items mports and exports (table 1).

By excluding woodpulp from the data, a clearer picture can be obtained of the trend for other products, which previously moved through inland ports n small quantities, if at all (fig. 1). Except for 1960 when relatively large exports of logs and paper products were made, imports have generally well exeeded exports.

Product classifications.—In general, five major cateories are used to differentiate product types: (1) Wood, non-manufactured: (2) sawmill products; (3) wood, manufactures; (4) paper base stocks; and (5) paper, related products and manufactures.[3] Under these broad categories, specific products that are frequently shipped, such as logs, lumber, or woodpulp, may be recorded separately. Each broad category also has an unclassified group which includes products shipped only occasionally or in small quantity. An example is wood manufacturers n.e.c. (not elsewhere classified); this group contains a wide variety of products made from wood.

In addition, some items may be placed in one category until the volume and frequency of occurrence become large enough to justify carrying a separate category. For instance, at one time veneer and plywood were in the lumber category, and paperboard was in the paper, related products, and manufactures n.e.c. group. Despite these classification problems, trends can be traced with reasonable accuracy for many of the more important products or product groups.

Woodpulp still important import item.—Even before seaway expansion woodpulp had been imported from overseas in considerable quantity, especially during pre-World War II days. For instance, 211,326 tons were moved through 12 Lake States ports in 1936 and 158,130 tons in 1937. While the amount imported since seaway expansion has been generally above that from 1947 to 1958, the 1964 volume marks a 13-year low (fig. 2). For the first time woodpulp was not the number-one import; it was surpassed by the plywood, veneer, and cooperage group. This latter group, however, may include somewhat more diverse products than the homogeneous woodpulp category.

1 Carpenter, E. M. *Lake States wood-products imports and exports via the St. Lawrence Seaway.* U.S. Forest Serv. Res. Note LS-4, 1963, 2 pp.

2 *The upper lakes ports are those on Lake Huron, Lake Michigan, and Lake Superior and include Detroit and the Detroit River.*

3 *For the purposes of this Note, items classed in the first three groups are referred to as wood products and those in the latter two groups as paper products.*

Table 1.—Upper Lakes ports overseas imports and exports of forest products via the Great Lakes-St. Lawrence Seaway, 1954-1964[1] *(Thousand short tons)*

Year	Minnesota Imp.	Minnesota Exp.	Wisconsin Imp.	Wisconsin Exp.	Michigan Imp.	Michigan Exp.	Illinois Imp.	Illinois Exp.	Total 2/ Imp.	Total 2/ Exp.
ALL WOOD, WOOOPULP, ANO PAPER PROOUCTS										
1954	2.43	..	12.76	0.18	14.75	0.06	5.48	0.06	35.40	0.30
1955	3.74	..	9.10	0.26	16.64	0.05	4.22	0.29	33.69	0.60
1956	6.09	..	9.96	0.30	16.81	0.16	5.58	0.17	38.44	0.63
1957	2.66	..	8.77	0.15	16.11	0.02	0.96	0.18	28.50	0.34
1958	3.80	..	13.13	0.43	22.53	0.25	3.28	1.07	42.74	1.75
1959	*	..	31.39	0.64	44.19	0.32	6.48	2.86	82.06	3.82
1960	2.20	0.02	12.42	4.50	21.62	0.16	6.14	6.62	42.39	11.30
1961	*	..	14.53	1.25	19.41	0.77	8.37	4.58	42.31	6.61
1962	0.01	0.03	25.63	1.72	35.68	2.67	12.63	2.64	73.96	7.06
1963	0.01	..	16.80	1.98	20.29	2.81	14.93	3.95	52.02	8.74
1964	0.10	0.32	15.06	3.05	19.54	3.25	19.27	7.46	53.97	14.08
ALL WOOD AND PAPER PRODUCTS, EXCL. WOODPULP										
1954	..	..	0.09	0.18	0.16	0.06	4.82	0.06	5.08	0.30
1955	..	..	0.05	0.26	0.97	0.05	4.22	0.29	5.24	0.60
1956	..	..	0.44	0.30	0.31	0.16	5.49	0.17	6.24	0.63
1957	..	..	0.07	0.15	0.74	0.02	0.96	0.18	1.77	0.34
1958	0.04	..	0.53	0.43	3.12	0.08	3.28	1.07	6.97	1.59
1959	*	..	0.72	0.64	3.06	0.32	6.48	2.86	10.27	3.82
1960	*	0.02	0.46	4.49	3.91	0.16	6.14	6.62	10.51	11.29
1961	*	..	1.50	1.25	4.35	0.77	8.37	4.58	14.22	6.61
1962	0.01	0.03	1.60	1.66	4.40	2.64	12.63	2.63	18.65	6.97
1963	0.01	..	4.09	1.98	6.16	2.81	14.93	3.95	25.20	8.74
1964	0.10	0.32	8.96	3.05	9.01	3.25	19.27	7.46	37.34	14.08
Woodpulp										
1954	2.43	..	12.66	..	14.59	..	0.65	..	30.33	..
1955	3.74	..	9.04	..	15.67	..	..	..	28.45	..
1956	6.09	..	9.53	..	16.50	..	0.10	..	32.21	..
1957	2.66	..	8.70	..	15.37	..	..	..	26.73	..
1958	3.76	..	12.60	..	19.41	0.17	..	..	35.77	0.17
1959	..	..	30.67	..	41.13	..	..	..	71.80	..
1960	2.20	..	11.96	0.01	17.71	..	*	..	31.87	0.01
1961	..	..	13.03	..	15.06	..	..	..	28.09	..
1962	..	..	24.03	0.05	31.28	0.03	..	0.01	55.32	0.09
1963	..	..	12.70	..	14.12	..	..	..	26.83	..
1964	..	..	6.10	..	10.53	..	*	..	16.63	..
Paper Base Stocks, N.E.C. 3/										
1954	..	..	..	..	0.06	..	..	..	0.06	..
1955	..	..	..	0.01	..	0.02	..	0.02	..	0.04
1956	..	..	..	..	..	..	..	..	..	..
1957	..	..	..	..	..	..	..	..	..	..
1958	..	..	..	..	..	..	..	..	..	..
1959	..	..	..	..	0.06	..	0.03	0.07	0.09	0.07
1960	..	..	..	..	..	..	0.04	0.10	0.04	0.10
1961	..	..	..	..	..	0.53	0.04	1.05	0.04	1.58
1962	..	..	..	..	..	0.08	..	0.16	..	0.24
1963	..	..	0.01	0.01	..	..	..	0.36	0.01	0.37
1964	..	..	..	0.01	..	..	..	0.13	..	0.13
Paperboard										
1962	..	..	..	*	..	0.39	..	0.02	..	0.40
1963	..	..	..	..	..	0.35	..	*	..	0.35
1964	..	..	..	0.01	..	0.50	..	0.08	..	0.59
Paper, Related Products, and Manufactures, N.E.C. 3/										
1954	..	..	0.06	0.18	0.05	0.05	0.97	0.05	1.08	0.28
1955	..	..	0.04	0.02	0.28	0.02	0.54	0.04	0.85	0.07
1956	..	..	0.35	0.06	0.23	0.10	1.66	0.06	2.24	0.23
1957	..	..	0.04	0.12	0.52	*	0.62	0.04	1.18	0.16
1958	0.04	..	0.48	0.04	1.39	0.08	1.01	0.04	2.92	0.16
1959	..	..	0.30	0.31	2.43	0.22	2.46	0.09	5.19	0.62
1960	..	*	0.36	3.82	2.32	0.07	2.33	1.51	5.02	5.40
1961	*	..	0.51	0.68	2.05	0.12	3.54	0.40	6.10	1.20
1962	0.01	..	0.62	1.14	2.81	0.06	3.89	0.11	7.34	1.31
1963	*	..	0.56	1.31	2.62	0.13	4.76	0.20	7.94	1.63
1964	..	0.29	0.44	0.95	2.22	0.20	3.70	0.51	6.36	1.94
ALL WOODPULP ANO PAPER PROOUCTS										
1954	2.43	..	12.72	0.18	14.69	0.05	1.62	0.05	31.46	0.28
1955	3.74	..	9.08	0.03	15.95	0.03	0.54	0.05	29.30	0.11
1956	6.09	..	9.88	0.06	16.73	0.10	1.75	0.06	34.45	0.23
1957	2.66	..	8.74	0.12	15.89	*	0.62	0.04	27.91	0.16
1958	3.80	..	13.07	0.04	20.80	0.25	1.01	0.04	38.69	0.33
1959	..	..	30.97	0.31	43.61	0.22	2.50	0.16	77.08	0.69
1960	2.20	*	12.32	3.83	20.04	0.07	2.38	1.61	36.93	5.51
1961	*	..	13.54	0.68	17.11	0.65	3.58	1.45	34.23	2.77
1962	0.01	..	24.65	1.19	34.10	0.55	3.89	0.30	62.66	2.04
1963	*	..	13.27	1.32	16.74	0.47	4.76	0.56	34.77	2.35
1964	..	0.29	6.54	0.96	12.75	0.70	3.70	0.71	23.00	2.66

1/ Source: Water-borne Commerce of the U. S., Part III, Waterways and Harbors of the Great Lakes, U. S. Corps of Engineers, for the Years 1954-1964. Data do not include trade with Canada, nor a Michigan import of 11 tons of pulpwood in 1963; the import of 4596 tons of newsprint in 1956; the category cork and manufactures. No data were listed for those years missing from individual categories. The line between 1958 and 1959 data indicates year of seaway expansion.

2/ Tables may not add because of individual rounding.

Year	Minnesota Imp.	Minnesota Exp.	Wisconsin Imp.	Wisconsin Exp.	Michigan Imp.	Michigan Exp.	Illinois Imp.	Illinois Exp.	Total 2/ Imp.	Total 2/ Exp.
ALL PAPER PRODUCTS (EXCL. WOODPULP)										
1954	..	..	0.06	0.18	0.10	0.05	0.97	0.05	1.13	0.
1955	..	..	0.04	0.03	0.28	0.03	0.54	0.05	0.85	0.
1956	..	..	0.35	0.06	0.23	0.10	1.66	0.06	2.24	0.
1957	..	..	0.04	0.12	0.52	*	0.62	0.04	1.18	0.
1958	0.04	..	0.48	0.04	1.39	0.08	1.01	0.04	2.92	0.
1959	..	..	0.30	0.31	2.48	0.22	2.50	0.16	5.28	0.6
1960	..	*	0.36	3.82	2.32	0.07	2.38	1.61	5.06	5.5
1961	*	..	0.51	0.68	2.05	0.65	2.58	1.45	6.14	2.7
1962	0.01	..	0.62	1.14	2.81	0.52	3.89	0.29	7.34	1.9
1963	*	..	0.56	1.32	2.62	0.47	4.76	0.56	7.94	2.3
1964	..	0.29	0.44	0.96	2.22	0.70	3.70	0.71	6.36	2.6
Logs										
1958	..	..	..	..	..	..	..	0.14	..	0.
1959	..	..	0.06	0.18	..	0.03	0.01	1.15	0.06	1.3
1960	..	..	..	0.49	0.01	0.04	*	3.78	0.02	4.3
1961	..	..	..	0.35	..	0.05	0.02	2.56	0.02	2.9
1962	..	..	..	0.44	..	2.10	..	1.99	..	4.5
1963	..	..	0.03	0.39	..	2.29	*	2.62	0.03	5.3
1964	..	..	..	1.91	..	2.29	0.23	5.47	0.23	9.6
Wood Unmanufactured, N.E.C. 3/										
1955	..	..	..	..	..	..	0.01	..	0.01	..
1956	..	..	..	..	..	..	0.01	..	0.01	..
1957	..	..	..	..	..	..	0.01	..	0.01	..
1958	..	..	..	..	..	..	0.02	..	0.02	..
1959	..	..	..	..	..	..	0.02	..	0.02	..
1960	..	..	..	..	0.02	..	0.02	..	0.03	..
1961	..	..	..	0.01	0.01	..	0.04	..	0.04	0.0
1962	..	..	0.01	..	0.01	..	0.07	..	0.08	..
1963	..	..	0.04	..	0.30	..	0.11	0.13	0.17	0.1
1964	..	..	0.01	..	0.30	..	0.37	..	0.41	..
Lumber										
1955	..	..	..	0.16	..	..	..	0.01	..	0.1
1956	..	..	..	0.01	..	..	..	*	..	0.0
1957	..	..	0.03	0.01	0.17	..	0.22	..	0.41	0.0
1958	..	..	..	0.38	1.34	..	*	0.02	1.34	0.4
1959	..	..	..	0.13	0.02	0.05	0.02	0.22	0.04	0.3
1960	..	0.02	..	0.13	0.08	0.03	0.03	0.22	0.11	0.4
1961	..	..	0.26	0.19	0.82	0.03	0.77	0.02	1.86	0.2
1962	..	..	0.34	0.05	0.12	..	0.16	0.09	0.63	0.1
1963	..	..	0.26	0.05	0.14	0.01	0.58	0.34	0.98	0.4
1964	0.04	..	0.33	0.02	0.16	0.11	0.62	0.81	1.15	0.9
Plywood, Veneer, and Cooperage										
1954	..	..	0.02	..	0.04	..	3.69	..	3.75	..
1955	..	..	0.01	..	0.67	..	3.54	0.03	4.22	0.0
1956	..	..	0.08	..	0.05	0.02	3.56	..	3.68	0.0
1957	..	..	..	..	..	..	..	..	..	..
1958	..	..	0.04	..	0.24	..	2.00	0.20	2.28	0.2
1959	..	..	0.22	0.01	0.39	..	3.52	0.63	4.14	0.6
1960	..	..	0.06	0.01	1.29	0.01	2.64	0.78	3.99	0.7
1961	..	..	0.61	*	1.19	*	2.23	0.18	4.03	0.1
1962	..	0.02	0.43	*	1.26	*	7.33	0.14	9.02	0.1
1963	..	..	3.05	0.22	3.14	0.01	8.36	0.20	14.54	0.4
1964	0.06	0.01	8.04	0.15	6.22	0.07	12.55	0.34	26.87	0.5
Wood Manufactures, N.E.C. 3/										
1954	..	..	0.01	0.01	0.01	*	0.17	0.01	0.19	0.0
1955	..	..	0.01	0.07	0.02	0.02	0.14	0.20	0.16	0.3
1956	..	..	0.01	0.23	0.03	0.04	0.27	0.11	0.30	0.3
1957	..	..	*	0.02	0.06	0.02	0.11	0.13	0.17	0.1
1958	..	..	0.02	0.01	0.14	..	0.25	0.68	0.41	0.6
1959	*	..	0.15	0.01	0.16	0.02	0.42	0.69	0.73	0.7
1960	*	..	0.05	0.04	0.18	0.01	1.08	0.22	1.30	0.2
1961	*	..	0.11	0.02	0.28	0.04	1.74	0.3[illegible]	2.13	0.4
1962	*	*	0.20	0.03	0.19	0.01	1.18	0.12	1.57	0.1
1963	0.01	..	0.16	0.01	0.25	0.02	1.12	0.10	1.53	0.1
1964	*	0.01	0.15	0.01	0.36	0.08	1.80	0.13	2.32	0.2
ALL WOOD PRODUCTS										
1954	..	..	0.03	0.01	0.06	*	3.85	0.01	3.95	0.0
1955	..	..	0.02	0.24	0.69	0.02	3.68	0.24	4.39	0.4
1956	..	..	0.08	0.24	0.08	0.06	3.83	0.11	3.99	0.4
1957	..	..	0.03	0.03	0.23	0.02	0.34	0.13	0.59	0.1
1958	..	..	0.06	0.39	1.73	..	2.27	1.03	4.05	1.4
1959	*	..	0.42	0.33	0.58	0.10	3.98	2.69	4.99	3.1
1960	*	0.02	0.10	0.67	1.59	0.09	3.76	5.01	5.45	5.7
1961	*	..	0.99	0.57	2.30	0.12	4.79	3.14	8.08	3.8
1962	*	0.03	0.98	0.52	1.59	2.12	8.74	2.34	11.31	5.0
1963	0.01	..	3.53	0.66	3.55	2.34	10.17	3.40	17.25	6.4
1964	0.10	0.03	8.52	2.09	6.79	2.55	15.57	6.75	30.98	11.4

3/ N.E.C. not elsewhere classified.

* Less than 5 tons.

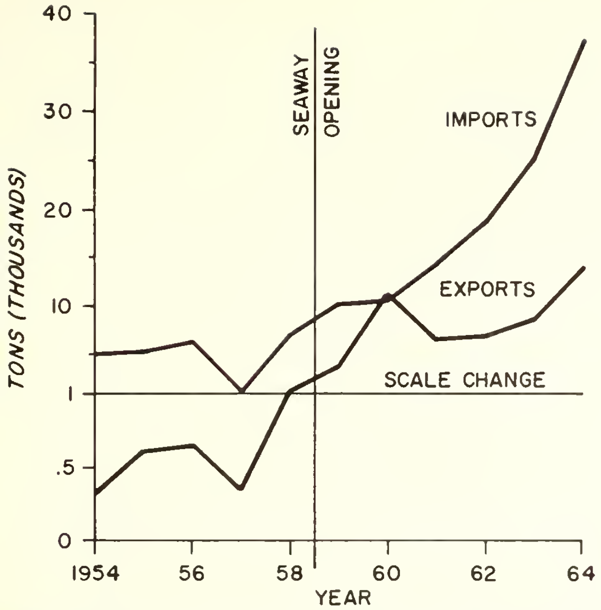


Figure 1.—Overseas imports and exports, all wood and paper products excluding wood pulp, Upper Lakes ports, 1954-1964.

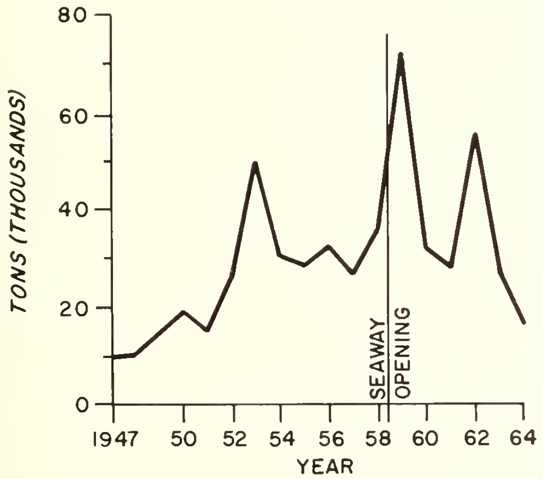


Figure 2.—Overseas woodpulp imports—Upper Lakes ports, 1947-1964.

In view of the general situation in world pulp and paper demand, this downward trend might continue. European countries have steadily increased their per capita and absolute consumption of paper products, and demand in African and Asian countries (especially Japan) has also increased. The Nordic countries have been, along with Canada, the principal suppliers of market pulp. While postwar woodpulp production in the Nordic region has expanded substantially it has not been able to keep pace with

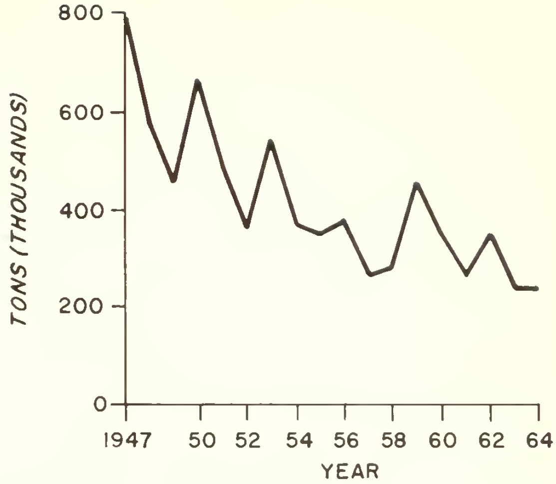


Figure 3.—U.S. imports of European woodpulp, 1947-1964.

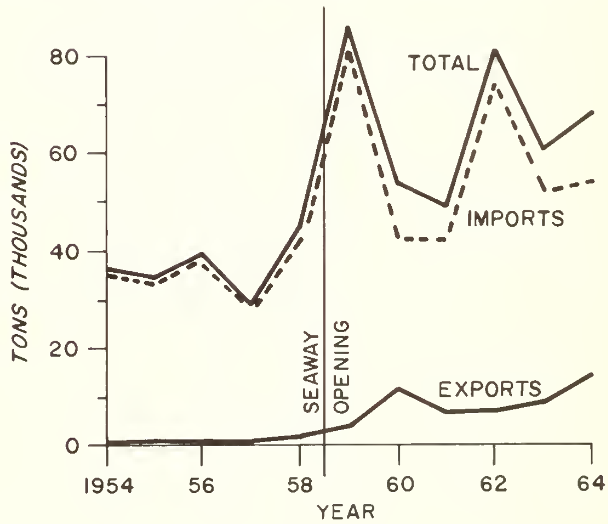


Figure 4.—Total volume of forest products moved through Upper Lakes ports, 1954-1964 (overseas traffic only).

Europe's rising needs. Consequently, Europe has become a net importer of woodpulp from the United States. This trend is expected to continue because European woodpulp capacity expansion appears to be limited by timber resource availability. Therefore, within the next decade, the United States will likely become an increasingly important supplier of woodpulp and pulp-based products for growing overseas markets, and woodpulp imports may continue to decline (fig. 3).

Relative growth of wood products significant.—The yearly total volume of overseas shipments has fluctuated widely since seaway expansion (fig. 4), partly because of changes in woodpulp shipments. The large total volumes experienced in 1959 and 1962 were due primarily to exceptionally large imports of woodpulp. The recent decrease in woodpulp imports has caused the percent of total volume for most other product groups to increase. The woodpulp decrease has also resulted in shifting the relative importance of wood products as compared to paper products. Thus wood products accounted for more than 60 percent of the overseas trade in 1964. The percent of total volume by the two broad groups is as follows:

Year	*Wood products (percent)*		*Pulp and paper products (percent)*	
	Imp.	*Exp.*	*Imp.*	*Exp.*
1954	11.0	0.1	88.1	0.8
1958	9.1	3.2	87.0	0.7
1959	5.8	3.6	89.8	0.8
1964	45.5	16.8	33.8	3.9

Increases in the log and the veneer and plywood categories were dominant factors in altering the position of wood products.

Income generated to Upper Lakes port areas.—The value to the local economy generated by a ton of general cargo moving through a port has been estimated at various figures. These estimates consider the use of port and terminal services, such as pilots, tugs, etc.; banking service; crew expenditures; purchase of ships' supplies; and the various types of labor attendant to processing accounts and handling cargo. Values used have ranged from approximately $11 to $20 per ton. Using a rate of $15 per ton, the 68,052 tons of wood and paper products moved in 1964 generated approximately $1,020,000 of income. The average for the last 6 years is $996,000. Those ports accounting for the bulk of the overseas trade are Detroit, Port Huron, Muskegon, South Haven, and the Saginaw River, Michigan; Milwaukee and Green Bay, Wisconsin; Chicago, Illinois; and Duluth, Minnesota.

Summary.—Although the total volume of wood and paper products moving in overseas trade has been lower for the past two seasons than for the peak years of 1959 and 1962, the increased amounts of veneer and plywood, paperboard, logs, wood manufactures, and paper and paper products have somewhat offset the decline in woodpulp volume. Local producers may not find it encouraging to see imports of competitive products, nor the export of scarce walnut logs. However, imports that are processed by local industry or added to existing product lines may not be particularly detrimental. Imports of certain strategic materials may encourage a greater use of existing raw materials. For instance, the importing of certain grades of "market pulp" could mean expanded pulping of abundant local wood species by providing a missing ingredient to the pulp mix or "furnish." And it is encouraging to see the export volume trending upward, particularly in the manufactured items.

It is impossible to predict the magnitude of the potential for overseas commerce for Upper Lakes ports. An impressive start has been made, however, and with continued favorable conditions for world trade the steady growth might be expected to continue in the near future.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-8

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE--U.S. DEPARTMENT OF AGRICULTURE
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Firebreak Maintenance With Soil Sterilants

In 1959 and 1962 the Minnesota Division of Forestry and the North Central Forest Experiment Station established a series of tests to determine the effectiveness of several herbicides in maintaining firebreaks free of vegetation. The primary objectives of these tests were to determine: (1) how long one application of soil sterilant can keep firebreaks satisfactorily free of vegetation and (2) how much chemical firebreak maintenance will cost. The tests continue a study on chemical firebreak maintenance which began in 1955.[1]

Establishment of Study. Areas selected for treatment represented difficult conditions for herbicidal control of vegetation as well as flashy fuel types. In 1959, tests were installed near Palisade, Minn., on two sites: (1) an undisked upland site with a sandy loam soil and bracken fern, sedge, and clover as the dominant vegetation and (2) a lowland peat site with grass, sedge, and moss as the dominant vegetation. On each site four chemical treatments were randomly allocated to 10x10-foot plots and replicated four times.

The 1962 plots, 12x55 feet, were installed on two disked, sandy loam sites east of Hill City, Minn. One site was almost entirely covered with grass, and the other was predominantly covered with bracken. Treatments were randomly applied to plots and replicated four times.

Granular chemicals were applied with a hand spreader. Wettable powders were mixed with a volume of water sufficient to provide for an application rate of 200 gallons per acre. Both hand-operated and gasoline-powered sprayers which created 200 p.s.i. pressure were used. Rate of application and chemical formulations are shown in table 1.

Plots were evaluated in the spring and fall according to their effectiveness as a firebreak and the percent of plot area occupied by vegetation. Firebreak effectiveness was rated according to the following categories (fig. 1):

1. G (good)—vegetation absent or sparse; a fire could not cross on fuel in plot.
2. I (intermediate)—vegetation present but not continuous; a fire might be able to cross under adverse fire weather conditions.
3. P (poor)—vegetation present and continuous across at least a portion of the plot; a fire could easily carry across the plot.

Percent of vegetation growing on plots was visually estimated, using vegetation on adjacent undisked soil as a reference with a rating of 100 percent. A treatment was reapplied when at least two of the four plots receiving it rated poor.

Effectiveness of Chemicals. The best control of vegetation, using one application of soil sterilant, was obtained with Ureabor (tables 2 and 3). Karmex and Simazine(80W) provided less effective control and Urox still less effective than Ureabor. Garlon and Simazine(50) yielded poor results, affording very short control of vegetation.

On the Hill City plots where dense bracken was present, only Ureabor showed promise of maintaining firebreaks free of this tough-to-kill plant. On plots dominated by upland grass, a single application of Ureabor produced the longest period of good control. However, two treatments of Urox, about as expensive as one treatment of Ureabor, furnished nearly 3 years of good control.

On the upland Palisade plots, two applications of Karmex in successive years provided 5 years of good control. One application of Ureabor provided 3 years

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[1] *Gaylord, G., and E. I. Roe. Sodium borates show promise for grass control. U.S. Forest Serv., Lake States Forest Exp. Sta. Tech. Note 515, 2 pp. 1958.*

Gaylord, G., and E. I. Roe. Tests of some chemicals for grass control on firebreaks. U.S. Forest Serv., Lake States Forest Exp. Sta. Tech. Note 516, 2 pp. 1958.

Table 1.—Chemical formulation and cost of herbicides applied at rates recommended by manufacturers

Chemical[1/]	Active formulation	Per acre[2/] Rate	Per acre[2/] Cost
Garlon	Diethylene glycol bis 2-2 dichloropropionate and 2(2,4,5-trichlorophenoxy) propionic acid	5 gals.	$ 33.00
Karmex(80W)	Diuron (3-(3,4-dichlorophenyl)-1,1-dimethyl urea)	50 lbs. 37-1/2 lbs. 31-1/4 lbs.[3/]	127.50 95.62 79.69
Simazine(50)	2-chloro-4, 6-bis-(ethylamino)-s-triazine	20 lbs.	(4/)
Simazine(80W)	2-chloro-4, 6-bis-(ethylamino)-s-triazine	50 lbs. 37-1/2 lbs.[3/]	122.50 91.88
Ureabor 31	Disodium tetraborate pentahydrate, disodium tetraborate decahydrate, 3-(p-chlorophenyl)-1, 1-dimethylurea, 2,3,6-trichlorobenzoic acid and related isomers	871 lbs. 652 lbs.[3/]	261.36 196.02
Urox 22	Monuron trichloroacetate ((3-p-chlorophenyl)-1, 1-dimethylurea trichloroacetate)	150 lbs.	124.50

1/ Trade names are used solely for information. No endorsement by the U.S. Department of Agriculture is implied.
2/ One acre corresponds to a strip of firebreak 12 feet wide and 0.7 mile long.
3/ These lower rates are for reapplications subsequent to initial treatment.
4/ Data not available.

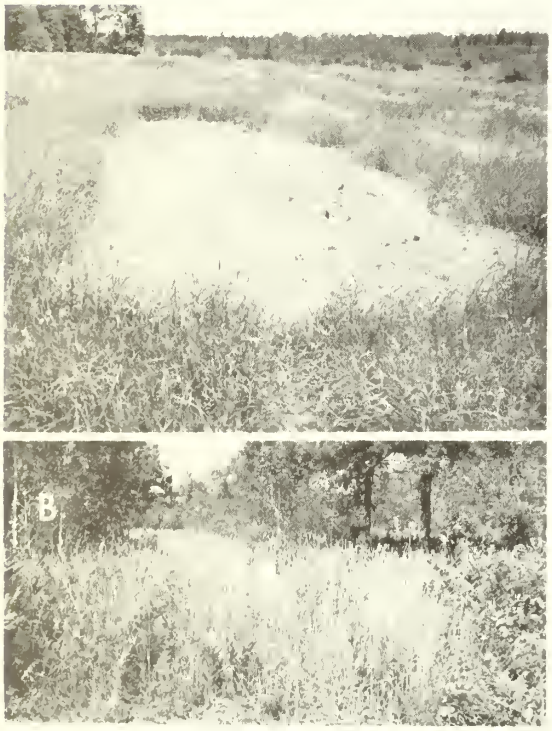

Figure 1.—Two plots treated for control of vegetation. Firebreak effectiveness and percentage of area covered with vegetation were estimated respectively as follows: *A* (near Hill City, Minn.)—good, 5 percent; *B* (near Palisade, Minn.)—poor, 95 percent.

of good control but a second and lighter application only 1 year of good control.

Control of marsh vegetation on peaty soil was unsuccessful with two repeated treatments of soil sterilants. Assuming rates of application reported for marsh plots in table 3, apparently at least three annual applications of Ureabor, Karmex, or similarly effective chemicals would be needed to provide 3 or more years of good control of marsh vegetation.

To avoid creating a strip of readily flammable dead plant material, soil sterilants should be applied to firebreaks on which the vegetative cover has been removed by disking or prescribed fire. The best time to apply soil sterilants for firebreak maintenance is in the spring before new growth emerges.

Timing in applying chemicals is important to successful control of vegetation. Ideally, a light rainfall should occur within a few days after treatment. A heavy rainfall occurring shortly after treatment washes away some chemical and reduces its effectiveness.

Cost Considerations. In selecting a soil sterilant for maintaining firebreaks, both effectiveness of single applications and cost of chemical treatment should be considered. Two applications of a comparatively inexpensive, moderately effective herbicide may control vegetation for a longer time than one application of a more expensive but very effective chemical. For

Table 2.—Treatment and evaluation of certain herbicides for maintaining firebreaks free of vegetation, Hill City, Minn.

Chemical	Date[1/]	Grass type			Bracken type		
		Amount applied	Percent vegetation[2/]	Firebreak effect[2/]	Amount applied	Percent vegetation[2/]	Firebreak effect[2/]
		Pounds per acre			Pounds per acre		
Urox	S. '62	150	--	--	150	--	--
	F. '62		30	I		40	P
	S. '63	150	10	G	150	35	1
	F. '63		10	G		35	1
	S. '64		5	G	150	30	1
	S. '65		10	G		25	1
	F. '65		30	1		35	P
Simazine(80W)	S. '62	50	--	--	50	--	--
	F. '62		5	G		35	1
	S. '63		10	G		40	P
	F. '63		20	1		55	P
	S. '64		35	P	50	50	P
	S. '65		65	P		35	P
	F. '65		75	P		50	P
Karmex(80W)	S. '62	37-1/2	--	--	37-1/2	--	--
	F. '62		10	G		45	P
	S. '63		15	G		55	P
	F. '63		25	I		70	P
	S. '64		40	1	31-1/4	60	P
	S. '65		35	1		45	P
	F. '65		40	P		60	P
Ureabor 31	S. '62	871	--	--	871	--	--
	F. '62		5	G		5	G
	S. '63		0	G		10	G
	F. '63		0	G		25	1
	S. '64		10	G	652	5	G
	S. '65		40	I		0	G
	F. '65		30	I		5	G
Control	S. '62	--			--		
	F. '62		100	P		90	P
	S. '63		100	P		95	P
	F. '63		100	P		95	P
	S. '64		100	P		100	P
	S. '65		100	P		100	P
	F. '65		100	P		100	P

[1/] S = spring. F = fall. Actual dates of application or reapplication were 5/1/62, 5/7/63, and 5/1/64.
[2/] Average of four replicated plots.

example, two applications of Karmex should result in a longer period of control than one application of Ureabor (table 3). The chemical costs would be approximately the same (table 1). In comparing total costs of chemical treatments, the expense of handling, shipping, and applying chemicals should be taken into account.

Experience from this study indicates that the length of time good vegetation control can be obtained with one application of soil sterilant will vary with herbicide used, amount and timing of rainfall, and type of soil and vegetation present. At most, 3 years of good control can be obtained; but where tough-to-kill plants predominate treatments repeated every 1 or 2 years appear necessary. Herbicide manufacturers suggest that once good initial kill of vegetation is obtained, chemicals can be reapplied at lower concentrations than applied initially. Average annual costs of chemical firebreak maintenance would then be

Table 3.—Treatment and evaluation of certain herbicides for maintaining firebreaks free of vegetation, Palisade, Minn.

Chemical	Date[1/]	Disked upland: Amount applied per acre	Disked upland: Percent vegetation[2/]	Disked upland: Firebreak effect[2/]	Undisked marsh: Amount applied per acre	Undisked marsh: Percent vegetation[2/]	Undisked marsh: Firebreak effect[2/]
Garlon	1959	10 gal.[3/]	5	G	5 gal.	5	G
	1960	5 gal.	30	P	5 gal.		P
	1961			P			P
Simazine(50)	1959	20 lbs.	10	G	20 lbs.	55	P
	1960	20 lbs.	20	I	20 lbs.		P
	1961			P			P
Karmex(80W)	1959	50 lbs.	15	G	50 lbs.	5	G
	1960	50 lbs.	5	G	50 lbs.		P
	1961		5	G			G
	1962		5	G		35	I
	1963		10	G		50	I
	1964		70	P			P
	1965		70	P			
Ureabor 31	1959	871 lbs.	0	G	871 lbs.	10	G
	1960		10	G			P
	1961		15	G			P
	1962		60	P		100	P
	1963	652	0	G	652 lbs.	80	P
	1964		30	I			P
	1965		40	I			
Control	1959	--	95	P		100	P
	1960		100	P		100	P
	1961		100	P		100	P
	1962		100	P		100	P
	1963		100	P		100	P
	1964		100	P			
	1965		100	P			

1/ Actual dates of application or reapplication were 6/25/59, 8/8/59, 7/12/60, 7/20/60 (Garlon), and 5/7/63.

2/ Average of four replicated plots.

3/ Two 5-gallon applications were made, one in June and one in August.

lower, as an example, for a 10-year period than for a period of 3 or 4 years.

Soil sterilants are a possible means for maintaining firebreaks free of vegetation. In some circumstances they may prove as economical or even less costly than annual disking and are particularly useful where repeated disturbance of soil is undesirable.

July 1966

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[2] *Since this study was made, the author has been transferred to the Intermountain Forest and Range Experiment Station.*

U. S. FOREST SERVICE

RESEARCH NOTE NC-9

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE--U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Forest Floor Fuels in Red and Jack Pine Stands

An investigation to determine the quantity and density of forest floor fuels in red pine (*Pinus resinosa* Ait.) and jack pine (*Pinus banksiana* Lamb.) stands was conducted on National Forests in Michigan and Minnesota. The study was designed to answer three questions:

How much fuel per acre exists in individual layers of the forest floor?

How reliably can weight of forest floor fuels be estimated from specific stand characteristics?

What is the density of individual layers of the forest floor?

In 1963, Dieterich[1] published information on weight and density of litter fuels in red pine plantations for the Lake States. This Note covers fuels in jack pine plantations and natural red pine stands.

Study procedures. — During 1963, nine red pine stands and five jack pine plantations with the following characteristics were selected for study:

	Red pine	*Jack pine*
Site index	59-69	56-65
Age, years	21-180	15-43
Basal area per acre, sq. ft.	85-195	90-170

Thirteen 1/10-acre plots were randomly located in red pine stands and 10 in the jack pine plantations. On each plot, forest floor fuels were collected from ten 1-foot-square subsamples systematically placed along the plot diagonals.

Samples of the *L*, *F*, and *H* layers of the forest floor were collected separately, oven-dried, and weighed. The *L* or litter layer, consisting of undecomposed litterfall, was separated into needle, branchwood, herbaceous vegetation, and miscellaneous components. Average composition of the *L* layer on an ovendry weight basis for all plots was as follows:

	Red Pine (percent)	*Jack pine* (percent)
Needles	55	40
Branches	20	45
Herbaceous and miscellaneous vegetation	25	15

The *F* layer, containing partially decomposed material often lightly bound by fungal mycelium (fig. 1), was fairly simple to distinguish from the *L* layer.

The *H* layer, composed primarily of amorphous organic matter, was poorly developed in the sampled plantations, whereas it was clearly defined in the natural stands. Samples of humus 8 to 10 grams in dry weight were incinerated in a muffle furnace. Results indicated that less than 3 percent of the entire forest floor consisted of mineral matter. Fuel weights reported here were not adjusted for this small amount of mineral matter.

Thickness of the forest floor was measured with a small wood frame, 1 inch wide and 8 inches long, which held a sliding rule. The frame, placed at the top of each layer,

[1] *Dieterich, J. H. Litter fuels in red pine plantations. U.S. Forest Serv. Res. Note LS-14, 3 pp. 1963. (Lake States Forest Exp. Sta., St. Paul, Minn.)*

FIGURE 1. — The forest floor in this natural red pine stand, 65 years of age with site index of 60 and basal area of 190 square feet per acre, contained 6,700 pounds of material in the *L* layer and 20,300 pounds in the *F* and *H* layers together per acre.

provided an upper reference mark; and the rule, lowered to the top of the next lowest layer, provided a lower reference mark for the layer being measured. Thickness of each layer was measured 10 to 20 times per plot, depending upon its variability in individual stands. This provided an estimate of average thickness with a standard error of less than 10 percent of the mean.

Fuel weight per acre. — Weight of forest floor material per acre was extremely variable in natural red pine stands but considerably less variable in jack pine plantations as shown in the following tabulation:

	Pounds per acre, dry weight	
	Red pine	*Jack pine*
L layer:		
Average	5,600	3,400
Range	2,900-9,800	2,300-6,600
Total forest floor:		
Average	32,800	23,420
Range	10,800-74,600	17,400-30,200

Regression analyses of total forest floor weight per acre on age of stand, site index, basal area per acre, and number of trees per acre showed no significant relationships (at the 0.05 level). A history of erratic fire occurrence in the natural red pine stands may have obscured relationships and increased variability of forest floor weights under given stand conditions. On the other hand, red pine *plantations* show *less* variability in stand characteristics and forest floor fuel weights than do jack pine plantations. Dieterich's work in red pine plantations showed good correlation ($r^2 = 0.796$) between basal area per acre and forest floor weight.[2] Most of the plantations he studied were 15 to 25 years of age, on good sites, and had never been burned. Although the sampling procedures used in jack pine plantations were similar to those used by Dieterich, the relationship of fuel weight to basal area was not as strong in jack pine as it was in red pine. Perhaps a larger sample of jack pine plantations would reveal a stronger correlation.

Predictions of forest floor fuel weight from stand characteristics are most dependable in stands having uniform structure, a history of no fire, and an origin on other than old forest floor material. Plantations approach these requirements. Estimates in natural stands, which frequently originate on existing forest floor material and may have been modified by fire, would tend to be less reliable.

Density of forest floor. — Density was computed from volume and weight per acre of each layer. Volume of each layer was determined from average thickness and contains both solid material and void space. The litter layer in jack pine plantations was about twice as dense as in red pine plantations and natural stands (table 1). Also, the litter layers of both species were less dense than their corresponding *F* and *H* layers.

Density, expressed as pounds per acre-inch, partially reflects the spacing between individual fuel particles and is a rough measure of fuel bed compactness. The large difference in density between litter layers of jack pine and red pine is due to differences in the physical characteristics of their needles. Fallen red pine needles are long and curved and form a loose litter layer. Jack pine needles

[2] *Dieterich, 1963. See footnote 1.*

TABLE 1. — *Density and thickness of layers of the forest floor from red pine and jack pine stands in the Lake States*

Forest floor layer	Red pine				Jack pine	
	Plantations[1/]		Natural stands		Plantations	
	Density	Thickness	Density	Thickness	Density	Thickness
	Lb./ac.-in.[2/]	Inches	Lbs./ac.-in.[2/]	Inches	Lbs./ac.-in.[2/]	Inches
L	7,000	0.7	9,000	0.6	17,700	0.2
F and H	11,600	.6	15,700	1.5	22,200	.9
Total	9,300	1.3	13,400	2.1	20,900	1.1

[1/] From Dieterich, 1963; see footnote 1 of text.

[2/] Some expressions of fuel density found in fire research literature have been in terms of pounds per cubic foot of fuel (solids and voids). Density expressed by pounds per acre-inch, when multiplied by 2.75×10^{-4}, can be converted to pounds per cubic foot.

are short and form a more compacted litter layer than red pine needles.

Compared to jack pine, the less compact red pine litter contains more free air space between needles. As a result, air movement is less restricted. This indicates that the drying rate and potential combustion rate of red pine litter is higher than that of jack pine litter.

The forest floor plays an important role as a source of fuel for both wildfires and prescribed burns. Eventually, fuel weight determinations may be used in combination with other fuel properties such as moisture content, particle size, and compactness to predict fire behavior with operable precision.

September 1966

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THE FOREST SERVICE CREED

The Forest Service of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

U. S. FOREST SERVICE

RESEARCH NOTE NC-10

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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The Impact of Insects in the Northern Hardwoods Type

The northern hardwoods type occupies about 16 percent — 8.2 million acres — of the commercial forest land in the Lake States. The timber has high unit values and represents about 42 percent of the total value of all the commercial forest in the region. Increasing values and markets for northern hardwoods in recent years have stressed the need for better quality in the finished product. Industry, therefore, is vitally interested in clear material, particularly for veneers and furniture stock and even for the relatively new use of the denser hardwoods for pulp. This interest, in turn, has focused attention on agents affecting growth and grade.

Until recently, the role of insects in the development, growth, and quality in this type either was not recognized or was considered of minor importance. Insects can and do play an important role, however, in limiting the production of high-quality trees; they serve as entrance courts for degrading pathogens, and cause crooks and other form defects as well as growth and grade reductions. Recent studies of "maple blight" in Wisconsin indicate that insects played an important role leading up to mortality of sugar maple in all age classes.

Existing information on insects in northern hardwoods has recently been reviewed.[1] This Note condenses some of that information, especially the material concerning sugar maple and yellow birch. The available data, though scanty, indicate that insects attack these species from regeneration to maturity. For ease in presentation, the type of insect damage has been placed in four stages of a tree's development.

1. Damage to seeds and natural reproduction that modifies future stand composition. This damage, however, may be obscured and attributed in later years to some other natural factor, such as a disease organism or deer browse.
2. Defects causing poor tree form in the early growth stages and resulting in reduced values as the stands develop.
3. Growth reduction leading up to tree mortality and deterioration (probably of greatest importance in stands approaching merchantability).
4. Defect and degrade affecting all stages of growth but most noticeable and of greatest importance in merchantable trees and logs.

Insect Injury to Sugar Maple and Yellow Birch

Seeds and reproduction.—There is little factual information on the impact of insect damage to seeds and reproduction in the northern hardwoods type and only a small amount on the occurrence of certain insect species. Moth larvae (*Proteoteras* sp.) can cause heavy losses in sugar maple seeds. Shigo and Yelenosky (1963) reported destruction of 50 percent of yellow birch seeds in the Northeast by a seed weevil (*Apion walshii*). Random samplings of yellow birch seed, collected in October 1965 at the Dukes Experimental Forest in northern Michigan, showed that about 48 percent of the seeds were damaged by moth and beetle larvae. Sugar maple reproduction may be girdled at the ground line by the sugar maple timber beetle (*Corthylus punctatissimus*); trees up to 6 feet in height may be killed, and when the stand density is low, regeneration can be adversely affected.

Form defects. — Insect attacks that cause form defects in young stands may escape notice at the time they occur; or the symptoms may be confused with those of some other agent. Attacks by the gall-making maple borer (*Xylotrechus aceris*) and the birch-and-beech girdler (*X. quadrimaculatus*) are quite common in young trees up to 2 inches d.b.h. The damage may not be evident until the stem breaks. A twig pruner (*Elaphidion villosum*) may seriously deform and retard the growth of young maple trees, particularly nursery stock. Kulman (1965) reported that destruction of the terminal bud by larvae of the moth, *Obrussa ocherfasciella,* caused forking and reduced total shoot growth. A recent study by Tigner[2] in Upper Michigan revealed that larvae of this and another moth,

[1] *Problem Analysis, "The Impact of Insects in the Northern Hardwoods Forest in the Lake States," by H. J. MacAloney. July 1965.*

[2] *Tigner, T. C. The wood-boring insects in sugar maple sapling stands in northern Michigan with special reference to their identification and possible long-term effect on tree form. Unpublished thesis in partial fulfillment of the requirements of the Degree of Master of Forestry, Univ. Mich. 1966.*

Proteoteras sp., destroyed more than 20 percent of current leader buds of sugar maple saplings.

Growth loss and deterioration. — Sugar maple and yellow birch are attacked by free feeders, skeletonizers, miners, rollers, and webworms. When feeding persists for several years, there may be a measurable reduction in radial increment; and complete defoliation for 2 or more years may kill the tree. Value losses in sugar maple and yellow birch are not available, but Duncan and Hodson (1958) reported a reduction in growth amounting to as much as 2¼ cords per acre in aspen stands attacked by the forest tent caterpillar (*Malacosoma disstria*). This periodic insect also feeds heavily on sugar maple.

Recently, heavy mortality of sugar maple of all sizes and ages occurred during a critical period in late July and early August in northern Wisconsin due to a complex relationship of two leaf rollers (*Sparganothis acerivorana* and *Acleris chalybeana*) and a webworm (*Tetralopha asperatella*) (Giese and Benjamin 1964). Contributing to the severity of damage were the shoe-string root rot, low stand density, severe late spring frosts, and a high proportion of sugar maple.

Skilling (1964), studying the effect of below-normal precipitation and insect defoliation on the development of maple blight symptoms, found that 2 years of heavy mechanical defoliation caused severe tree mortality.

The bronze birch borer (*Agrilus anxius*) contributes to postlogging decadence and death (Spaulding and MacAloney 1931, Hall 1933). Under forest conditions, attack begins in the exposed crowns, causing branch mortality; it progresses downward, and in the final stages of attack the bole may be completely girdled. Trees of low vigor, especially those suddenly exposed by heavy cutting, are especially vulnerable. Jensen and MacAloney (1949) suggested that partial cutting would lessen the hazards of postlogging decadence. This borer, probably as a secondary agent, was also associated with the recent birch dieback problem in the Northeast, which caused a loss of 494 million board feet of birch (Hepting and Jemison 1958). Environmental factors, chiefly climatic, were the direct cause of dieback.

Defect and degrade. — This type of damage is present in all northern hardwood species, but research gives information for insects on only one species — sugar maple. The two most important species attacking merchantable trees are the sugar maple borer (*Glycobius speciosus*) and the sugar maple cambium miner (*Phytobia setosa*). Larvae of the sugar maple borer construct extensive galleries in the wood, mostly in the lower part of the boles of trees above 6 inches d.b.h. Occasionally a stem will break, but reduction in value for flooring and furniture stock is the most important item. Talerico (1962), studying relatively young merchantable stands in northwestern Pennsylvania, found that attacks were most numerous in the codominant trees. The beetles are sunloving, and there was some evidence that trees of low vigor on the southerly aspects were more susceptible to attack.

The cambium miners — larvae of small flies — begin their attacks in the small, upper branches and mine downward into the roots between the bark and the cambium, causing pith ray flecks. These flecks are apparent deep in the wood, in cross-section cuts, years after the actual attack. Ward and Marden (1964) estimated losses as high as 13.6 percent of the monetary value of fleck-free face veneer. Hanson[3] stated that the grade loss had been conservatively estimated at 35 to 40 per cent of the value of face-grade veneer stock. Paneling with this defect, however, is popular in some markets.

Wormhole or pinhole defects in both maple and birch are caused by ambrosia beetles and may be characterized by stained burrows in the sapwood. The Columbian timber beetle (*Corthylus columbianus*), one of the most important in the Lake States, attacks living, vigorous sugar maples; but there is no published information on value losses. In the central hardwoods region, however, Wilson (1959) reported rejection of 30 percent of white oak logs intended for high-grade veneer. Timber worms and powder-post beetles are often associated with wounds or sunscald and increase the degrade problem, particularly in decayed areas.

On the whole, information on defect and degrade in yellow birch due to insect activity is lacking except as it refers to deterioration following death due to defoliation or girdling. Roughened areas on the bark can indicate attack by scale insects such as *Xylococculus betulae*, which may result in stem lesions and cracks, possible entrance courts for wood rots and cankers (Shigo 1962). Nectria cankers, for example, are commonly found on sugar maple and yellow birch.

Associated Tree Species

Brief mention should be made of insect injury to the more important tree species associated with sugar maple and yellow birch in the northern hardwoods type. The hemlock borer (*Melanophila fulvoguttata*) is essentially a secondary insect which may build up to tremendous populations in stands disturbed by natural factors or heavy logging. Following severe drought and windthrow in central Wisconsin about 30 years ago, this insect was an important factor in the mortality of about 135 million board feet of overmature hemlock; fortunately, much of this was salvaged. The hemlock looper (*Lambdina fiscellaria*) caused heavy mortality 35 to 40 years ago in Wisconsin and Upper Michigan in small acreages where hemlock was

[3] *Hanson, J. B. The biology of the sugar maple cambium miner,* Phytobia setosa *(Loew), and notes on other cambium miners in diffuse porous woods. Unpublished thesis in partial fulfillment of the requirements of the Degree of Master of Science, Univ. Wis. 1965.*

the predominant species. Economic conditions at that time precluded salvage of much of this dead material.

The red oaks and basswood are periodically attacked by the walkingstick (*Diapheromera femorata*). Fortunately, this insect is wingless, and spread is relatively slow. It also requires 2 years for development, and, unless alternate-year broods overlap, attack occurs every other year.

To date, beech has had comparatively little insect damage in the Lake States. Tree mortality, however, was widespread in trees of all ages in the Northeast between 1930 and 1950 due to attack by an imported insect, the beech scale (*Cryptococcus fagi*); and mortality is still continuing at lower levels. A fungus (*Nectria coccinea* var. *faginata*) attacks the infested trees 3 to 5 years after the scale becomes apparent and hastens tree mortality. The scale, *Xylococculus betulae,* also attacks beech, causing damage similar to that in yellow birch.

Research Needed

Some insect buildups appear to be associated with stand conditions that are altered by management or logging or by natural factors such as windthrow. Where this occurs, an integration of management practices with knowledge of insect behavior would be a fruitful approach.

Other insect outbreaks are periodic and associated with environmental or climatic factors rather than management or stand conditions. Here research should be aimed at gaining a knowledge of the factors which may "trigger" a condition suitable for development of an infestation. Studies of population dynamics may provide key factors which could be exploited for control.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-11

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Seasonal Fluctuation in Moisture Content of Pine Foliage

Green or living fuels, particularly pine crowns, are commonly consumed by forest fires burning during hot, windy weather. In some cases the pine crowns burn rapidly; in young pine stands crown fire has been known to burn ahead of surface-burning fire for some distance before dropping to the ground.

We know that moisture content of dead or cured fuels greatly influences the way they burn. So we conducted a study to find out to what extent seasonal variations in moisture content of green pine foliage influence the crown-fire potential of coniferous stands in the Lake States.

Sampling Methods

Red pine needle samples were collected during 1962 and 1963 from three stands: two located about 10 miles north of St. Paul, Minn., and one in the Manistee National Forest in Michigan. Jack pine needle samples were collected during 1963 from the Manistee National Forest. Needles were collected on irregularly scheduled days between noon and 3:00 p.m.

Each sample, consisting of eight subsamples of 10 to 20 grams, was analyzed for moisture content by ovendrying. Old-growth (second-year or older) needles were separated from new-growth needles in the subsamples. New-growth needles collected at the Minnesota sites during April-June 1963 were from the 1962 growing season and were almost 1 year old. The sampling error was estimated to be 5 percent or less of the mean percent moisture content (dry basis) using the .95 confidence level.

Supplemental samples were collected to determine if meaningful differences in moisture content existed between needles taken from upper crown and lower crown positions.

Results

Seasonal trend of needle moisture-content was similar for both species, both locations, and both years (figs. 1, 2, and 3). The latter was true despite the fact that 1962 was a wet year in Minnesota (summer precipitation 4.5 inches above normal) and 1963 a dry year (5.2 inches below normal). Both years were dry in Michigan: precipitation was 5.3 inches below normal during the summer of 1962 and 6.5 inches below in 1963.

Moisture content of new-growth needles decreased steadily throughout the summer from about 200 percent in late June to about 135 percent in October. Both Buck (1939, 1965) and Philpot (1963), working with different species, reported similar decreases in moisture content of new-growth foliage with the advance of the growing season.

Moisture content of old-growth needles usually fluctuated between 100 and 125 percent. Only a few samples contained less than 100 percent moisture — the lowest being 95 percent in red pine in Minnesota during the drier, slightly cooler spring of 1963 (fig. 2). Needle moisture averaged about 4 percent less during the spring of 1963 than in 1962.

No difference in needle moisture content was found between samples of the upper and lower crowns of red pine.

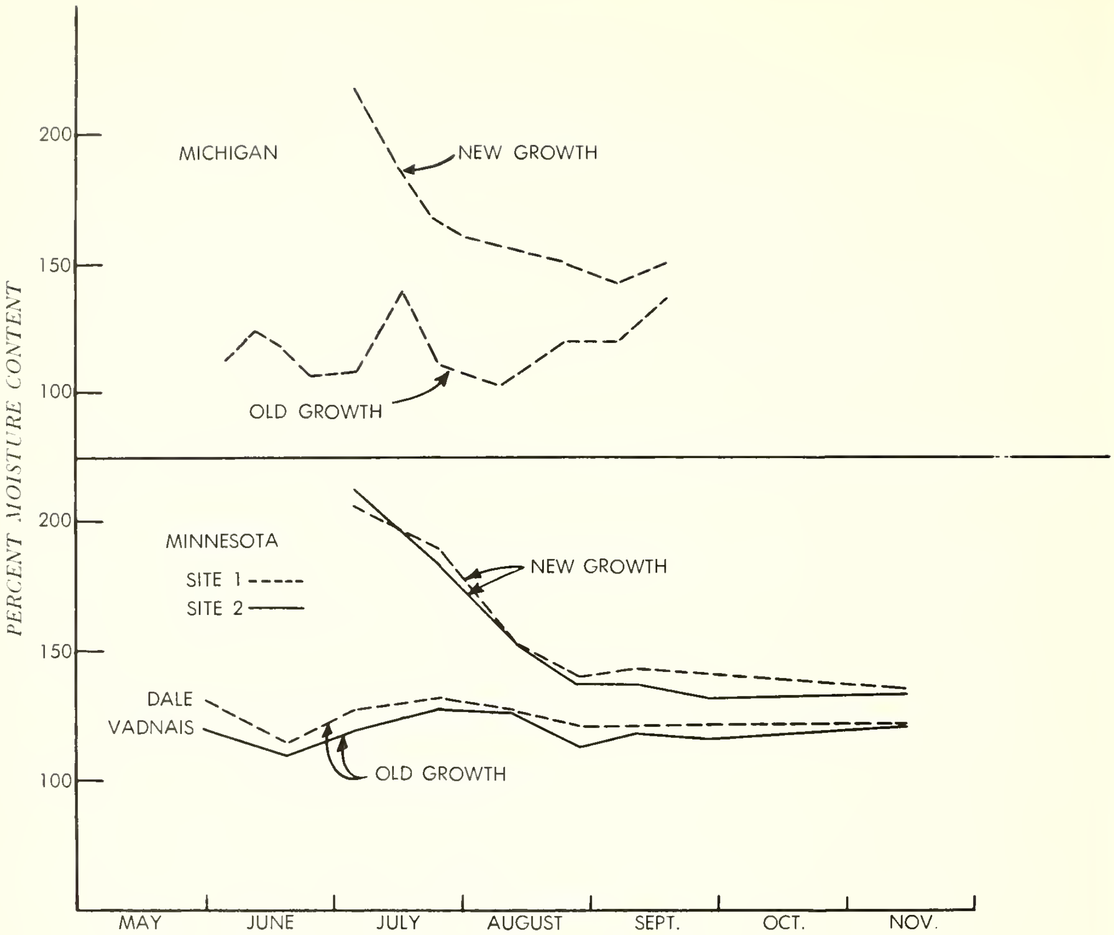

FIGURE 1. — Moisture content of red pine needles during 1962.

Discussion

Seasonal fluctuation of moisture in mature foliage is the result of a complex interaction of factors such as soil moisture tension and evaporation potential of the air. The cause of the fluctuation is not completely understood. However, it is evidently due in part to cell wall thickening as the needles mature, which results in an increase of dry weight in proportion to moisture. Richards (1940) found that similar trends in seasonal moisture content of freshly picked snowbrush leaves resulted in a net change of caloric content from 900 calories per gram in spring to 2,000 calories per gram in autumn.

Fuels containing 100 to 125 percent moisture do not logically constitute a serious fuel hazard. In fact, at moisture contents as low as 65 percent, Scots pine, balsam fir, and white spruce Christmas trees are relatively resistant to combustion. Van Wagner (1961) found that flaming ceases immediately on removal of an 8-inch Bunsen flame ignition source. We must conclude then that live needle moisture content is not a critical factor in crown fires.

We do know, however, that coniferous crowns will support combustion during severe burning situations. Under hot and windy conditions the convective and radiant heat produced from fires burning in dry ground fuels may ignite overstory green fuels. At other times, under apparently similar conditions, ignition of green fuels does not occur.

If needle moisture is not the critical factor, what is? Hubert suggested in 1932 that leaf oil content of coniferous needles might have an influence on forest fires. He showed that oils extracted from green pine and fir foliage have average flash points of 54° C. and 46° C. respectively. Extractable oils

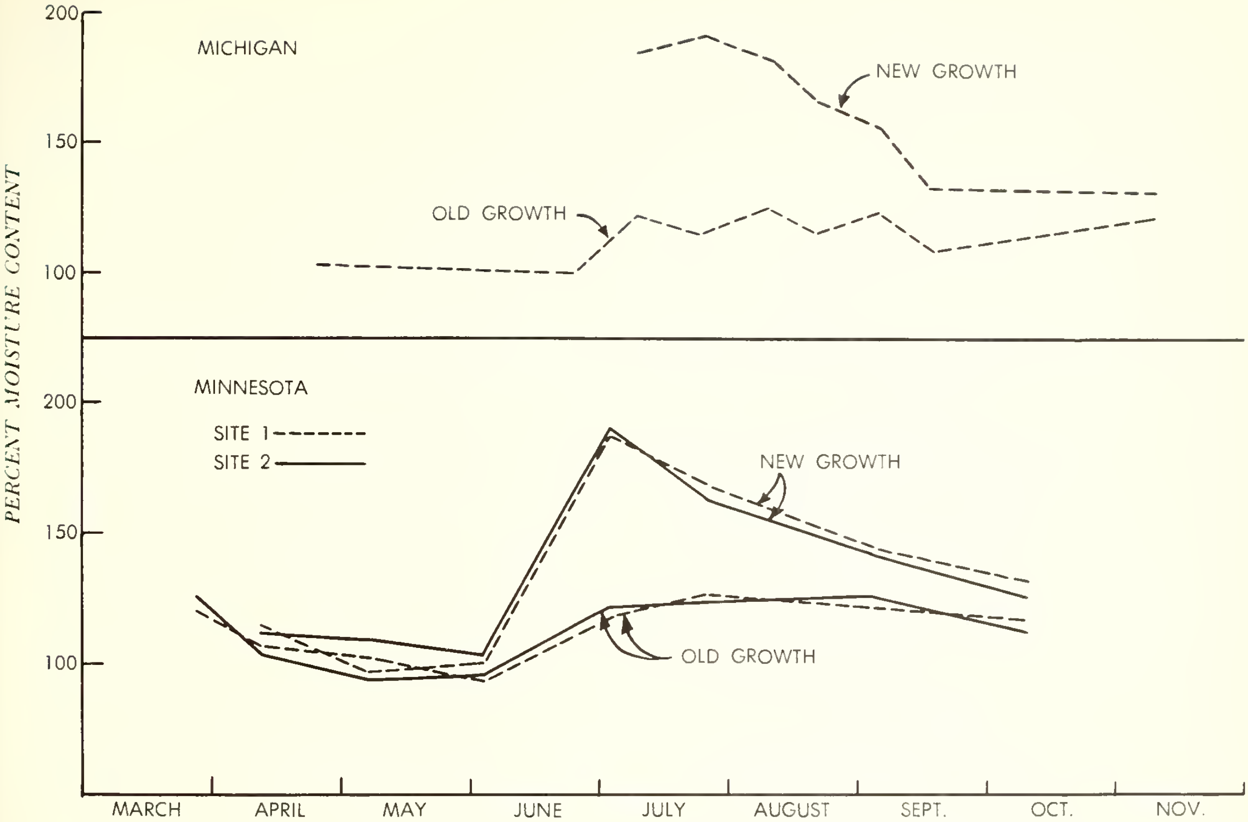

FIGURE 2. — Moisture content of red pine needles during 1963.

amounted to .015 to 1.2 percent of the total green weight. Exactly how variations of oil content affect the flammability of green needles is not known. Perhaps a higher concentration of nonaqueous volatiles (oils, fats, resins, and waxes) in green foliage during certain seasons or under particular weather conditions causes an acceleration in moisture release during preheating. This would provide a threshold for crown-fire development.

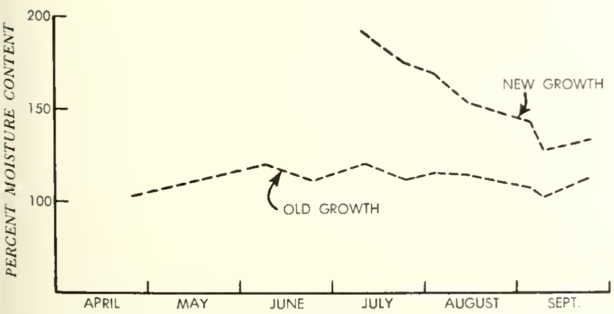

FIGURE 3. — Moisture content of jack pine needles in Michigan during 1963.

At any rate, in our search for a satisfactory explanation for crown fires we must apparently look beyond needle moisture content.

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September 1966

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RESEARCH NOTE NC-12

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Effect of Staining Caused by Sapstreak Disease on Sugar Maple Log and Lumber Values

Sapstreak, a killing disease of sugar maple (*Acer saccharum* Marsh.), caused by the fungus *Ceratocystis coerulescens* (Munch) Bakshi, was first described by Hepting in 1944 in North Carolina. It was reported in the Lake States by Kessler and Anderson in 1960 and in the Northeast by Houston and Fisher in 1964. It has also been found on occasional yellow-poplars (*Liriodendron tulipifera* L.) in scattered locations in Tennessee and North Carolina (Roth *et al.* 1959). In 1963, Ohman and Kessler reported several new cases in the Upper Peninsula of Michigan, including one stand in which the incidence was probably about 10 percent. They also presented evidence indicating that the fungus enters primarily through root wounds caused by logging.

Since 1963 sapstreak has been observed in over 100 living or recently killed sugar maples throughout Upper Michigan. All but two of these trees were in stands partially cut 3 to 10 years previously, and the fungus appeared to have entered through low stem or root wounds caused by logging. Two trees were found in old-growth stands that had never been logged; in both cases, windfalls of nearby trees had caused similar wounds that served as entry courts for the fungus.

The fungus causes extensive staining in infected but still living trees (Hepting 1944, Ohman and Kessler 1963). It is a common cause of sapstain in hardwood lumber throughout the East (Davidson 1935), and the fungus is very common on recently cut surfaces of stumps and logs (Ohman and Kessler 1963, Shigo 1962). However, the stain caused by the fungus in living trees is not superficial and is much darker than that found in dead material. Since such discoloration would obviously cause reductions in log and lumber quality, this study was made to obtain some idea of the magnitude of such loss. Mr. Leo Gannon, President, Gannon Lumber Corp., Marquette, Mich., cooperated in the mill phase of the study.

During a 2-year period, 14 sugar maple saw logs infected by sapstreak (fig. 1) were brought to the mill. These were segregated from normal logs and later sawed separately. Most were from a tract of old-growth northern hardwoods in which all merchantable eastern hemlock (*Tsuga canadensis* (L.) Carr.) had been logged 5 years previously.

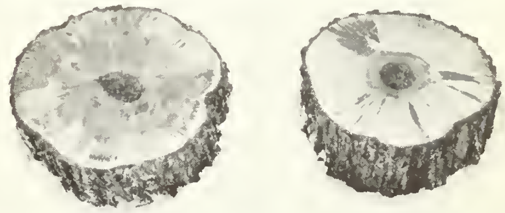

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FIGURE 1. — Cross-sections showing characteristic stain patterns caused by sapstreak in living sugar maples. *Left*: Large end of a 16-foot butt log. *Right*: Scaling end of same log. Note the many narrow points extending toward the cambium. On freshly cut surfaces the apices of these points are green. Reddish to gray radial streaking is present within the main body of tan to brown discoloration. The circular, darker stain in the center is dark heart and not caused by sapstreak.

Each infected log was scaled, then graded, using log grades developed by the Forest Products Laboratory (1959), in two ways: as the log actually appeared and as it would have been graded had the sapstreak stain not been a defect. Lumber obtained from these logs (figs. 2 and 3) was measured and graded by National Hardwood Lumber Association (1962) rules and also graded as if the sapstreak stain was no defect.

All infected logs had heavy stain extending to the cambium, well beyond the allowable limits for grade 1 and 2 logs and these were thus reduced one grade. Four grade 1 logs were reduced to grade 2, and six grade 2 changed to grade 3 (table 1). The four grade 3 logs were unchanged. Value of all the logs was reduced by 32 percent based on 1966 log prices, f.o.b. mill.

F-514380

FIGURE 2. — Surface view of sugar maple boards from infected logs. *Left*: Board cut from the main body of the discoloration. The stain is tan to brown with reddish to gray streaks. *Right*: Board cut from a zone nearer the cambium includes green streaks.

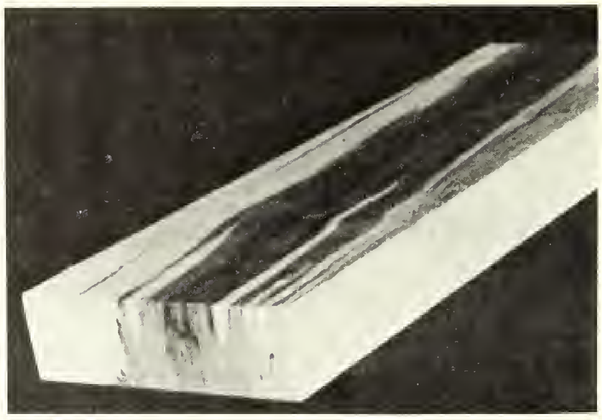

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FIGURE 3. — End view of a board similar to that shown in Figure 2, right.

Most of the lumber derived was also deeply stained and so did not yield the required percentages of clear cuttings for the higher grades (table 2). Based on current prices, f.o.b. mill, lumber value was reduced by 57 percent with most of the change occurring in the highest value lumber. Nearly all of the number 1 and better grades dropped to 3B common, the lowest grade.

These results suggest that value loss due to sapstreak stain is so great that salvage of infected trees for lumber is not feasible, even if they are located and removed before death. Infected logs cut during logging operations would probably best be utilized for pallet lumber, industrial blocking, or chemical-wood if a market is nearby.

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TABLE 1. — *Value loss from sapstreak stains based on change in log grade*

Sapstreak stain no defect				Sapstreak stain a defect				
Log grade	No. logs	Board feet[1]	Value[2]	Board feet[1] in log grade: 1	2	3	Value[2]	Value loss (percent)
1	4	590	$ 64.90	-	590	-	$ 41.30	36
2	6	640	44.80	-	-	640	28.80	36
3	4	290	13.05	-	-	290	13.05	0
Total	14	1,520	$122.75	-	590	930	$ 83.15	32

[1]Net scale, Scribner Dec. C.

[2]Based on f.o.b. mill prices for log grade No. 1, $110/MBF; No. 2, $70/MBF; No. 3, $45/MBF.

TABLE 2. — *Value loss from sapstreak stains based on change in lumber grade*

Sapstreak stain no defect			Sapstreak stain a defect					
Lumber grade	Board feet	Value[1]	Board feet in lumber grade: 1C & Better	2C	3A	3B	Value[1]	Value loss (percent)
#1C & Better	652	$ 136.92	30	22	84	516	$ 36.36	73
#2C	382	31.32	-	148	-	234	22.67	28
#3A	116	6.96	-	-	99	17	6.71	4
#3B	385	17.32	-	-	-	385	17.32	0
Total	1,535	$ 192.52	30	170	183	1,152	$ 83.06	57

[1]Based on f.o.b. mill prices for #1C & Better, $210/MBF; #2C, $82/MBF; #3A, $60/MBF; #3B, $45/MBF.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-13

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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Cordwood Yields From Thinnings in Young Oak Stands in the Missouri Ozarks

Proposed construction in Missouri of pulpmills using oak cordwood should result in a greater demand for pole-size oak trees, thus making needed thinnings feasible in young oak stands. According to the 1958 forest survey, poletimber stands (which are mainly oak) occupy 39 percent of the commercial forest area of the eastern Ozarks, more than any other size class.[1] More intensive management of the large areas of oak-hickory poletimber stands will be possible as markets improve. Recent experimental thinnings in young, even-aged oak stands cut to several stocking levels provide data on possible cordwood yields.

During 1962 and 1963, a level-of-stocking study was established in fully stocked 20- and 40-year-old oak stands in the Missouri Ozarks. Most of the trees are black oak (*Quercus velutina Lam.*); other species include white oak (*Q. alba* L.), scarlet oak (*Q. coccinea* Muenchh.), red oak (*Q. rubra* L.), post oak (*Q. stellata* Wangenh.), and hickories (*Carya* spp.). These even-aged, oak-hickory stands are growing on soils classified as Clarksville cherty loam or silt loam. Site indices range from 50 to 80 feet.

There are 60 half-acre plots, 30 in each age class. Basal area of the plots before thinning ranged from about 60 square feet per acre in the younger stands to 110 square feet in the older stands.

The density measure used in this study is stocking percent based on the tree-area ratio.[2] Plots were thinned to four stocking levels — 30, 50, 70, and 90 percent. The original stand, yield, and residual stand were measured (Table 1).

Because only small trees were cut in the 20-year-old stands, the volume yields were low. Such early thinnings probably will not pay an immediate net return and may be justified only on the better sites where production of high-quality trees is a reasonable objective.

In the 40-year-old stands, however, larger trees are available and higher yields per acre are possible. Thinning to about 70 square feet of basal area produced 4.2 cords per acre, and thinning to 50 square feet yielded nearly 10 cords per acre.

Experience indicates that desirable stocking for 40-year-old oak stands is about 60 square feet after thinning. Such a thinning in fully stocked stands would yield about 7 cords per acre and leave the stands in better condition to produce more high-quality wood. The development of a pulpwood market should make such thinnings more attractive to timberland managers.

These data should be useful for estimating cordwood yields from initial thinnings in well-stocked oak-hickory stands. Additional growth and yield data for the several thinning schedules in this study will be available in the future.

[1] *Mendel, Joseph J. Timber resources of the eastern Ozarks. U.S. Forest Serv. and Univ. Missouri Agr. Exp. Sta. Bull. B779. 1961.*

[2] *Chisman, H. H. and Schumacher, F. X. On the tree-area ratio and certain of its applications. J. Forest. 38: 311-317. 1940.*

TABLE 1. — *Original volumes, yields and volumes left after thinning fully stocked 20- and 40-year-old oak-hickory stands to several density levels*

Density level after thinning		Original stand		Thinning yield		Residual stand	
Stocking percent	Basal area, sq. ft.	Cubic feet[1/]	Cords[2/]	Cubic feet[1/]	Cords[2/]	Cubic feet[1/]	Cords[2/]
				Age 20			
30	24	290	4.4	133	2.0	157	2.4
50	39	267	4.1	43	0.7	224	3.4
70	52	388	6.0	47	0.7	341	5.3
90	66	265	4.0	9	0.1	256	3.9
				Age 40			
30	30	1,536	23.6	943	14.5	593	9.1
50	50	1,617	24.9	640	9.8	977	15.1
70	70	1,605	24.7	276	4.2	1,329	20.5
90	88	1,745	26.9	111	1.7	1,634	25.2

1/ Gross peeled cubic-foot volume in trees 4.6 inches d.b.h. and larger to a 3-inch top d.i.b.

2/ Rough cords computed at 65 cubic feet per cord.

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RESEARCH NOTE NC-14

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Hardwood Face Veneer and Plywood Mill Closures in Michigan and Wisconsin Since 1950

In recent years there has been a great deal of concern about the closure of numerous hardward face veneer and plywood mills in Michigan and Wisconsin. As part of an overall study of that industry in the northern Lake States region, the basic reasons leading to the closure of these mills were investigated. In the past 15 years, there have been eight known mill closures[1] within the study area with an estimated total employment loss of 1,600 people. Presumably, each of these closures affected the economic equilibrium of the geographic areas in which they were located.

One or two former officials associated with each of these firms were interviewed to learn the chief reasons behind these closures. A second interview served as a means of confirming opinions secured from the first interviewee. How available raw material resources affected the closures was a primary point discussed. Information pertaining to markets, products manufactured, affiliations with larger companies, and reasons for closure was solicited. In addition, historical data on each company was recorded, including information regarding disposal of plant equipment and resettling of employees after the mill closed.

The products made by these firms did not fall into any special category, although each mill was primarily a hardwood plywood producer. Some produced a mixed line of door and wall paneling, whereas others manufactured cabinet and lumber core plywood. In one case, the product-mix included the fabrication of plywood boxes for certain specialty items. The products of these eight mills were marketed in a number of geographical areas, and some were even sent abroad for foreign consumption.

[1] *The number of closures was equally divided among Michigan and Wisconsin. The total number of hardwood face veneer and plywood mills in the region has varied little in the past 15 years, with the total population remaining at approximately 30 to 32 mills. This relatively narrow range is largely due to either the creation of totally new operations or reactivation of closed mills under new management.*

All of the mills closed their operations within 10 years of one another; that is, between the years of 1953 and 1962. Four were owned by the same company and ended production within 4 years of one another. These four mills were part of a large-scale closure operation conducted by the parent company throughout the nation. Three of the other mills were independently owned by one or two individuals or by local stockholders. A fourth was absorbed by a large national firm and closed shortly thereafter. There appeared to be no correlation between the size of the firm (in terms of the number of employees) and closure inasmuch as some mills employed as few as 30 and others as many as 300 people.

PRIMARY PROBLEMS OF THE REGION'S MILLS

The interviews, plus study of data and literature on the industry, disclosed several problems that are of primary importance to mills in the region. These problems are discussed below, while specific reasons for each mill's closure are offered in the next section.

Raw Material Supplies

A preliminary evaluation of the veneer log supply shows a declining trend in quality of the raw material available to regional mills. As the quality becomes poorer, the mill manager is faced with numerous alternatives. He may find that veneers needed for various markets and operations can be obtained only by more intensively managing his manufacturing operations. Unit costs normally increase when such action is taken. On the other hand, the mill operator can utilize the material from the poorer logs and expect his final products to be altered accordingly, but they must still be marketable.

The quantity of veneer logs available is also an important consideration. As this raw material supply dwindles, mills either seek new sources of logs or enter into stiff competition with one another for the available log supply. In either case, the result is higher unit costs.

Data on veneer log production and consumption in Michigan and Wisconsin show sharp declines in the 11-year period, 1952-1963 (tables 1 and 2). At least part of this declining veneer log production may have been due to mill closures within the Lake States region, but even after the bulk of the closures had taken place (up through 1958) a decline was still evident. To further complicate matters, the downward trend in the region has occurred in a time when domestic consumption of hardwood veneer and plywood products has greatly expanded.

TABLE 1. — *Annual veneer log production in Michigan and Wisconsin for selected years*
(Thousand board feet, Int. ¼" scale)

Year	Veneer log production		
	Wisconsin	Michigan	Total
1952	29,956	40,219	70,175
1954	27,109	34,499	61,608
1956	30,403	39,655	70,058
1958	23,740	19,958	43,698
1960	25,467	18,486	43,953
1963	25,203	15,300	40,503

Source: Compiled from North Central Forest Experiment Station data presented in numerous Research and Technical notes for the years indicated.

TABLE 2. — *Annual veneer log consumption in Michigan and Wisconsin for selected years*
(Thousand board feet, Int. ¼" scale)

Year	Veneer log consumption		
	Wisconsin	Michigan	Total
1952	60,629	28,338	88,967
1954	59,572	21,872	81,444
1956	53,234	10,838	64,072
1958	43,063	12,597	55,660
1960	51,298	12,075	63,373
1963	41,918	7,598	49,516

Source: Compiled from North Central Forest Experiment Station data presented in numerous Research and Technical Notes for the years indicated.

Competition from Imports and Substitute Materials

In 1951, a reduction in the tariff on imported hardwood plywood (table 3) apparently resulted in an increased flow of low-cost foreign hardwood plywood into the United States, mostly in the form of wall panels, door material, and kitchen cabinet stock. Tariff rates for birch and "other" hardwood plywood were either halved or nearly halved between 1945 and 1951. Significantly, imported hardwood plywood began accounting for an increasing percentage of domestic consumption in 1952. By way of comparison, imports represented about 8 percent of the total U. S. consumption of hardwood plywood in 1951 and about 54 percent in 1964.[2]

In addition to the imports, the markets of hardwood veneer and plywood have been threatened by many types of substitute products. Steel, plastics, aluminum, and composition materials have captured many traditional wood markets. Their effect has been felt at one time or another by nearly every hardwood veneer and/or plywood manufacturer in the region.

Corporate Management Decisions and Policies

When profit margins diminish, corporate management decisions and policies take on added meaning. Most of the factors associated with mill closures mentioned thus far may be termed as "external to the firm." Corporate management decisions and policies, on the other hand, represent something entirely different. As the quality and quantity of the raw material resource decline, the mill manager and his associates must decide what action should be taken. When the company's product line falters, changes must be made. Undoubtedly, some corporations are better managed than others, and the degree to which they are effectively managed is of utmost importance. Of all the factors mentioned in regard to closure, management decisions and policies are perhaps the most important and yet, least subject to quantification.

REASONS FOR EACH MILL CLOSURE

In our opinion, no single factor was responsible for the closure of regional mills. The competitive position of each firm appeared to be weakened by several external factors (imports, substitutes, raw materials). When these were combined with a series of inappropriate management decisions, the mill closed. One might question whether obsolete equipment may have been a factor in some of the closures. The investigation showed that the majority of the firms were either less than 10 years

[2] *McDonald, Clark E. Hardwood plywood: 1.5MM. Forest Industries, Miller-Freeman Publications, Portland, Oregon. January 1965, p. 46.*

Table 3. — *Hardwood plywood: United States rates of duty under the Tariff Act of 1930, in specified years 1930 to 1955*
(Percent ad valorem)

Species	Tariff rate		
	In 1930	On Jan. 1, 1945	In 1955
Birch	50	[1] 25	[2] 15
Alder	50	50	[3] 25
Spanish cedar	40	40	40
Other	50	40	[2] 20

Source: The Production, Importation, and Marketing of Hardwood Plywood in the United States. U.S. Tariff Commission, Washington, D. C., December 1955, p. 11

[1] Trade Agreement with Finland, effective November 1936. Agreement terminated May 24, 1950, after Finland acceded to the General Agreement on Tariffs and Trade, pursuant to Annecy negotiations.

[2] General Agreement on Tariffs and Trade (Torquay), effective June 1951.

[3] General Agreement on Tariffs and Trade (Annecy), effective April 1950.

old at the time of closure or had some equipment and buildings renovated during the 5 years preceding closure. In many cases the equipment in these closed mills was quickly sold to other veneer and plywood manufacturers within the region.

Shortage of Quality Veneer Logs

The general decline in the veneer log resource during recent years did not appear to be a major factor in any of the closures investigated. Four of the firms did not mention raw material supply as a factor in the decision to close down operations. The remaining firms, all part of a nationwide veneer and plywood complex, had access to considerable quantities of company-owned timber within their normal procurement areas. During liquidation, this timber was sold on the market, with the parent firm realizing a substantial profit.

Competition from Imports and Substitute Materials

All of the former executives interviewed believe that their firms were affected by competition from imports and substitute materials. An executive of the company that once operated four plywood mills within the region stated his belief that at least two of the mills would be in operation today if it were not for competition from imports. In addition the plywood box line that these firms manufactured lost markets to domestically produced paper products which performed as substitutes. Another firm experienced competition from "fir" plywood as a construction material in the mobile home industry.

Our entire regional veneer and plywood industry almost certainly has been affected by the influx of imported hardwood plywood. But some mills, with their enlightened and informed management, have met this challenge quite adequately. Others have seen their profit margins diminish, but still remain in business. We believe that the competition of imports with domestically produced hardwood veneer and plywood was but a *contributing* factor in the closure of some operations.

Management Oriented Decisions and Policies

In the previous section, mention was made of a situation in which a company official felt that imports were basically responsible for the closure of two mills. Closer examination of the circumstances surrounding these closures, however, proved interesting. The parent company had operated "in the black" for some 25 years, but personnel changes in the top management and the firm's auditors had produced an apparent loss of

$10 million during one year.[3] As it turned out, closure of the four regional mills was but a part of a liquidation policy set up by the new management of the parent company. Whether all four mills were operating at a loss at the time of closure is not known, but at least one was having some difficulty maintaining acceptable quality standards.

In at least two of the other four mills, management decisions and policies appeared to play a major role in their closures. Heavy investment in capital equipment left one company short of funds to meet weekly payrolls and other short-term contractual agreements. In time, the company's financial status and credit rating deteriorated. The other mill faced a somewhat different problem. Apparently, the owner did not realize the extent to which imports were competing with his firm's products. Loss of markets and failure to alter the product-mix soon resulted in mill closure.

Over the past 5 years, mill managers have become increasingly aware of the advantages of sound management practices. They have come to accept the fact that wood raw material supplies and the flow of low-cost imports are, for the most part, factors which they do not control. These mill operators are now examining their production methods and management policies. Hopefully, small changes in these areas can substantially improve the overall profit picture.

[3] *See Fortune magazine, Volume LVII (1): 118. January 1958.*

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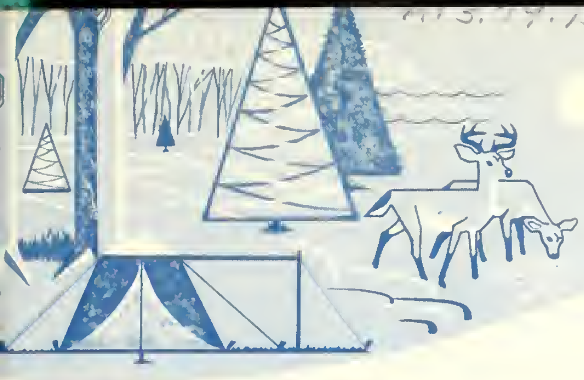

U. S. FOREST SERVICE

RESEARCH NOTE NC-15

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Private Pleasure Boating In the National Forests of Minnesota

Summary

The two National Forests of Minnesota accommodate slightly over one-tenth of the private pleasure boaters in the State. There are more private boaters in the Superior National Forest than in the Chippewa. Boaters within each Forest come predominantly from the local area. Of the boaters from outside the local area, one-half come from the Twin Cities Metropolitan Area.

Within the Superior National Forest, boaters from outside the local region concentrate near the edge of the Boundary Waters Canoe Area. In contrast most local boaters use lakes away from the Canoe Area. Because population growth is much greater outside the Superior local region than inside it, future increases in boating use may tend to concentrate on the wilderness fringe.

One-half of the Chippewa National Forest boat launchers use the three large lakes—Cass, Leech, and Winnibigoshish. These large lakes are predominantly used by transient launchers (cartop or trailered boats) while on the smaller lakes most launching is from seasonal or permanent dwellings.

State and National Forest Boat Launching Totals

There were 143,700 licensed private boats in Minnesota in 1964 (excluding rental boats). A recent mail survey[1] indicated that 11 percent of these were used primarily on lakes within the Chippewa (4 percent) and Superior (7 percent) National Forests during 1963.[2]

Statewide, 59 percent of the boat launchers normally launched boats from "seasonal dwellings or year-round homes," hereafter called "homes" (table 1). The remaining 41 percent were transient boaters who usually hauled their boats to public or privately owned launching sites. On the Superior National Forest, however, home launchers made up only 43 percent of the total Superior boat launchers, compared with 57 percent on the Chippewa and 59 percent for the State. These figures suggest that seasonal home development is not as far advanced in the Superior National Forest as in the rest of the State.

The type of launching facility used was related to the days of boat use per season. The average number of boat-use days for each primary use area in 1963 were:

	For home launchers	*For transient launchers*
Superior	47	25
Chippewa	51	31
Both Forests	48	27
Rest of State	57	31
State average	56	30

1 *Basic data were obtained from the Minnesota Outdoor Recreation Resources Commission (MORRC). In summer 1964, MORRC conducted a survey of the 143,700 private pleasure boat launchers (excluding boats owned by resorts or other commercial establishments) who license their boats in Minnesota. Questionnaire post cards were sent to a 7-percent random sample. The returns (35 percent) were fairly evenly distributed among the sending areas. The 390 cards for boat owners that launched most often on lakes within or partly within either the Chippewa (144) or the Superior (246) National Forests were used for this study. The most pertinent MORRC publications are: MORRC Report 3,* Public Access in Minnesota; *MORRC Staff Report 4,* A Study of Private Enterprise in Outdoor Recreation.

2 *Assuming a random return, the standard errors on the estimated number of launchers throughout this report at the 95-percent confidence level are as follows:*

Estimated number		*Standard error*
20,000	±	*1,660*
10,000	±	*1,210*
5,000	±	*870*
1,000	±	*400*
500	±	*260*

Table 1.—*Number of boats launched by type of launching site primarily used*

Primary use area	Home launchers[1/] Number	Home launchers[1/] Percent of area total	Transient launchers[1/] Number	Transient launchers[1/] Percent of area total	Total number of launchers[1/]
Superior	4,400	43	5,800	57	10,200
Chippewa	3,400	57	2,600	43	6,000
Superior & Chippewa	7,800	48	8,400	52	16,200
Rest of State	77,000	60	50,500	40	127,500
State total	84,800	59	58,900	41	143,700

1/ Every boat license owner was considered a launcher.

An average boat launched from a "home" in Minnesota was used 56 days, whereas the average transiently launched boat was used 30 days, only slightly more than half as much. The National Forest length-of-use averages for both home and transient launchers were lower than the overall State averages, particularly in the Superior National Forest. There appear to be two principal reasons for this: (1) compared with the rest of the State, neither Forest has many permanent lakeshore residences, which have longer use periods, and (2) the length of the boating season is shorter in the northern part of the State, particularly in northeastern Minnesota.

Statewide, about three-fourths of the total boat-use days come from home launchers (table 2). Even in the National Forests, with less lakeshore home development than in many other areas of the State, the majority of private boat use comes from home launchers.

Origin of Private Boat Launchers

Four origin regions were established for each National Forest (fig. 1). These were (1) local, (2) Twin Cities Metropolitan Area (TCMA), (3) rest of Minnesota, and (4) other States. For the two Minnesota National Forests combined, private pleasure boaters came predominantly from the local area.

Origin	*In percent* *Superior*	*Chippewa*	*Both*
Local	78	34	61
TCMA	13	28	19
Rest of State[1]	5	27	13
Other States	4	11	7

[1] For each Forest, "rest of State" includes the local area of the other Forest.

Approximately one-half of the boaters from outside the local area came from the Twin Cities Metropolitan Area.

Table 2.—*Total boat-use days*

Primary use areas	For home launchers: Thousands of days	For home launchers: Percent of area total	For transient launchers: Thousands of days	For transient launchers: Percent of area total	Total days in thousands
Superior	206	59	145	41	351
Chippewa	173	69	80	31	253
Rest of State	4,370	74	1,542	26	5,912
State total	4,749	73	1,767	27	6,516

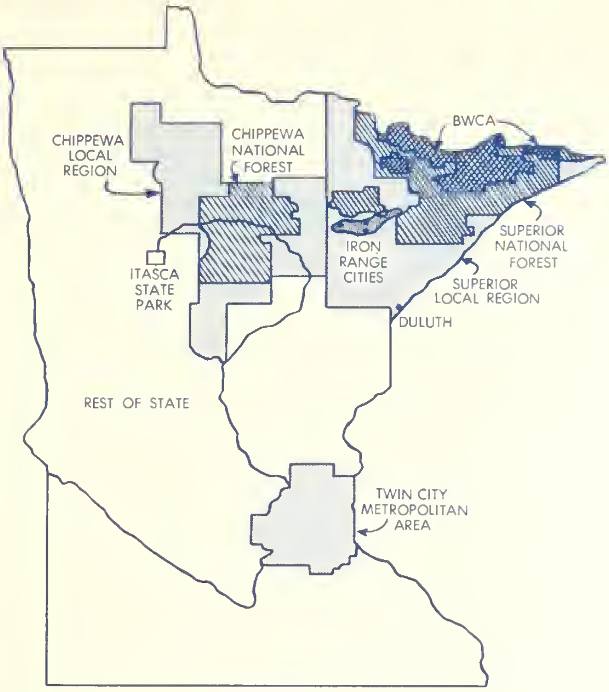

Figure 1.—Origin regions for private boat launchers using the Superior and Chippewa National Forests.

However, the two Forests differed sharply in boater origins. Pleasure boaters on the Superior were mainly local, whereas the majority of Chippewa boaters came from outside the local area.

Local boater figures are influenced by the shape of local regions (which encompass whole counties), especially within the Superior National Forest. The Superior local region contains Duluth and most of the Iron Range cities. Duluth, however, contributed only 18 percent of the local boaters. Most Superior local use originated from the Iron Range cities and the North Shore. The Chippewa had a lower proportion of local boaters than the Superior because of three principal factors: (1) a lower local-region population from which to draw visitors, (2) more accessibility to the population concentrations of the Twin Cities Metropolitan Area and southern Minnesota, and (3) location near Itasca State Park, the major northern Minnesota tourist attraction.

There was little difference between the origins of transient boaters and home boaters in the Superior (table 3). On the Chippewa, however, more local boaters were transient.

Distribution of Boating Within the Superior National Forest

The Superior National Forest was divided into three separate destination regions: (1) the wilderness (lakes on the edge of the Boundary Waters Canoe Area), (2) Lake Vermilion, and (3) the rest of the Forest. Lake Vermilion was set apart because it ranked as the third most heavily used lake for private boating in the State (surpassed only by Minnetonka and Mille Lacs lakes).

One-third of the Superior launchers and almost 40 percent of the home launchers were concentrated on Lake Vermilion (table 4). Lakes on the edge of

Table 3.—*Origin areas of pleasure boaters by launching type*

(In percent)

Launching type	Local	TCMA	Rest of State	Other 1/ States
		SUPERIOR		
Transient	79	13	9	2
Home	76	12	5	7
		CHIPPEWA		
Transient	42	29	27	2
Home	27	28	27	18

1/ The other States percentage totals show more home than transient launchers. However, outstate transient launchers having a boat licensed in another State were missed in the survey.

Table 4.—*Percentage of launchers in Superior National Forest from each origin region*

Primary use areas	Local			TCMA			Other areas			All areas			Number of launchers
	Home	Transient	Total	Home	Transient	Total	Home	Transient	Total	Home	Transient	Total	
Wilderness 1/	11	24	19	36	53	46	67	50	58	20	30	26	2,600
Vermilion	40	32	36	36	6	18	33	42	38	39	30	34	3,500
Rest of Forest	49	44	45	28	41	36	0	8	4	41	40	40	4,100

1/ The Wilderness includes all lakes in or partly in the Boundary Waters Canoe Area, plus Crane Lake.

the Boundary Waters Canoe Area accounted for another one-quarter of the total boaters. Thus, 60 percent of the total private boat launchers in the Superior used the edge of the wilderness and Lake Vermilion.

There is a considerable difference in the pattern of use between visitors from the local area and those from other areas. This suggests some basic differences in visitor preferences. Use patterns show no strong wilderness attraction for local boat launchers; only 19 percent went to the edge of the wilderness. Apparently local boaters used the closest launching places. In contrast, over half of the non-local visitors to the Superior National Forest launched their boats on the edge of the Boundary Waters Canoe Area. For non-local boaters the wilderness seems an important attraction. This difference was particularly sharp for boating from home sites: Only 11 percent of the local home boating took place on wilderness or edge-of-the-wilderness lakes compared with nearly half of the seasonal home boating by people from non-local origin areas.

The population projections imply that increasing future recreational use of the Superior National Forest will consist primarily of visitors from outside the local area.[3] If present visitor-use preferences persist, most of this increase will take place on the wilderness fringe or in areas of similar recreation environment. The Crane Lake Recreation Area (Superior National Forest) and the border lakes west from there to International Falls, if they retain their wild character, may be viewed as an alternative wilderness fringe by boaters.

[3] *In 1960, 90 percent of the Superior local region population lived in urban places (urban centers of over 2,500). Between 1960 and 1975 urban population growth of the region has been projected at only 28,000 (an 11-percent increase) compared to 530,000 (35 percent) for the Twin Cities Metropolitan Area, and 91,000 (17 percent) for the rest of the State. Of the projected urban growth in Minnesota 97 percent is expected to take place outside the local Superior region. (From: Borchert, John R., and Russell B. Adams,* Projected Urban Growth in the Upper Midwest: 1960-1975, *Upper Midwest Econ. Study, Univ. Minn. 1964, table 1).*

Distribution of Boating Within the Chippewa National Forest

The Chippewa National Forest was divided into two areas, one of large lakes (Cass, Winnibigoshish, and Leech), and a second containing all other lakes within or partly within the Forest boundary. The number of launchers was 2,800 on large lakes and 3,200 on the other lakes. In percentage they were divided between the primary use areas as follows:

	Large lakes	*Other lakes*
Home launchers	34	66
Transient launchers	63	37
Both	46	54

Almost one-half of the private pleasure boat launchers were concentrated on the three large lakes. These lakes attracted almost two-thirds of the Chippewa transient launchers, but only one-third of the home launchers. Seventy-one percent of the launchers on the smaller Chippewa lakes were from lakeshore homes, compared with only 42 percent on the large lakes.

In terms of total recreation impact on the Chippewa, home launchers are the most important. Today they account for 69 percent of the private pleasure boating days of use on the Forest (table 2). MORRC projections show that Statewide the number of home boaters will increase by 150 percent between 1960 and 1975, a rate of growth three times that of transient boaters. If these projections are applied to the Chippewa boat-use day figures, by 1975 over 80 percent of the private boat-use days within the Forest will originate from homes, seasonal or permanent. This means, if the location of future home development can be predicted, most of the future private boating increase within the Forest can be anticipated. Though present figures show that two-thirds of the seasonal homes are on the smaller lakes of the Forest, there is no good evidence to indicate why this settlement pattern exists or if it will continue.

December 1966

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RESEARCH NOTE NC-16

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Botanical and Commercial Range of Balsam Fir In the Lake States

Accurate maps showing the distribution of important tree species are valuable to foresters, botanists, wildlife specialists, land managers, and others. Although the general natural ranges for our principal tree species have been well known for some time, new information continues to develop. Commercial ranges, however, have not previously been mapped precisely, and artificial extensions of ranges generally have not been mapped at all. For these reasons, range maps of the principal forest tree species have been prepared[1] for the Lake States (Michigan, Minnesota, and Wisconsin), and that for balsam fir (*Abies balsamea* (L.) Mill.) is presented here (fig. 1.).

Accuracy depends in part on the scale of the map being used. On this map, it is not practical to separate out isolated stands except when they are some distance from the main range. Accordingly, the main range boundary as drawn may include several outliers near the edge of the principal distribution.

In the silvical characteristics reports for the Lake States tree species,[2] commercial ranges were mapped (balsam fir, however, was not included), but they were based on the following broad definition: "Commercial range is defined as that portion of the natural range in which the species grows to commercial size and is a major or important species in the type." In the present Note commercial ranges are defined on a wood-volume basis and are indicated for each county that presently has at least 1,000 cords of balsam fir (fig. 1). Counties with 10,000 to 99,000 cords and those with at least 100,000 cords are specially designated. The commercial range is based primarily on published reports of the Forest Survey and is supplemented for completeness by unpublished data from the same source and modified where local information justifies it. For example, reports of the second Forest Survey in southern Michigan (1947-1956) show small volumes of balsam fir in counties south of the known botanical range. This resulted from pooling timber volumes for adjacent lightly forested counties.

The natural range is based on the available published reports[3] as modified by the observations of qualified foresters and botanists.[4] A supplemental map (fig. 2) shows the plots used in making the distribution map. These plots were derived from actual herbarium specimens or from other reliable sources.

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[1] *Previously published reports in this series are for jack pine (U.S. Forest Serv. Res. Note LS-15), red pine (U.S. Forest Serv. Res. Note LS-62), eastern white pine (U.S. Forest Serv. Res. Note LS-63), white spruce (U.S. Forest Serv. Res. Note LS-73), and black spruce (U.S. Forest Serv. Res. Note LS-74).*

[2] *See Station Paper 67 and related Station papers published by the Lake States Forest Experiment Station.*

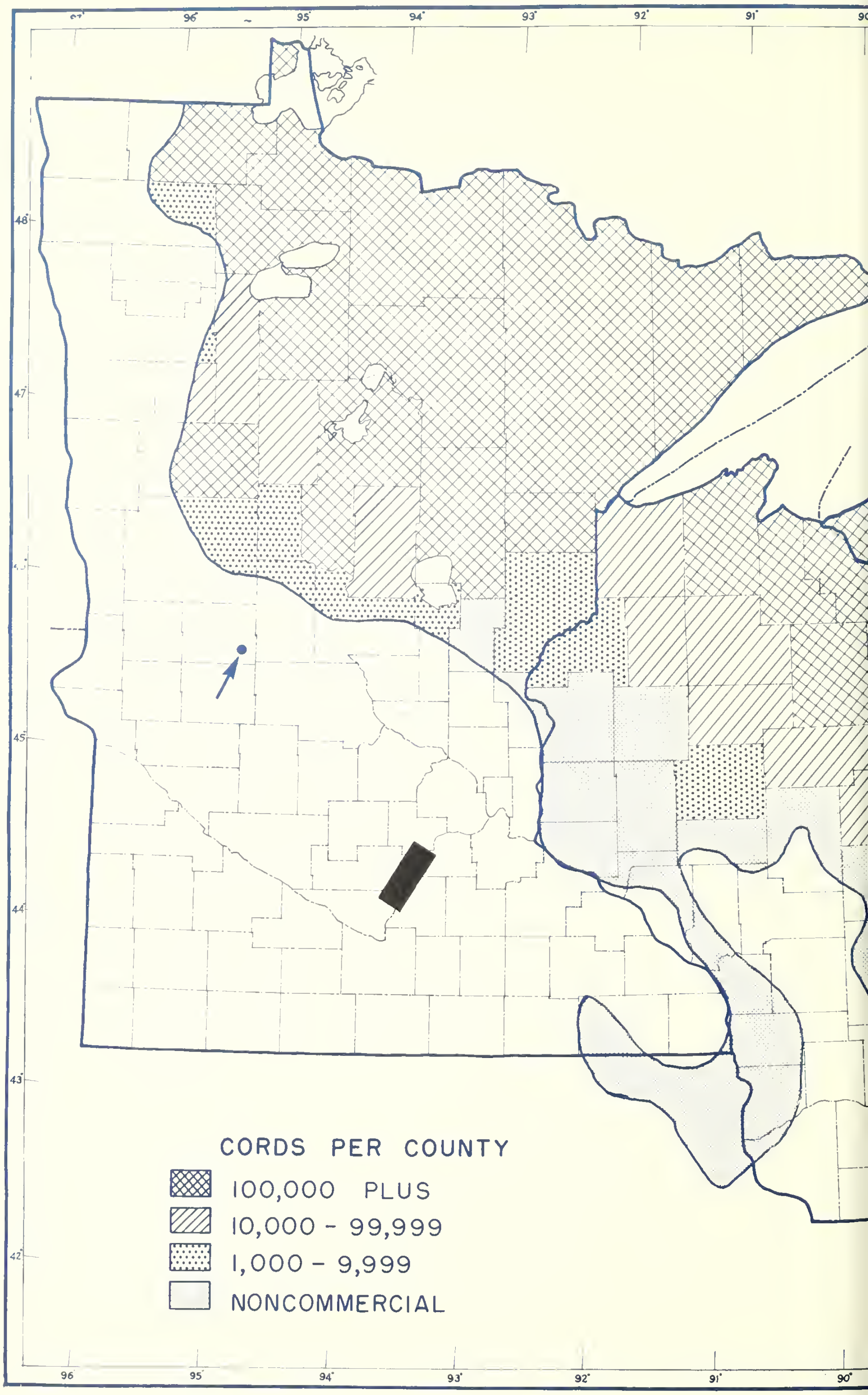
[3] *Bakuzis, E. V. and H. L. Hansen. 1965. Balsam fir—A monographic review. 445 pp (see pp. 38, 39, 65-70, and 332), illus. Univ. Minn. Press. Minneapolis.*

Dodge, C. K. 1921. Miscellaneous papers on the botany of Michigan. Mich. Geol. and Biol. Surv. Publ. 31, Biol. Ser. 6.

Fassett, Norman C. 1930. Preliminary reports on the flora of Wisconsin V. Coniferales, Wis. Acad. Sci., Arts and Lett. Trans. 25: 177-182, illus.

Hart, Arthur C. 1959. Silvical characteristics of balsam fir, U.S. Forest Serv., Northeast. Forest Exp. Sta., Sta. Paper 122, 22 pp., illus.

[4] *Information in this Note has been reviewed by Drs. Edward Flaccus and Paul Monson, University of Minnesota (Duluth); Dr. Egolfs Bakuzis, University of Minnesota (St. Paul); Dr. Thomas Morley, University of Minnesota (Minneapolis); Dr. Edward G. Voss, University of Michigan; Dr. John W. Andresen, Southern Illinois University; staff members of all Divisions of the North Central Forest Experiment Station and of its field offices in the Lake States; staff members of the U.S. Soil Conservation Service in Minnesota; and staff members of the National Forests and State Conservation Departments in Michigan, Minnesota, and Wisconsin.*


CORDS PER COUNTY
100,000 PLUS
10,000 - 99,999
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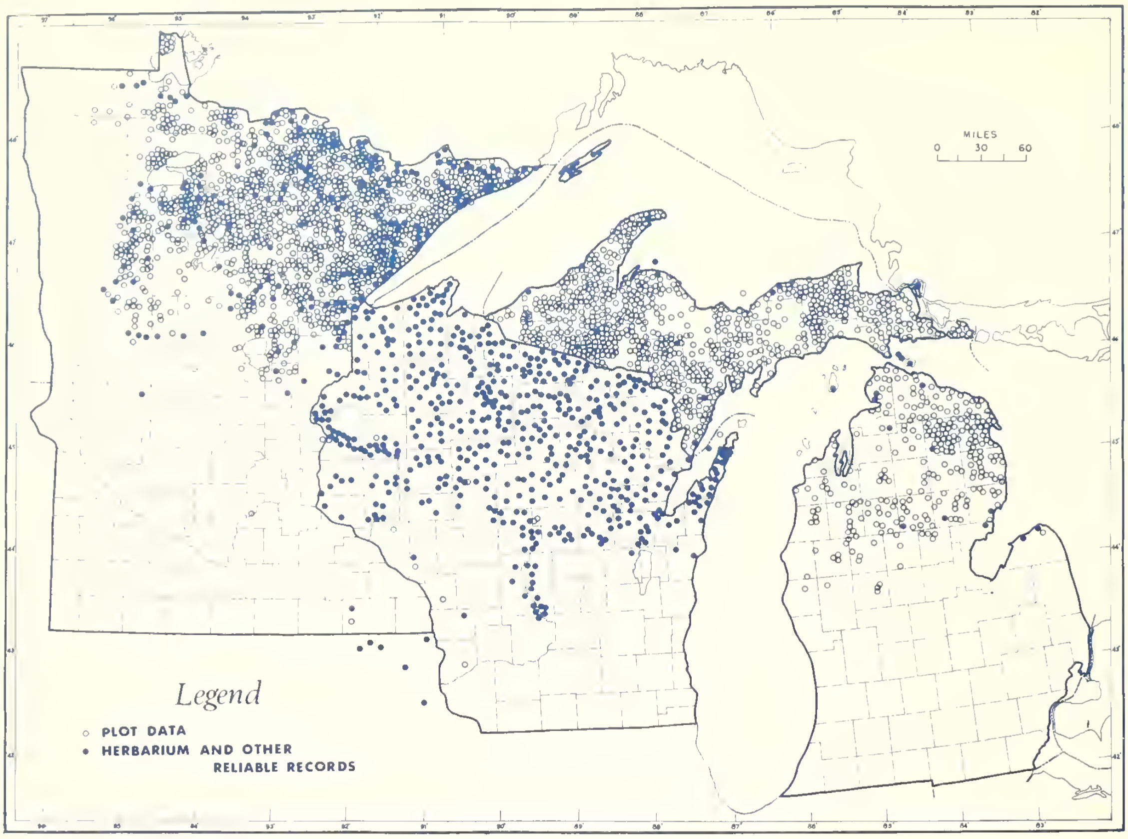
NONCOMMERCIAL

Figure 1.—Natural and commercial range of balsam fir in the Lake States. The natural range includes the areas within the heavy line. Arrows point to isolated stands that are some distance from the main range. The commercial range includes all counties within the natural range that have at least 1,000 cords of balsam fir.



Within its natural range in the Lake States balsam fir grows on many types of soil and drainage conditions. It develops best on deep, moist but well-drained loams or silt loams between 4.0 and 6.0 pH and grows well on limestone outcrops in northeastern Wisconsin. It will grow, but more slowly, on gravelly sands, shallow soils over rock, and on peat. Pure stands are not common. As a rule balsam fir grows with one or more associates, the most common of which in approximate order of frequency as they occur on some 2,000 Forest Survey plots are paper birch, quaking aspen, northern white-cedar, white spruce, red maple, yellow birch, black spruce, black ash, sugar maple, balsam poplar, and eastern white pine. Associates vary geographically and according to site conditions. For example, in Michigan eastern hemlock and tamarack, and in Minnesota, basswood, are fairly common associates in addition to the other species listed.

The natural distribution of balsam fir is outlined on the map. Planting of balsam fir has not been extensive. There is little probability, therefore, that artificial regeneration will blur the outlines of the natural range in the foreseeable future, as it may for white spruce and the pines.

Figure 2.—Localities from which native balsam fir is represented in established herbaria or other valid sources. Includes material from (1) the following herbaria: Cranbrook Institute of Science, Michigan State University, Milwaukee Public Museum, University of Michigan, University of Minnesota (Duluth), University of Minnesota (Minneapolis), University of Wisconsin (Madison), and University of Wisconsin (Milwaukee); (2) seed collection records of the North Central Forest Experiment Station, the University of Minnesota, and Michigan State University; (3) superior tree records of the North Central Forest Experiment Station; (4) a vegetational survey made by Dr. Egolfs Bakuzis of the University of Minnesota; (5) Fassett, 1930 (see footnote 3) for most of the Wisconsin locations; and (6) Forest Survey plots.

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RESEARCH NOTE NC-17

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Botanical and Commercial Range of Tamarack In the Lake States

Accurate maps showing the distribution of important tree species are valuable to foresters, botanists, wildlife specialists, land managers, and others. Although the general natural ranges for our principal tree species have been well known for some time, new information continues to develop. Commercial ranges, however, have not previously been mapped precisely, and artificial extensions of ranges generally have not been mapped at all. For these reasons, range maps of the principal forest tree species have been prepared[1] for the Lake States (Michigan, Minnesota, and Wisconsin), and that for tamarack *(Larix laricina* (DuRoi) K. Koch) is presented here (fig. 1).

Accuracy depends in part on the scale of the map being used. On this map, it is not practical to separate out isolated stands except when they are some distance from the main range. Accordingly, the main range boundary as drawn may include several outliers near the edge of the principal distribution.

In the silvical characteristics reports for the Lake States tree species,[2] commercial ranges were mapped, but they were based on the following broad definition: "Commercial range is defined as that portion of the natural range in which the species grows to commercial size and is a major or important species in the type." In the present Note commercial ranges are defined on a wood volume basis and are indicated for each county that presently has at least 1,000 cords of tamarack (fig. 1). Counties with 10,000 to 99,000 cords and those with at least 100,000 cords are specially designated.

The commercial range is based primarily on published reports of the Forest Survey supplemented for completeness by unpublished data from the same source and modified where local information justifies it. For example, reports of the second Forest Survey in Southern Michigan (1947-1956) show commercial volumes in several counties in the Thumb, where tamarack stands are few, small, and scattered. These reports resulted from pooling timber volumes for adjacent lightly forested counties.

The natural range is based on the available published reports[3] as modified by the observations of qualified foresters and botanists[4] and by collections of specimens on file. A supplemental map (fig. 2) shows the plots used in making the distribution map. These plots were derived from actual herbarium specimens or from other reliable sources.

Within its natural range in the Lake States tamarack usually grows on organic soils in bogs and swamps. When planted, however, it will grow fairly well on very dry soils also. It makes its best growth on rich, moist but well-drained, loamy soils along streams, lakes, and swamps; seep areas; and shallow

[1] *Previously published reports in this series are for jack pine (U.S. Forest Serv. Res. Note LS-15, 1963), red pine (U.S. Forest Serv. Res. Note LS-62, 1965), eastern white pine (U.S. Forest Serv. Res. Note LS-63, 1965), white spruce (U.S. Forest Serv. Res. Note LS-73, 1965), black spruce (U.S. Forest Serv. Res. Note LS-74, 1965), and balsam fir (U.S. Forest Serv. Res. Note NC-16, 1966).*

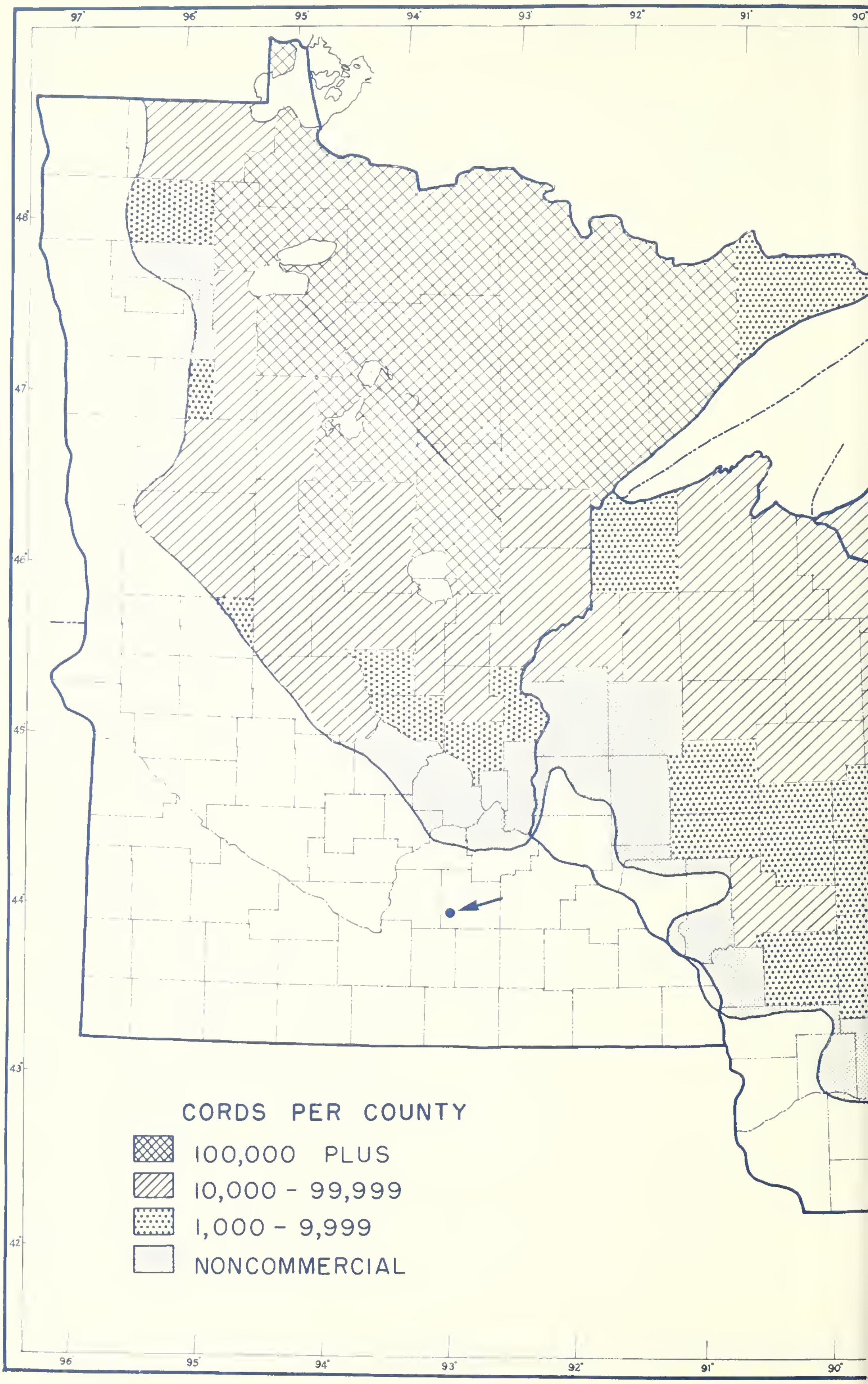
[2] *See Lake States Forest Experiment Station, Station Paper 67 and related Station papers.*

[3] *Dodge, C. K. 1921. Miscellaneous papers on the botany of Michigan. Mich. Geol. and Biol. Survey, Publ. 31, Biol. Ser. 6.*

Fassett, Norman C. 1930. Preliminary reports on the flora of Wisconsin. V. Coniferales. Wis. Acad. Sci., Arts, and Lett. Trans. 25: 177-182, illus.

Roe, E. I. 1957. Silvical characteristics of tamarack. U.S. Forest Serv., Lake States Forest Exp. Sta., Sta. Pap. 52, 22 pp., illus. 1957.

[4] *Information in this Note has been reviewed by Dr. Paul Monson, University of Minnesota (Duluth); Dr. Thomas Morley, University of Minnesota (Minneapolis); Dr. Edward G. Voss, University of Michigan; Dr. John W. Andresen, Southern Illinois University; staff members of all Divisions of the North Central Forest Experiment Station and of its field offices in the Lake States; Staff members of the National Forests and State Conservation Departments in Michigan, Minnesota, and Wisconsin. L. O. Miller, Area Forester at Cassopolis, Mich., gave especially valuable help.*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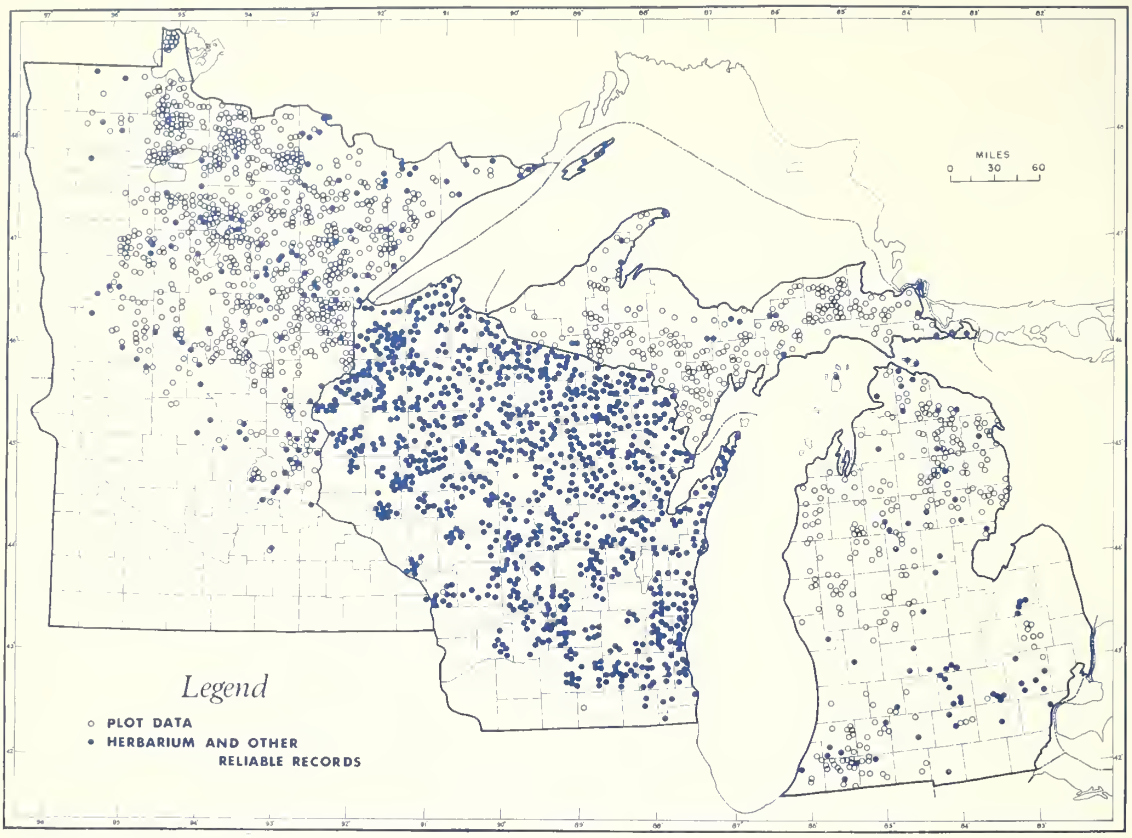
CORDS PER COUNTY
100,000 PLUS
10,000 - 99,999
1,000 - 9,999
NONCOMMERCIAL

Figure 1.—Natural and commercial range of tamarack in the Lake States. The natural range includes the areas within the heavy line. Arrows point to isolated stands that are some distances from the main range. The commercial range includes all counties within the natural range that have at least 1,000 cords of tamarack.



layers of muck or well-decomposed peat over mineral soils. Pure stands are characteristic, but tamarack frequently grows with one or more associates, the most common of which in approximate order of frequency as they occur on some 770 Forest Survey plots are black spruce, northern white-cedar, balsam fir, paper birch, quaking aspen, eastern white pine, red maple, black ash, white spruce, and American elm. Associates vary geographically and according to site conditions. For example, in Minnesota red maple is a rare associate, but balsam poplar is moderately common.

The natural distribution of tamarack is outlined on the map. Planting of tamarack has not been common. There is little probability, therefore, that artificial regeneration will blur the outlines of the natural range in the foreseeable future, as it may for white spruce and the pines.

Figure 2.—Localities from which native tamarack is represented in established herbaria or other valid sources. Includes material from (1) the following herbaria: Cranbrook Institute of Science, Michigan State University, Milwaukee Public Museum, University of Michigan, University of Minnesota (Duluth), University of Minnesota (Minneapolis), University of Wisconsin (Madison), and University of Wisconsin (Milwaukee); (2) seed collection records of the North Central Forest Experiment Station, the University of Minnesota, and Michigan State University; (3) superior tree records of the North Central Forest Experiment Station; (4) seed production areas on record at the North Central Forest Experiment Station; (5) a vegetational survey made by Dr. Egolfs Bakuzis of the University of Minnesota; and (6) Fassett, 1930, (see footnote 3) for most of the Wisconsin locations.

December 1966

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RESEARCH NOTE NC-18

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Activity Patterns of Campers

Families camping in auto campgrounds on the Huron-Manistee National Forests were studied in 1962.[1] Among other questions, the campers were asked how much time they had spent in various activities on the day prior to the interview. This is a report on the replies to this question.[2]

The average time budget of the campers is shown below.

Activity[1]	*Hours*	*Percent*
Relaxation	8.3	67
Swimming	1.1	9
Fishing	1.0	8
Auto sightseeing	.9	7
Picnicking	.4	3
Hiking	.3	2
Boating	.1	1
Nature study	.1	1
Gathering forest products[2]	.1	1
Canoeing	.1	1
Waterskiing	([3])	....
	[4] 12.4	100

[1] *Travel and miscellaneous activities such as photography and rock collecting are not included.*
[2] *Gathering berries, pine cones, mushrooms, flowers, etc.*
[3] *Less than 0.5 hour.*
[4] *Some of the campers had arrived the day prior to the interview and had not spent a complete day in the campground; hence the total number of hours is less than 16.*

Obviously campers don't spend very much time at any one activity other than relaxation. In this case, relaxation may be a misnomer since it includes camp chores as well as general loafing, reading, visiting, and so on. Less than 10 percent of the day is spent in the next most time-consuming activity, swimming.

The fact that most of the campers' time is spent in and around their campsite means its immediate environment may be a most important determinant of satisfaction. Relaxation as used here is so broad that specific recommendations as to design factors that might enhance it cannot be made. For example, visiting with neighboring campers is one form of relaxation; meditation is another. The types of environment conducive to these two forms are very different. The point, often made, is that a variety of environments within and between campgrounds is probably desirable.

The relative time spent in an activity, however, is not necessarily a valid measure of importance or satisfaction. The frosting on a cake is only a small proportion of the total volume, but its importance is well known.

[1] *King, David A. 1965. Characteristics of family campers using the Huron-Manistee National Forests. U.S. Forest Serv. Res. Pap. LS-19, 11 pp., illus. North Central Forest Exp. Sta., St. Paul, Minn.*
[2] *Replies were obtained from 1,606 individual members of camping families.*

Another way of looking at what campers do is the proportion participating in each of the activities:

Activity[1]	*Percent of campers*
Relaxation	93
Swimming	40
Auto sightseeing	35
Fishing	32
Hiking	20
Picnicking	19
Boating	8
Nature study	8
Gathering forest products[2]	6
Canoeing	3
Waterskiing	([3])

[1] *Travel and miscellaneous activities such as photography and rock collecting are not included.*
[2] *Gathering berries, pine cones, mushrooms, flowers, etc.*
[3] *Less than 0.5 percent.*

Relaxation is again the most popular activity, and swimming the second most popular. A slightly higher proportion of campers participated in auto-sightseeing than in fishing, but the proportion of time spent in fishing was slightly higher.

Because camping involves essentially three picnics a day, it may seem surprising that so many campers picnicked elsewhere than in the campground. However, a large part of this was probably done on sightseeing trips.

Waterskiing ranks low because the lakes included in the study area are too small to provide good waterskiing opportunities.

Significantly, except for relaxing, no one activity was engaged in by a majority of the campers. This result, found in other studies as well,[3] illustrates the characteristic heterogeneity of camping as a recreation activity and the mutitude of reasons people may have for camping. Diversity in the kinds of facilities provided is an important consideration in recreation planning.

Of course, what the campers do depends on the facilities and resources available, in addition to their interests and preferences (table 1). Activities that are only loosely tied to facilities, such as hiking, gathering forest

[3] *Alden, Howard R. 1965. Characteristics and preferences of recreationists in selected northern Idaho state parks. Forest. Wildlife, and Range Exp. Sta., Univ. Idaho, Moscow. 2 pp. illus.*

Table 1.—*Percent of campers participating in various activities by campground type*

Activity	River and stream (n=530)	Lake, no beach (n=16)	Lake, beach (n=1,060)
Relaxation	91	87	94
Auto sightseeing	40	48	31
Fishing	26	47	33
Swimming	18	17	54
Picnicking	14	17	21
Boating	0	14	12
Canoeing	(1/)	0	4
Hiking	29	17	17
Gathering forest products 2/	18	7	4
Nature study	10	8	7

1/ Less than 0.5 percent.
2/ Gathering berries, pine cones, mushrooms, flowers, etc.

products, and nature study, are more likely to be engaged in by the campers using river or stream campgrounds. These activities are also more closely tied to a natural or primitive environment than are other activities. In general, the river-stream campgrounds on these forests are less highly developed and are smaller than the lake campgrounds. Thus, interest in these activities may be related to a preference for the less crowded, more primitive campgrounds.

All but one of the river-stream campgrounds were rated by Forest personnel as having good or outstanding fishing. But fishing at these campgrounds ranks slightly lower in popularity than auto sightseeing and hiking, whereas at the lake campgrounds fishing is more popular. This may be because stream fishing is more demanding physically and requires, perhaps, more specialized skill than lake fishing.

Although the larger lake campgrounds tend to receive the emphasis in interpretive programs, the need for hiking trails, nature trails, and interpretive programs appears to be greatest at the river-stream campgrounds.

An attempt to relate activity participation rates to the socio-economic characteristics of the campers showed no important associations.

These results point toward the need for diversity and variety in campground design, environment, and facilities for associated activities. A relation between type of campground preference and activity preferences is also indicated; this should be explored further since it may be an avenue to the definition of different kinds of camping. Better definition should improve our ability to relate participation to socio-economic variables and, hence, to predict use. The apparent greater demand for nature-oriented activities at the more primitive, stream campgrounds shows a need for the development of nature and hiking trails at them as well as at the larger, more popular campgrounds.

December 1966

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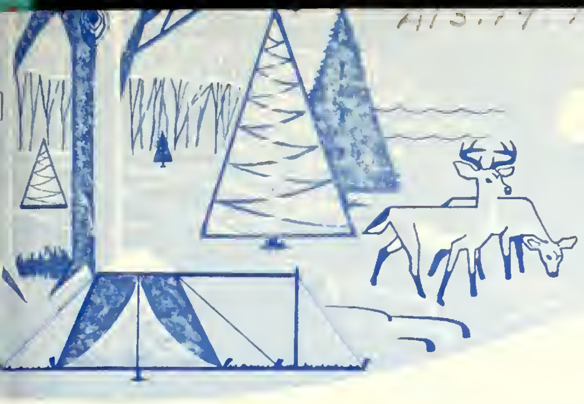
[4] *Since collecting the data for this Note, Mr. King has become an associate professor in the Department of Watershed Management at the University of Arizona, Tucson.*



U. S. FOREST SERVICE

RESEARCH NOTE NC-19

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Shortleaf Pine Seedling Inventory Methods On Broadcast-Seeded Areas In the Missouri Ozarks

The success of broadcast-seeding of shortleaf pine *(Pinus echinata Mill.)* after one or several years can be determined with specified precision by a systematic sampling procedure. Seeding results often are expressed as the total number of seedlings per acre, but good distribution is equally important. The total stocking and the stocked milacre methods described here provide these data.

A single random-start systematic sampling procedure is recommended for both methods, using circular milacre plots (radius 3.72 feet) equally spaced over the entire area. The number of plots needed depends on the precision desired and the estimated variance among samples.

Total Stocking Method

To find total stocking, estimate the number of sample milacres needed per uniform area, count the number of seedlings in each sample milacre, and multiply the average number per milacre by 1,000.

The number of sample milacres per uniform area (one in which treatments, such as seedbed preparation, degree of release, time of seeding, or seed source, are the same over the entire area) is obtained by the following formula:

$$\text{Sample milacres needed per uniform area} = \frac{t^2\ cv^2}{E^2}$$

where t is Student's t, cv is the coefficient of variation in percent, and E is the precision desired in percent.

The coefficient of variation of seedlings per acre for seeding studies in the Missouri Ozarks over the years has averaged 114 percent. To estimate the number of seedlings per acre with a precision of ± 10 percent (and a probability of being within that figure 2 out of 3 times) the number of milacres needed is: $114^2/10^2 = 130$ milacres, since t is approximately one at this probability. If ± 5 percent precision is desired, four times as many milacres must be inventoried, or 520 in this case. If some other degree of confidence is desired, use the appropriate value of t in the formula.[1]

Stocked Milacre Method

Obtain the percentage of milacres stocked with at least one seedling. The number of sample milacres needed is computed by the same formula as for total stocking. The coefficient of variation of stocking percentage has been found to be about 50 percent. Thus, the probability is that 2 out of 3 times a precision of ± 5 percent in the percentage of stocked milacres will be attained if $50^2/5^2$ or 100 milacres are counted.

The percentage of stocked milacres is directly related to the number of seedlings per acre (fig. 1). This can be expressed by the equation $Y = 163 + 0.548\ X^2$, where Y=seedlings per acre and X= stocking percentage.

This equation can be used to estimate the number of seedlings per acre from a stocked plot inventory, or the number of seedlings corresponding to the stocking percentage can be read from figure 1. For example, if an area is found to be 60-percent stocked (± 5 percent), then the estimated number of seedlings per acre is 2,135. The actual number of seedlings per acre may range from 1,500 to 2,800. This range is obtained from the lower confidence band at 55-percent stocking and the upper confidence band at 65-percent stocking in figure 1.

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1 *For a table of t values, see p. 46 of the 5th edition of "Statistical Methods" by G. W. Snedecor. Iowa State College Press, Ames. 1956.*

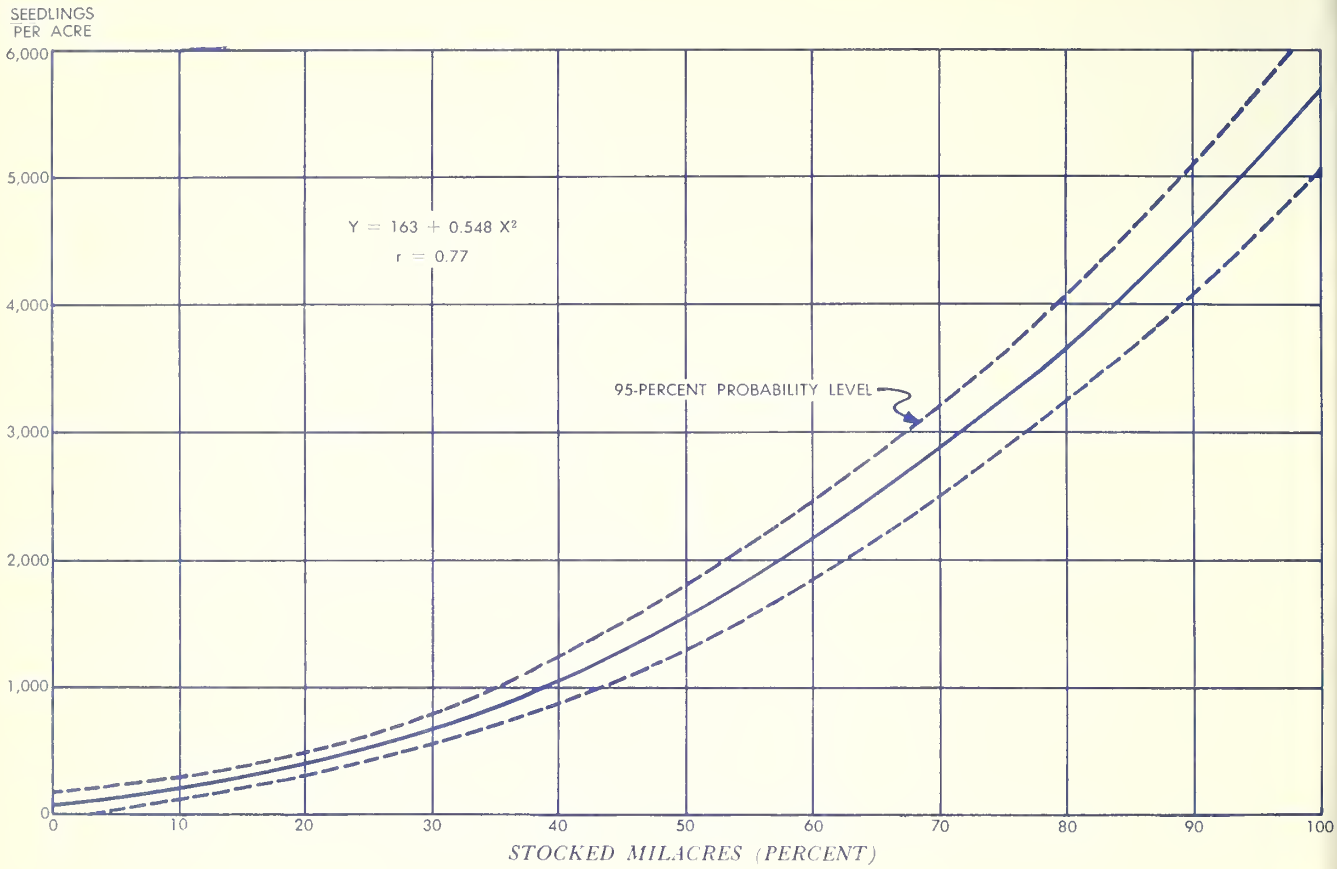

Figure 1.—Relationship between percentage of stocked milacres and number of seedlings per acre. Basis: 163 X and Y values; each value computed from a group of 20 milacre plots.

The size of the area being inventoried has no effect on the number of milacres needed as long as conditions are uniform over the entire area. In a large tract, however, variation in seedling numbers is expected because of differences in degree of release, seedbed preparation, or time of seeding. If known differences exist, divide the area into uniform subunits and inventory each unit separately.

The stocked milacre method is faster than the total stocking method but, for any given number of sample milacres, a more precise estimate of the number of seedlings per acre is obtained by the total stocking method.

December 1966

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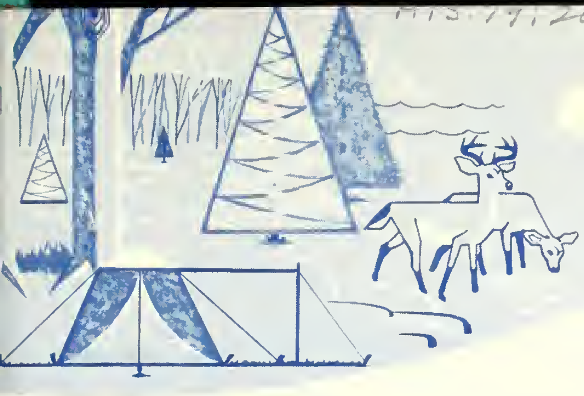

U. S. FOREST SERVICE

RESEARCH NOTE NC-20

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Establishing Mixtures of Redcedar In Poor Oak-Hickory Forests

Oak-hickory forests on the poorest sites in the Upper Mississippi Valley have both low productivity and little esthetic appeal. A mixture of the native evergreen redcedar would add beauty and increase wildlife values.

METHODS OF STUDY

During the spring of 1949 redcedar (*Juniperus virginiana* L.) and shortleaf pine (*Pinus echinata* Mill.) were planted in openings cut in oak-hickory stands on ridgetops and upper south slopes in southern Illinois. The height of the mature dominant hardwood trees was 50 to 60 feet. The chief species were black oak (*Quercus velutina* Lam.), post oak (*Q. stellata* Wangenh.), blackjack oak (*Q. marilandica* Muenchh.), white oak (*Q. alba* L.), and hickory (Carya sp.).

Three sizes of openings were cut. The diameters, from crown edge to crown edge, were one-half, the same as, and twice the height of the overstory trees. Eight openings of each size were completely cleared and half of these were planted at a 6- by 6-foot spacing to redcedar and half to shortleaf pine.

In June 1950 and May 1956 all hardwood sprouts in the openings were cut off near ground level; but the stumps were not poisoned, and new sprouts and oak seedling sprouts developed. The planted trees were measured 3, 8, and 16 years after planting.

RESULTS

Early survival of the planted trees was good, and growth of shortleaf pine in the 100- to 120-foot openings was satisfactory; but redcedar grew slowly as is normal for this species.[1] Subsequently, many pines were killed by pine sawfly larvae. In the smaller openings partial shade from perimeter overstory trees killed some trees. And although released twice, some redcedar and pine were inhibited and killed by direct competition from hardwood brush.

After 16 years redcedar had survived and grown better in the small openings than had pine (table 1). In the large openings, survival and height growth were about the same for redcedar and pine; and the redcedar was vigorous and healthy (fig. 1). In the open, however, shortleaf pine characteristically grows much faster than redcedar. The relative success of redcedar in the forest openings, even when hardwood sprouts were not killed, was probably related to four factors: (1) it is native to the region; (2) it is moderately shade tolerant; (3) it characteristically tolerates poor sites; and (4) it has no serious insect enemies.

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[1] *Minckler, Leon S. 1953. Poor oak sites may grow good pine. U.S. Forest Serv. Cent. States Forest Exp. Sta. Tech. Pap. 134, 6 pp., illus.*

Table 1.--*Survival and height growth of redcedar and shortleaf pine by opening sizes 16 years after planting*

Original diameter of forest opening 1/	Redcedar			Shortleaf pine		
		Top-free trees			Top-free trees	
	Percent survival	Number per opening	Height (feet)	Percent survival	Number per opening	Height (feet)
1/2-size (25-30 ft.)	28	9	6.4	13	4	1.2
1-size (50-60 ft.)	49	21	9.0	5	4	6.2
2-size (100-120 ft.)	34	47	11.8	32	50	13.6

1/ Openings were cut to a diameter one-half, the same as, and twice the height of the overstory trees.

Figure 1.--Redcedar in forest opening on poor oak-hickory site 16 years after planting. Original diameter of the opening was about 100 feet.

CONCLUSION

Redcedar can be successfully interplanted in oak-hickory stands on poor sites. Openings should be cut with a diameter of one to two times the height of the surrounding trees, and the seedlings should be planted inside the crown perimeter in the openings. Ideally, all hardwood brush should be killed with herbicides before planting. After planting, redcedar trees should be kept free of overtopping by hardwood brush.

Successful conversion of poor oak-hickory forests in southern Illinois to the non-native shortleaf pine would require larger clearcut areas, more intensive control of hardwood competition by use of herbicides, and protection from insect attacks. This appears to be a questionable practice. Stand conversion to pine in southern Illinois is expensive and the results are uncertain.

The introduction of redcedar into poor oak-hickory forests would increase cover and food for wildlife and improve the beauty of the usually drab oak-hickory forest, particularly in the winter when it would provide a touch of green among the leafless hardwoods and in the spring when it would provide background for the dogwood (*Cornus florida* L.) and redbud (*Cercis canadensis* L.) trees that are native on many of these sites. The improved esthetic and wildlife values may be the most desirable product on such sites.

December 1966

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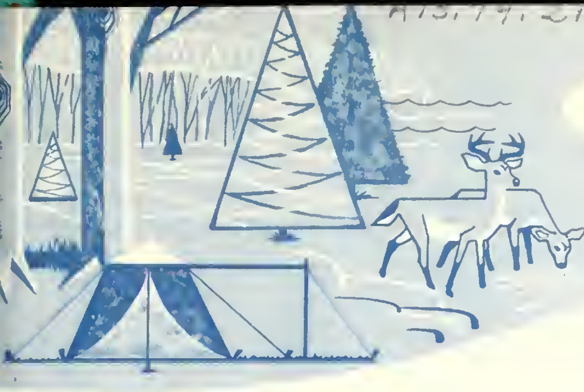

U. S. FOREST SERVICE

RESEARCH NOTE NC-21

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Distribution Methods and End-Uses For Hardwood Face Veneer and Plywood Manufactured In Michigan and Wisconsin In 1964

A number of distribution methods are currently used to market a wide variety of products manufactured by the hardwood face veneer and plywood industry in Michigan and Wisconsin. Wall paneling, door skins, and kitchen cabinet stock are major products, but specialty lines such as curved and molded plywood components for furniture, shoe heels, and golf club heads are growing in importance.

In 1964, there were 24 hardwood face veneer and plywood firms in Wisconsin and 8 in Michigan. As part of a general survey of the industry, each firm was visited to obtain information in a number of subject areas. Mills were classified according to the general type of product being made at the time of the visit: There were 11 veneer mills, 11 veneer and plywood mills, 7 plywood mills, and 3 specialty mills.

Location of Mills

Geographically, the industry in Michigan and Wisconsin tends to be located within the central to northern portions of each state. In the early days, many mills were situated within heavily forested areas to take advantage of abundant natural resources. Although the forest resource near the mills decreased over the years, truck and rail transportation played an important part in allowing these mills to continue operating profitably within the regions of their initial establishment. Gradually a small nucleus of mills evolved and a skilled labor force was formed. Today, much of the veneer and plywood manufactured in the North Central States comes from an area in Wisconsin within a 100-mile radius of Green Bay, Wisconsin (fig. 1).

Distribution Methods

Regional veneer and/or plywood mills use five basic distribution methods: The agent or broker, the parent-firm, company salesmen, the house account, and the wholesaler.

The agent or broker serves the smaller mills and charges a fee for his services, usually about 5 percent of the invoice valuation of the goods.

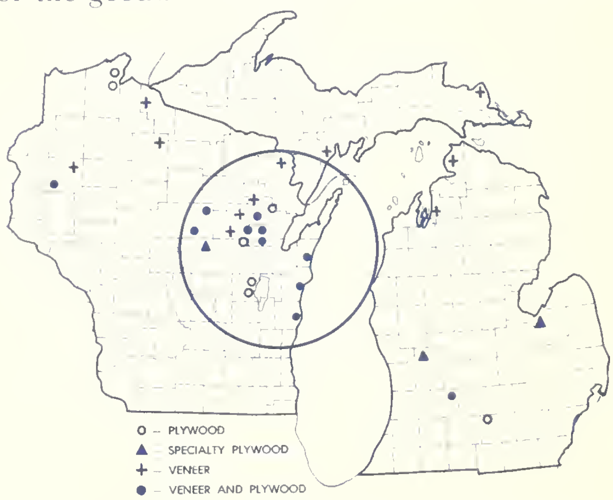

Figure 1.—Location of hardwood face veneer and/or plywood mills in Michigan and Wisconsin in 1964.

The parent-firm is a company that usually has a controlling interest in the veneer and/or plywood firm and takes all its production. The producing mill is frequently referred to as a "captive" operation under these conditions.

Company salesmen are employed by the producing firm to sell veneer and plywood.

In the house account method, no soliciting actually takes place. As a producing firm becomes well established in the business, it often finds that certain buyers become loyal to the firm. No salesmen need contact this type of customer to secure the order unless technical services are requested by the buyer.

The wholesaler buys plywood from the regional mills and redistributes it on a cost-plus basis. His markets are usually retail lumberyards or other market channels that sell directly to the ultimate plywood consumer.

Data on distribution methods for veneer mills show that company salesmen marketed nearly 40 percent of the total veneer produced in 1964 (table 1), and agents or brokers handled about 18 percent. The smaller veneer mills[1] frequently utilize brokers or agents because they provide a means of distributing veneer at a lower cost than is possible by other methods. Maintaining a sales staff can be a costly venture if the product volume is low.

[1] *For the purposes of this study, mills are classified by size (annual production in million square feet, surface measure) as follows: Veneer mills (veneer production)—small, up to 15; medium, 16-50; large, more than 50. Veneer and plywood mills (plywood production)—small, up to 1; medium 1-9; large, more than 9. Plywood mills—small, up to 3; medium 3-35; large, more than 35.*

Table 1.—*Distribution methods used in marketing veneer and/or plywood manufactured by mills in Michigan and Wisconsin, by industry grouping, 1964*

Distribution method	Percent of total production by:			
	Veneer mills	Veneer and plywood mills	Plywood mills	Specialty plywood mills
Agent or broker	18.4	6.1	17.7	8.3
Parent-firm	26.5	45.9	23.6	0
Company salesman	37.9	.2	42.1	62.5
House account	17.2	39.3	15.5	29.2
Wholesalers	0	8.5	1.1	0
No. of mills reporting	11	8	7	3
Estimated total production, million square feet, surface measure	431.5 1/	52.7 2/	169.8	6.0

1/ Veneer only. 2/ Plywood only.

For the veneer and plywood industry grouping, most of the plywood is handled through the house account (39 percent) and parent - firm (46 percent) arrangements. These data are substantially weighted by the output of 2 large mills that market through the parent-firm—that is, send their plywood directly to company-owned warehouses for further distribution. Because many of the regional veneer and plywood mills are large and well established, they also utilize the house account arrangement rather extensively.

Company salesmen market a considerable amount of the production of the firms making up the industry grouping for plywood mills. For the most part, these mills lack the marketing network that some of the large veneer and plywood mills seem to have. Also, they are less likely to be part of a large integrated forest products company, although their plywood production may equal or surpass that of the veneer and plywood mills. Consequently, they rely heavily upon company salesmen to market their products. The smaller plywood mills, like the small veneer mills, lean toward the use of agents or brokers.

Specialty plywood mills in the region produce a variety of items that go into the construction of both residential and non-residential furniture. Most of this is in the form of curved or molded plywood for chairs and sofas. Among other products, they also manufacture church pews and curved wall paneling. These specialty mills account for only a small part of the total plywood manufactured in Michigan and Wisconsin. Company salesmen market most of the material. House accounts are also an important marketing method.

End-Uses for the Products

Hardwood veneer manufactured in the region is incorporated into many kinds of plywood. Wall paneling, doors, and kitchen cabinets are the more common uses (table 2).

Table 2.—*End-uses for products of veneer and/or plywood mills in Michigan and Wisconsin, by industry groupings, 1964*

Product	Percent of total production by:		
	Veneer mills	Veneer and plywood mills	Plywood mills
Wall paneling	35.0	38.7	65.6
Doors	24.7	10.1	28.2
Kitchen cabinets	19.6	3.6	.8
Furniture	10.3	7.4	3.7
Die boards	0	4.6	1.2
Crossbands and cores	10.4	0	0
Specialty	0	35.6	.5
No. of mills reporting	10	8	7
Estimated total production, million square feet, surface measure	401.6[1/]	52.7[2/]	169.8

1/Veneer only. 2/Plywood only.

This veneer is consumed, to a large extent, by plywood operations in Michigan and Wisconsin, but some is shipped to firms outside the region.

Veneer and plywood mills have faced increasing competition from abroad in the form of low-cost plywood imports. In an attempt to minimize the effect of these imports, regional plywood mills have either customized some of their traditional products or have included many specialty items in their product lines. Wall paneling and door skins are being imported into the United States in considerable quantities and account for roughly 50 percent of all domestic hardwood plywood consumption. Whereas stock paneling, doors, and kitchen cabinets were once the mainstay of the regional veneer and plywood industry, they are now being replaced by specialty items or being modified to some extent. For example, some firms are currently manufacturing doors which are specially machined to allow direct placement into the opening for which they were intended. Prefinished-plywood manufacturers are using new coating techniques and materials on wall paneling and doors. The net effect is the creation and expansion of markets not served by the imports. Specialty products, such as shoe heels, golf club heads, and die boards (a form of plywood used by the printing industry), are also growing in popularity among the regional mills. Altogether, these specialty products accounted for nearly 25 million square feet (surface measure) of plywood in 1964.

Over 65 percent of the nearly 170 million square feet of plywood produced by plywood mills was in the form of wall paneling (table 2). The product-mix, however, is heavily weighted toward this particular product by one mill which manufactured only wall paneling and accounted for a large percentage of the total production of the seven mills in this industry grouping. Significantly, it was the only plywood mill exclusively engaged in the manufacture of wall paneling, one area in which low-cost imports have been most competitive and have accounted for large volumes of plywood. This same firm operates its own core and crossbanding mill in Africa and is geared to high-speed production techniques, both here and abroad. The face veneer used in this mill is mostly domestic, but some quantities are imported.

In future years, specialty items may comprise a greater percentage of the total plywood volume manufactured in the region. Kitchen cabinets will probably also grow in importance in the product-mix, largely because wood is again becoming the preferred material for this popular consumer item. The enactment of a proposed reduction in the tariff on hardwood plywood will place increased pressure on regional mills manufacturing wall paneling and doors. Technological innovation and production efficiency will be needed to offset rising log and labor resource costs.

The region is also currently going through a phase of "expansion by acquisition" in which some veneer and/or plywood mills have been purchased by large national wood products firms. The net effect on the distribution methods is that more veneer and plywood will probably be marketed under the parent-firm arrangement in future years. Undoubtedly, distribution methods and end-uses for hardwood face veneer and plywood will continue to shift.

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December 1966

U. S. FOREST SERVICE

RESEARCH NOTE NC-22

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Establishing Grass Range In the Southwest Missouri Ozarks

ABSTRACT.—Prescribed burning to prepare a seedbed, seeding native grasses or fescue on proper sites, and fertilizing are all necessary for successfully establishing good grass production where trees have been killed by aerially applied herbicides.

Ozark cattlemen have become increasingly interested in creating pasture and range by aerial spraying of chemicals to kill trees and other woody plants. Since 1950, by conservative estimates, they have sprayed between 1½ to 2 million acres for this purpose. In 1966, approximately 250,000 acres were sprayed in Oklahoma, Missouri, and Arkansas.

Each year interest mounts. Beef demand and price have increased. Costs of spraying an acre have decreased with improved techniques and increases in amount of area sprayed. In 1966, a number of landowners near Ava, Missouri, organized and contracted for a first spraying of 11,000 acres by helicopter at $5 per acre. Lower conversion costs and higher beef prices have stimulated interest so that we expect even more acreage to be sprayed in 1967.

Brushland can be converted to good grassland at low cost by aerial spraying, but it is also easy to make costly mistakes. If conversion from trees to grass is not done properly and then maintained properly, the sprayed area will revert to a dense sea of hardwood sprouts that are much more difficult to eliminate than the original stand of trees. Broomsedge, less palatable and more deficient in nutrients than fescue, Indiangrass, switchgrass, big bluestem, or little bluestem, will reseed an improperly converted area and hinder establishment of desirable grasses. The purpose of this paper is to explain briefly how certain areas producing little or no wood of commercial value can be converted to productive grassland.

What Was Done

To find out how to properly convert low-quality hardwood stands to good grass cover, the North Central Forest Experiment Station, in cooperation with the Agricultural Research Service, established several study plots on the Mark Twain National Forest near Bradleyville, Missouri. Plots were located on (1) shallow soil on south and west facing upper slopes, (2) deep soil on south facing lower slopes, and (3) shallow soil on north and northeast facing upper slopes. Sites were classified by their ability to grow black oak. The upper south slopes have a black oak site index of 35, which means a dominant black oak grows 35 feet tall in 50 years. Black oak site index for lower south slopes is near 45, and that for north slope sites is near 55.

These plots were similar to many low-quality hardwood stands in this part of the Ozarks. Overstory trees were primarily post and blackjack oak with some black and white oaks on better sites. Crown cover was almost complete except for strips of overgrazed open glades on the upper south slopes. Understory plants were sparse: primarily shade tolerant poverty oatgrass, sedges, and panic grasses, with scattered clumps of more desirable forage species such as little bluestem. Soil depth and type differed greatly within a small area; Corydon, Baxter, Linker, Hobson, and Gasconade soils were found on the study area.

The study areas were aerially sprayed with 2,4,5-T in July 1959 and June 1961. The second spraying was considered necessary in view of the poor defoliation of trees and brush (less than 65 percent) obtained from the first application. One-half gallon of 4 pounds acid equivalent per gallon herbicide in 4.5 gallons of fuel oil was applied per acre in each application. Half of each plot was burned in August and September 1959 for seedbed preparation. Sprayed plots were seeded by hand broadcasting with (1) a mixture of 24 pounds of K-31 fescue and 3 pounds each of Korean and sericea lespedeza per acre in September 1959, and an additional 8 pounds per acre of fescue in early March 1960, or (2) a native grass mixture of 7 pounds of little bluestem and 3.5 pounds each of big bluestem, Indiangrass, switchgrass, and side-oats grama per acre in late February and early March 1960, or (3) left for natural seeding. An 8-24-8 fertilizer was applied to some of the plots at the rate of 320 pounds per acre in March 1960.

What We Learned

Prescribed burning to prepare a seedbed, seeding native grasses or fescue on proper sites, and fertilizing are all important for efficiently and successfully establishing good grass production on sprayed areas (fig. 1).

Figure 1.— Prescribed burning (left) to prepare seedbed is essential for the successful establishment of a good stand of grass compared to no burning (right). Both areas seeded with native grasses.

Sprayed but unseeded areas produced little desirable[1] grass (fig.2). At best, unseeded areas produced only one-third as much as burned, seeded, and fertilized plots. Even with a natural seed source, it took four growing seasons to produce over 700 pounds per acre of ovendry desirable grass; whereas, the burned, fertilized plots seeded to fescue produced over 700 pounds per acre the first growing season and most seeded native plots produced that amount after the second season (fig. 3). Quick revegetation is essential to prevent erosion and excessive runoff from heavy storms and can best be assured by full treatment. Most unseeded plots were without an adequate seed source and therefore failed to produce much more than 50 pounds per acre even when removal of overstory was followed by total protection from grazing for 7 years.

[1] *Desirable grass is little bluestem, big bluestem, Indiangrass, switchgrass, and side-oats grama grass.*

Fescue and native grass production after prescribed burning and fertilizing was greatest on north and east upper slopes (fig. 3). Fescue production exceeded natives in 1960 but decreased to less than 1 ton per acre in 1961 and 1962 due to drought. Native grasses, better adapted to drought, produced over a ton in 1961 and 2 tons in 1962. With better growing conditions in 1963, fescue yields increased to almost 2 tons per acre, about equal to native grass yields.

On lower south and west slopes yields of fescue were slightly greater than those of native grass in 1960 and 1961. In 1962 native grass yields increased substantially while fescue yields increased only slightly. This trend continued in 1963.

On upper south and west slopes, yields of native grasses and fescue were about the same in 1960 and 1961. By 1962 the native grasses had enough time to

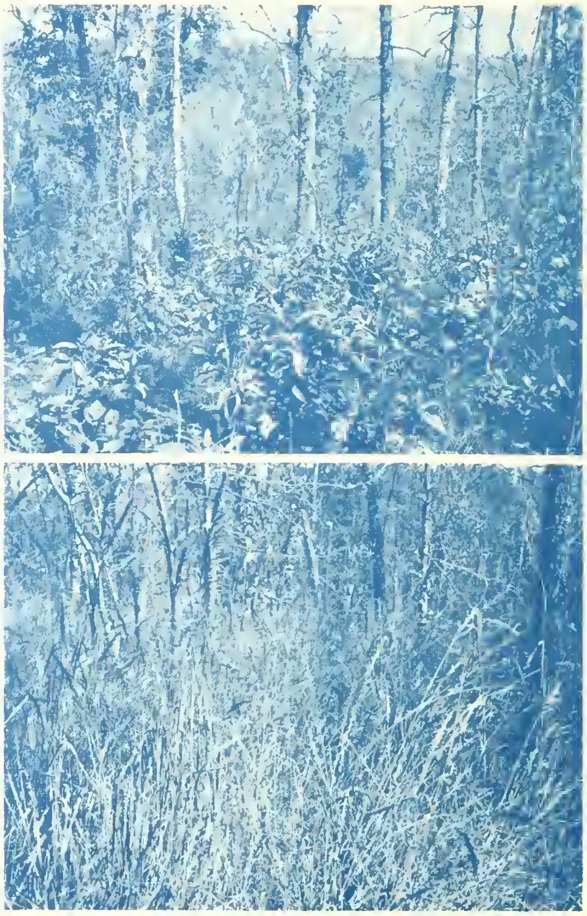

Figure 2.— Little desirable grass is produced on areas sprayed, burned, fertilized but not seeded (above) compared with sprayed, burned, fertilized, and seeded (below). Pokeweed, a poor livestock forage plant, is predominant in unseeded plot above. Indiangrass is most abundant in the seeded plot.

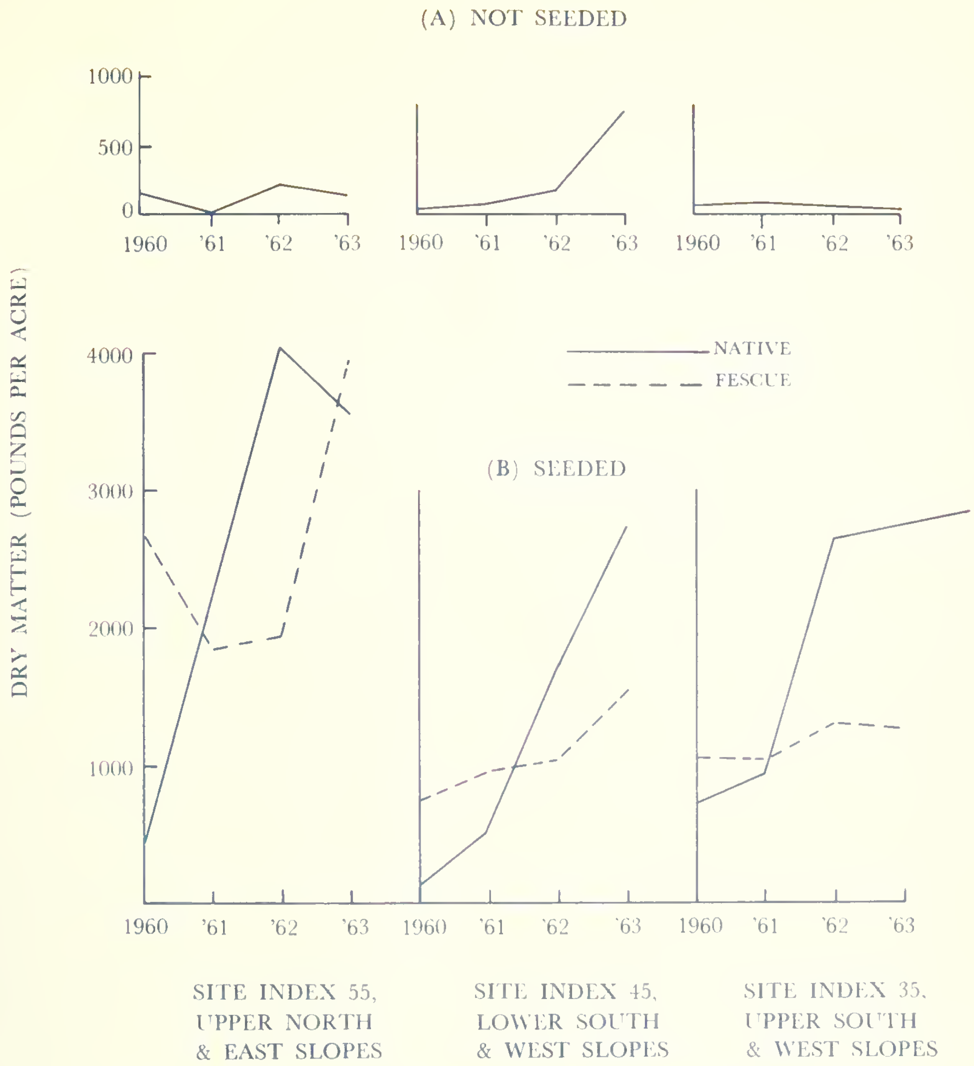

Figure 3.— Desirable grass production after spraying, burning, and fertilizing. (A) Not seeded, (B) seeded to native grasses or fescue.

develop an adequate root system and greatly out-produced fescue on these shallow soil, droughty sites. Native grasses continued to produce well into 1963.

No measurements were taken in 1964 and 1965. Measurements in 1966 show a substantial decline from the 1963 yields on all seeded plots. Several factors help account for this. Some larger trees that originally suffered great crown damage began to develop another crown. Basal sprouts increased in number and size. Grass litter increased greatly without grazing, clipping, or burning, and became so dense that new growth received only small amounts of light. Shade tolerant, poorer forage grasses increased under the grass litter.

Retreatment possibly at 3- to 5-year intervals will be necessary to control encroaching hardwoods. Grazing will prevent a heavy litter accumulation, but it will also reduce grass competition with hardwood sprouts unless grass is adequately and properly fertilized.

Recommendations

Much more must be learned before a complete set of recommendations on range establishment in the Ozarks can be published. We have investigated only three of many sites, and even on these sites we need more information — we especially need to know how to graze these sites best to keep the grass resource producing near its potential.

The type of land we studied with black oak site index from 35 to 55 offers a potential for a workable range operation. Upper south and west slopes should be seeded to native grasses. Our best producers were Indiangrass and switchgrass. Shallow-soil north and east slopes should be seeded to fescue to give a balance of cool- and warm-season grasses in nearby pastures. The lower south and west slopes will produce a greater volume of native grasses than fescue, but extra fescue will be needed for drought years, so deep soil areas on lower slopes which receive more runoff might be put into fescue. Because of differences in stem-to-foliage ratios, about 80 percent of the fescue plant is edible compared to about 60 percent edibility in the native grasses. This further strengthens the recommendation of fescue for better sites but does not change the recommendation on poorer sites.

Burning is necessary before seeding. Burning is tricky and must be done right or the effects may be bad rather than good. Much has been written in the Ozarks on preventing fires but little on properly using fire. The main objective of burning is to remove the dry leaf litter that prevents the light grass seed from reaching moist ground and germinating in a proper environment. The fire should not be so severe that it burns the nutrient-rich, moisture-retaining humus found between the leaf litter and mineral soil. Areas that have been burned yearly may not have a humus layer and would not be safe risks for conversion. Until we do more research, we cannot give a firm set of burning rules. However, some obvious precautions can be mentioned. Test burn a small spot. Remember, burning conditions can change rapidly, so conditions that are proper at 8:00 a.m. may be wrong or even highly dangerous at 9:00 a.m. Late afternoon or shortly before dark is often a good time. Get help and burn only small areas at one time. Have good fire lines and be careful. Fire, like any tool, when used improperly can be dangerous to man and land.

Fertilizer helps get the grass off to a good start. We have no information on fertilizer needs after grazing has started. Hilly rangeland presents a different fertilization problem from level pastures.

Grazing should be deferred at least 1 year after fescue seeding and 2 years after seeding native grasses. Fescue grassland will need to be fenced and managed separately from native grassland. Grazing too soon will ruin chances of getting a good grass stand, will increase hardwood sprouting, and will give a ground cover of undesirable and often poisonous plants.

The successful establishment of a grass stand does not ensure a lasting return. Mismanagement can quickly ruin an excellent pasture. Plants require the attention given to other living things. Excess removal of the top growth by continuous grazing weakens the plant and if continued may even kill it. *Periodic* rests of at least one growing season — June, July, and August for native grasses, and March, April, and May or September and October for fescue — after each season of intensive grazing will allow the plants to restore vigor and maintain maximum production. Fertility must be maintained or rest periods will do little good.

Livestock prefer some plants over others and graze them more heavily. A rest-rotation system whereby an area is intensively grazed for short periods of time —one growing season or less—encourages use of less preferred plants as well as preferred plants. During rest periods, the preferred species can recover equally with the less preferred. The rest-rotation system requires additional costs in management but gives more returns in the long run.

Last but not least, retreatment will be necessary. Because of the amount of rainfall in southwest Missouri, the natural plant succession is to woody growth, especially on north and east slopes with deeper soils—better tree sites. Respray intervals will depend on success of the initial treatment, type of management, rainfall, and site. Better tree-growing sites will probably grow more vigorous sprouts. If you skimp on proper management, it will cost more for retreatment. Killing sprouts is more difficult than killing fully grown trees. Do not fail to consider costs of retreatment in planning your operation.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-23

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Cattle in the Woods or Woods in the Pasture?

ABSTRACT. — Most of the intensive grazing on forested land in the Missouri Ozarks is occurring on land with a low potential for growing commercial timber.

Woods grazing reportedly is detrimental to good hardwood timber production and has been discouraged for many years by forestry interests. Yet approximately half of the privately owned commercial woodland in the Missouri Ozarks were being grazed as late as 1959 (table 1). Seemingly private landowners have failed to "get the message."

However, there is more to the story. About 25 percent of the land defined as commercial forest is less than 10 percent stocked, and much of it is actually range land or brushy pasture. Additionally, most of the intensive grazing takes place in the submarginal post-blackjack oak and redcedar stands common in the northwestern and southwestern Ozarks (fig. 1) and little takes place in the truly "commercial" stands of the eastern Ozarks where more timber is grown.

When one realizes that low-potential commercial forest land may be more efficiently and profitably used to grow grass,[1] it becomes apparent that the message is getting across to many landowners — that cattle grazing and the maximum growth of high-quality timber do not mix[2] and that as much grass can be grown on one acre of brush-free range land as is grown on 50 to 100 acres of wooded range.[3]

[1] *Ehrenreich, John H., and Robert A. Ralston. Forage and timber production alternatives on shallow soils in the Ozarks. Soc. Amer. Forest. Proc. 1963: 80-83. 1964.*

[2] *Martin, S. C. The place of range livestock in the Missouri Ozarks. J. Range Manage. 8: 105-111, 1955.*

[3] *Ehrenreich, John H., and R. F. Buttery. Increasing forage on Ozark wooded range. U.S. Forest Serv. Cent. States Forest Exp. Sta. Tech. Pap. 177, 10 pp. 1960.*

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April 1967

Table 1. —*Commercial forest acreage and grazing on private land in Regions of the Missouri Ozarks, 1959*

(In thousands of acres)

Item	Total	Regions: Eastern	Regions: Southwest	Regions: Northwest	Regions: Riverborder
Total land area 1/	22,586	6,150	5,528	5,058	5,850
Total commercial forest land (private)	10,361	3,279	2,818	2,252	2,012
Grazed commercial forest land (private)	5,079	1,574	1,465	1,396	644
Intensively grazed 2/	3,308	721	1,071	1,013	503
Lightly grazed 3/	1,771	853	394	383	141

1/ From Areas of the United States, 1950 Bureau of the Census.

2/ Intensive grazing: 50 percent of better herbaceous species removed, poorer forage plants and sprouts grazed, many cow chips present, and evidence of livestock trampling.

3/ Light to moderate grazing: 0-50 percent of better herbaceous species removed, few or no poor species grazed, only a very occasional cow chip, and may be some evidence of trampling.

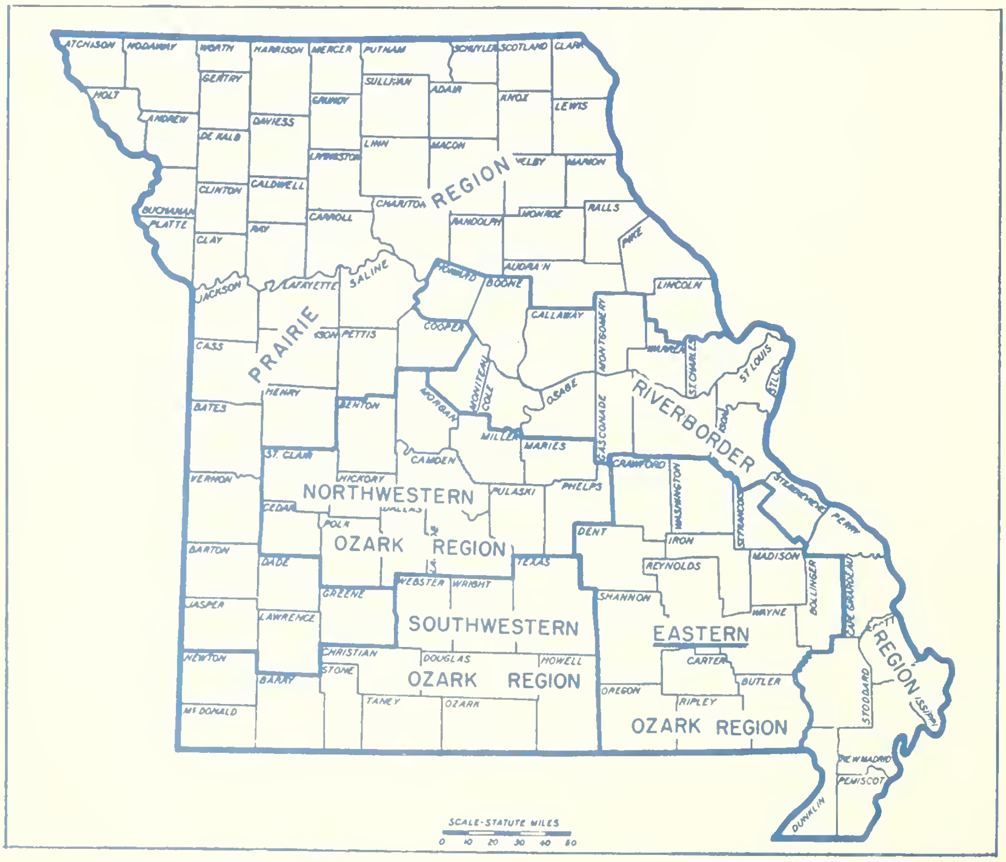

Figure 1. —Location of Ozark regions in Missouri.

U. S. FOREST SERVICE

RESEARCH NOTE NC-24

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Stand Volume Equations for Shortleaf Pine In Missouri

ABSTRACT. — Presents stand volume equations and a stand volume table for shortleaf pine in Missouri and describes their development and application.

Stand volume equations provide direct estimates of volume using such simple stand data as basal area per acre and height of dominant trees. This technique is much easier and faster than the traditional sampling methods based on volumes of individual trees. Precision is about the same and adequate for most management purposes. The increasing use of Bitterlich angle-count (point-sampling) cruising has made stand volume equations even more practical for the forest manager.

This paper presents stand volume equations and a stand volume table for shortleaf pine in Missouri and describes their development and application. The equations provide estimates of merchantable cubic-foot and board-foot volume per acre to specified minimum upper-stem diameters inside bark. The equations developed here can be used with point-sampling methods in Missouri and probably in other areas provided the same utilization standards apply.

The composite tree volume tables developed by Gevorkiantz and Olsen (1955) are based on a known relation: Conifers of given diameter and total height tend to have the same taper and hence similar volumes. Total cubic-foot volume of a tree was computed as 42 percent of the product of basal area and height.

Buckman (1961) expanded this concept to develop ratio and linear regression equations for total cubic-foot, cordwood, and board-foot volumes of stands using basal area per acre and the height of dominant trees. The regression of stand volume plotted against the product of basal area and height (B•H) was nearly linear or could be approximated by a linear relation.

In a later publication, Buckman (1962) used the independent variables of age, site index, and stand density to predict periodic annual basal-area growth. He then used the ratio of stand volume to B•H in preparing growth and yield tables for red pine. Using a similar approach, Vuokila (1965) found that the use of $B \cdot H^2$ and D, the diameter of the tree of average basal area, in total cubic volume equations greatly improved their accuracy for stands in early stages of development.

Method of Preparation

The stand volume equations are based on data from 57 shortleaf pine stands where volumes have been measured periodically over a period of 15 years. Nearly all the stands were thinned twice during this time. Stand ages ranged from 19 to 85 years and dominant trees were 34 to 85 feet tall. Apparent site indices of the stands ranged from about 55 to 75, but site index was not included as a variable in the stand volume equations.

Data were available for 347 measurements of cubic-foot volume and 297 measurements of board-foot volume. The minimum sizes of trees included were: 4.6 inches d.b.h. to a 3-inch top d.i.b. for cubic-foot volume, and 6.6 inches d.b.h. to a 5-inch top d.i.b. for board-foot volume. Volumes of individual trees in the stands were based on the following equations (Brinkman *et al.* 1965):

$$\text{Cubic-foot volume} = -0.5389 + 0.0023\,D^2H$$

$$\text{Board-foot volume} = -15.24 + 0.013\,D^2H$$

The cubic-foot volumes per acre of individual stands were plotted against the product of their basal area and total height (B•H). From these scatter diagrams it was apparent that the ratio method used by Buckman (1962) did not fit the data as well as a linear regression because many small trees have measurable total cubic-foot volume but no merchantable volume.

The board-foot volume data for individual stands were plotted against both B•H and $B \cdot H^2$. A much better fit of the volume data to a single regression line was indicated when $B \cdot H^2$ was used as the independent variable. Diameter of the tree of average basal area (D) also was included as a variable in the trial equations.

Stand Volume Equations

Plot data were analyzed on an IBM 7040 computer to find which combination of five variables gave the best estimate of stand volume per acre. For both cubic-foot and board-foot volume, the variables tested were: B, H, D, B•H, and $B \cdot H^2$.

For cubic-foot volume estimates, the R^2 value (0.97) with all five variables included was about the same as that for B•H alone, so a linear equation was chosen to estimate stand cubic-foot volume (table 1). Two board-foot volume equations were selected. Their R^2 values were about 0.92, and their standard errors of estimate of individual stand volumes also were similar (table 1). For most stands where board-foot volume is important, the equations produce similar estimates. But trials show that Equation III tends to overestimate the volume of young stands and underestimate volume of mature stands. Although Equation II is more accurate, it is somewhat harder to use.

For this reason, a table was prepared using Equation II showing board-foot volumes for representative combinations of B, H, and D (table 2). By interpolating as necessary in this table the forest manager can make a direct estimate of the present volume of shortleaf pine stands and estimate future volume growth.

Using the Stand Volume Equations

To find the volume of a shortleaf pine stand, substitute the appropriate stand data in the proper equation or use table 2. Small inaccuracies in measuring B and D are likely to produce compensating errors. However, because the value for H is squared in computing board-foot volume, a small error here may produce a large error in the volume estimate.

Basal area per acre should be determined from 10 or more sample points in the stand using a wedge prism or angle gauge with a factor of 10. Include only those trees with diameters larger than the minimum previously specified for the volume measurement involved. When board-foot volume is desired, also count the trees on each sample point so you can compute D. A rangefinder set at 26 - 1/3 feet, the radius of a 1/20-acre plot, can be used to check borderline trees. Knowing total basal area and the number of trees per acre, D to the nearest inch can be computed with the aid of a standard basal-area table. Measure total heights of at least 5 dominant trees in the stand with an accurate hypsometer.

To estimate stand cubic-foot volume, only basal area per acre and average height of dominant trees need be known. For example, assume a stand has a basal area of 70 square feet per acre and the average height of dominant trees is 60 feet. Merchantable cubic-foot volume per acre then is computed with Equation I as:

$$\begin{aligned} V &= 0.323\,(B \cdot H) + 92.18 \\ &= 0.323\,(70 \times 60) + 92.18 \\ &= 1{,}448.8 \text{ cubic feet} \end{aligned}$$

Board-foot volume is computed in a similar manner but another variable, D, is needed. Assuming stand data show that this is 12 inches, B is 90 square feet per acre and H is 70 feet, the calculation can be made with Equation III as follows:

$$\begin{aligned} V &= 0.019\,(B \cdot H^2) + 337.7\,D - 1{,}439 \\ &= 0.019\,(90 \times 70^2) + 337.7\,(12) - 1{,}439 \\ &= 0.019\,(441{,}000) + 337.7\,(12) - 1{,}439 \\ &= 10{,}992 \text{ board feet} \end{aligned}$$

For comparison, the volume per acre computed with Equation II for such a stand is 11,112 board feet. Rounded to the nearest 50 board feet as in table 2, these values become 11,000 and 11,100 board feet, respectively.

In most cases, it will be easier to determine board-foot volume per acre by using table 2. Find the tabular volume of the stand with B, D, and H most like the stand in question and interpolate as necessary.

Limitations of the Equations

Most shortleaf pine stands used in developing the stand volume equations had been thinned several times, but the equations seem applicable to the pine component of stands regardless of stocking density. The basic requirement is that all trees considered in computing B and D must be at least 4.6 inches d.b.h. for cubic-foot volume and 6.6 inches d.b.h. for board-foot volume.

For Missouri shortleaf pine stands, Equation I provides a realistic estimate of merchantable cubic-foot volume per acre. To test the equation in another area, it was applied to data for a young plantation in Indiana that had been thinned to several stocking densities (Williams 1959). Measured and corresponding computed cubic-foot volumes per acre were as follows:

Basal area per acre	*Measured volume*	*Computed volume*
177	2,562	2,550
170	2,432	2,454
143	2,089	2,079
122	1,837	1,789

Table 1. — *Cubic-foot and board-foot volume equations for shortleaf pine stands in Missouri: — gross volumes to specified minimum top diameters inside bark*

Volume	Equation[1/]	Standard error of estimate of individual stand volumes	Standard error of estimate as a percent of mean volume
Cubic feet[2/]	(I) $V = 0.323\ (B \cdot H) + 92.18$	177.4	9.31
Board feet[3/]	(II) $V = 0.0214\ (B \cdot H^2) - 79.54\ H + 624.16\ D - 247$	1,148.0	13.72
	(III) $V = 0.019\ (B \cdot H^2) + 337.7\ D - 1,439$	1,201.0	14.36

1/ V is volume per acre, B is basal area in square feet per acre, H is mean total height of the dominant stand, and D is diameter of the tree of average basal area.

2/ Cubic-foot volume per acre of all trees 4.6-inches d.b.h. and larger to a 3-inch top (d.i.b.).

3/ Board-foot volume per acre (Int. 1/4-inch rule) of all trees 6.6-inches d.b.h. and larger to a 5-inch top (d.i.b.).

Table 2. — *Board-foot volume per acre of shortleaf pine stands in Missouri in relation to basal area, height of dominant trees, and average tree diameter*[1]

Average diameter (inches)	Height of dominant trees (feet): 40	50	60	70	80	90
	70 Square Feet Basal Area Per Acre					
8	3,950	4,500	5,350	6,500	7,950	9,700
9	4,600	5,150	6,000	7,150	8,600	10,350
10	5,200	5,750	6,600	7,750	9,200	10,950
11	5,850	6,400	7,250	8,400	9,850	11,550
12	6,450	7,000	7,850	9,000	10,450	12,200
13	7,100	7,650	8,500	9,650	11,100	12,800
14	7,700	8,250	9,100	10,250	11,700	13,450
15	8,350	8,900	9,750	10,900	12,300	14,050
16	8,950	9,500	10,350	11,500	12,950	14,700
17	9,550	10,150	10,800	12,100	13,550	15,300
18	10,200	10,750	11,600	12,750	14,200	15,950
	90 Square Feet Basal Area Per Acre					
8	4,650	5,600	6,900	8,600	10,700	13,150
9	5,250	6,200	7,500	9,200	11,300	13,800
10	5,900	6,800	8,150	9,850	11,950	14,400
11	6,500	7,450	8,750	10,450	12,550	15,050
12	7,150	8,050	9,400	11,100	13,200	15,650
13	7,750	8,700	10,000	11,720	13,800	16,300
14	8,400	9,300	10,650	12,350	14,450	16,900
15	9,000	9,950	11,250	12,950	15,050	17,550
16	9,650	10,550	11,900	13,600	15,700	18,150
17	10,250	11,200	12,500	14,200	16,300	18,800
18	10,900	11,800	13,150	14,850	16,950	19,400
	110 Square Feet Basal Area Per Acre					
8	5,300	6,650	8,450	10,700	13,400	16,600
9	5,950	7,250	9,050	11,300	14,050	17,250
10	6,550	7,900	9,700	11,950	14,650	17,850
11	7,200	8,500	10,300	12,550	15,300	18,500
12	7,800	9,150	10,950	13,200	15,900	19,100
13	8,450	9,750	11,550	13,800	16,550	19,750
14	9,050	10,400	12,200	14,450	17,150	20,350
15	9,700	11,000	12,800	15,050	17,800	21,000
16	10,300	11,650	13,450	15,700	18,400	21,600
17	10,950	12,250	14,050	16,300	19,050	22,250
18	11,550	12,900	14,700	16,950	19,650	22,850
	130 Square Feet Basal Area Per Acre					
8	6,000	7,700	9,950	12,800	16,150	20,100
9	6,650	8,350	10,600	13,400	16,800	20,700
10	7,250	8,950	11,200	14,050	17,400	21,350
11	7,900	9,550	11,850	14,650	18,050	21,950
12	8,500	10,200	12,450	15,250	18,650	22,600
13	9,150	10,850	13,100	15,900	19,300	23,200
14	9,750	11,450	13,700	16,550	19,900	23,850
15	10,400	12,100	14,350	17,150	20,550	24,450
16	11,000	12,700	14,950	17,800	21,150	25,100
17	11,650	13,350	15,600	18,400	21,800	25,700
18	12,250	13,950	16,200	19,050	22,400	26,350

1/ Based on regression equation: $V = 0.0214 (B \cdot H^2) - 79.54H + 624.16D - 247$ where V is gross board-foot volume (Int. 1/4" rule) to a 5-inch top (d.i.b.), B is basal area in square feet per acre, H is mean total height of the dominant stand, and D is diameter of the tree of average basal area. Volumes rounded to nearest 50 board feet per acre.

Although the Indiana data were not used in preparing the basic equation and the plantation grew much faster than most Missouri stands, Equation I gave similar estimates of merchantable cubic-foot volume.

No comparable data were available for shortleaf pine stands in other areas to test the use of the board-foot volume equations, but they seem to be applicable to Missouri stands. If further experience shows that the equations result in consistently high or low volume estimates, minor adjustments should be made.

Growth Predictions

The stand volume equations and table 2 also can be used to predict volume growth for short periods when expected increments in basal area per acre, height, and mean tree diameter are known. Obviously, the growth predictions will be no more accurate than the estimates of changes in these variables.

In Missouri shortleaf pine stands, annual basal-area growth ranges from 2 to 4 square feet per acre, depending on stocking density and age of trees. On average sites, height growth will average a foot per year between ages 25 and 40, decreasing to 0.8-foot from age 41 to 60, and 0.5-foot in older stands. Mean d.b.h. growth generally is about 2 inches for every 10-foot increase in total height, but this depends on stand density. In unthinned stands, d.b.h. growth may be as low as 1. 3 inches per 10-foot height increase.

To illustrate one method of growth prediction, assume a 40-year-old shortleaf pine stand with 90 square feet of basal area per acre, dominant trees 60 feet tall, and a mean d.b.h. of 10 inches. The present volumes computed with Equations I and III are 1,836 cubic feet and 8,100 board feet per acre. During the next 5 years, it is estimated that the stand will add about 15 feet of basal area, 5 feet in total height, and 1 inch in mean d.b.h. When these values are added to those of the present stand, the expected volumes at age 45 become 2,296 cubic feet and 10,700 board feet per acre. This indicates a growth increment of 460 cubic feet, or 2,600 board feet in 5 years.

An indication of expected board-foot volume growth also can be obtained by using table 2. Interpolation nearly always is necessary. For the stand described in the previous example, the original volume shown in table 2 is 8,150 board feet. In 5 years this would increase to about 10,700 board feet per acre, the same as computed above.

APRIL 1967

Summary

Stand volume equations were developed for even-aged shortleaf pine stands in Missouri. The equations provide direct estimates of merchantable cubic-foot and board-foot volumes to specified top diameter limits using simple stand data. Expected volume growth also can be estimated with the equations.

Cubic-foot volume was found to be a linear function of the product of basal area per acre (B) and total height of the dominant stand (H) plus a constant. The two board-foot volume equations are based on multiple regression analysis using B and H plus the diameter of the tree of average basal area (D).

A board-foot volume table for shortleaf pine stands was prepared for various combinations of B, H, and D. By interpolating in the table as necessary the forester can obtain direct estimates of present stand volume and an indication of expected volume growth.

The equations should be satisfactory for inventory purposes in shortleaf pine stands in Missouri and probably elsewhere. Where experience shows that the equations give consistently high or low estimates of stand volume, minor adjustments can be made.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-25

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Seedbed Density Affects Size of 3-0 Green Ash Nursery Stock[1]

ABSTRACT. — Nursery seedbed density of 3-0 green ash, which ranged from 4 to 36 trees per square foot at Carlos Avery Nursery, Forest Lake, Minn., had a marked effect on caliper, height, fresh weight, and percent and amount of plantable stock. The highest number of good-quality trees was produced at a density of 12.5 trees per square foot.

One of the most common broadleaf species used in planting farm windbreaks and field shelterbelts in the prairies of western and southwestern Minnesota is green ash (*Fraxinus pennsylvanica* Marsh.).

Because of serious weed competition and the somewhat droughty conditions in the area, these trees are invariably cultivated for 3 to 6 years to achieve good survival and rapid growth. The stock should be large (mostly 15 to 28 inches high), sturdy, and well rooted, and have good caliper. Past research in the Great Plains (Stoeckeler 1937) has shown that broadleaf stock with a caliper of 4/32 inch or less (at 1 inch above the ground line) often had survivals of 10 to 30 percent less than premium grade stock with a caliper of 7/32 inch or larger.

In spring 1966 the relation of seedbed density of 3-0 green ash to sizes of trees produced was studied at the Carlos Avery Nursery, a Minnesota Division of Forestry nursery near Forest Lake, Minnesota, and about 35 miles north of St. Paul. Thirty lots of stock, 445 trees in all, were measured and weighed. The seed had been hand-sown in beds containing 7 drills spaced 5 inches apart. Bed density ranged from 4.2 to 36.0 trees per square foot. The trees were distributed rather uniformly within, as well as on either side of, the rows selected for lifting. The rows lifted were usually 4 feet long but occasionally only 2 feet.

[1] *Credit is due the Minnesota State Division of Forestry, especially Stan Karp, Superintendent of the Carlos Avery Nursery, and Emil Kukachka, in charge of the Cooperative Forestry Section, for their cooperation on the study; and Archie Cherry, North Central Forest Experiment Station, who measured the trees.*

Physical and Chemical Properties of the Soil

A composite of five soil cores from the 600-foot-long beds containing the 3-0 green ash sample rows showed the following physical and chemical properties: silt plus clay, 16.3 percent; organic matter, 1.5 percent; total nitrogen, 0.056 percent; available nitrogen, 75 pounds per acre; available phosphorus 49 pounds per acre; available potash, 57 pounds per acre; pH, 5.6.

The soil is deemed deficient in total nitrogen, available potassium, and to a lesser degree, in available phosphorus for production of high-quality trees for prairie windbreak planting (Engstrom and Stoeckeler 1941, Stoeckeler and Arneman 1960). Fertilization trials are now under way to improve the broadleaf stock in this nursery so that it can all be shipped as 2-0 stock.

Stand Density Effect on Tree Height, Stem Caliper, and Weight

As the density of the nursery seedling stand increases, the average tree height decreases (fig. 1A). At 5 trees per square foot the average tree height is 25 inches; at 10, about 20 inches; at 15, 16 inches; and at 35 it drops to 11 inches.

Stem caliper of trees is used in most public nurseries in the Great Plains to sort trees into plantable or cull grades. In the Northern Great Plains, a committee on stock grade standards composed of professional foresters from state and federal agencies and soil conservation district nurseries has set 7/32 inch (at 1 inch above ground line) as the minimum desired stem caliper for windbreak and shelterbelt stock of green ash seedlings. Only densities of 5 to 15 trees per square foot of 3-0 stock would achieve such average caliper at the Carlos Avery Nursery at the *present* level of soil fertility and current irrigation regimes (fig. 1B).

Average green weight per seedling is one criterion of size and quality of trees. A study in the Great Plains (Stoeckeler 1937, Engstrom and Stoeckeler

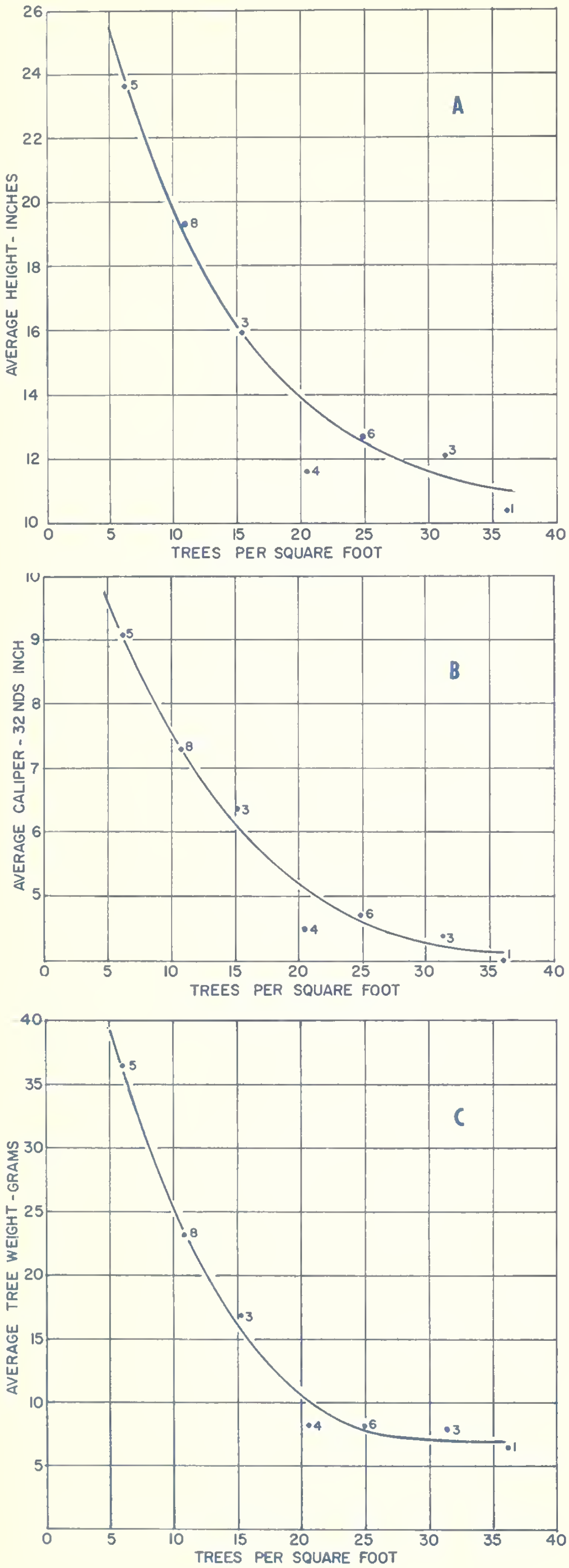

Figure 1.—Relation of stand density of 3-0 green ash to: *A*, height; *B*, caliper; and *C*, fresh weight per tree. The figure at each plotted point denotes number of lots (30 lots in all). Density classes include densities of 2.6 to 7.5 trees, 7.6 to 12.5 trees, etc.

1941) has indicated that green ash trees of 0.4 ounce (equivalent to 11.4 grams) or larger had superior survival and height growth and hence were labeled premium grade. At the Carlos Avery Nursery 3-0 densities of about 5 to 18 trees per square foot achieved this average weight class, but higher densities fared poorly (fig. 1C).

To achieve an average seedling weight of 11.4 grams, the tree must have a caliper of nearly 7/32 inch (fig. 2A). Such a tree would be about 15 inches or more tall (fig. 2B).

All trees in this study, regardless of density, were well rooted with many fine rootlets; the top-root ratio (leafless) averaged 0.64 for 30 lots, and ranged from 0.44 to 0.85. Hence, balance was not a problem.

Stand Density Effect on Percent and Number of High-quality Planting Stock

Stands of comparatively low density had the greatest percentage of high-quality stock (i.e. 7/32 inch caliper or over); stands of high density had less than 30 percent high-quality trees (fig. 3). Obviously the task of culling out the poorer trees would be less for the lower densities.

An important criterion of the "best" density is the *number* of high-quality trees (7/32 inch caliper or larger) produced per square foot of bed area. For the 3-0 green ash studied, best density was about 10 to 15 trees per square foot, with the peak at a density of 12.5 trees:

Trees per sq. ft.	
Density	*High quality*
5.0	4.8
7.5	6.6
10.0	8.0
12.5	8.7
15.0	8.4
17.5	7.7
20.0	6.9
25.0	5.1
30.0	3.2
35.0	1.2

Best density in terms of maximum number of high-quality trees for any tree species will, of course, vary by nursery, fertility level, and age class. Under the conditions cited here, densely sown drills of green ash should be thinned the first year to about 12.5 trees per square foot.

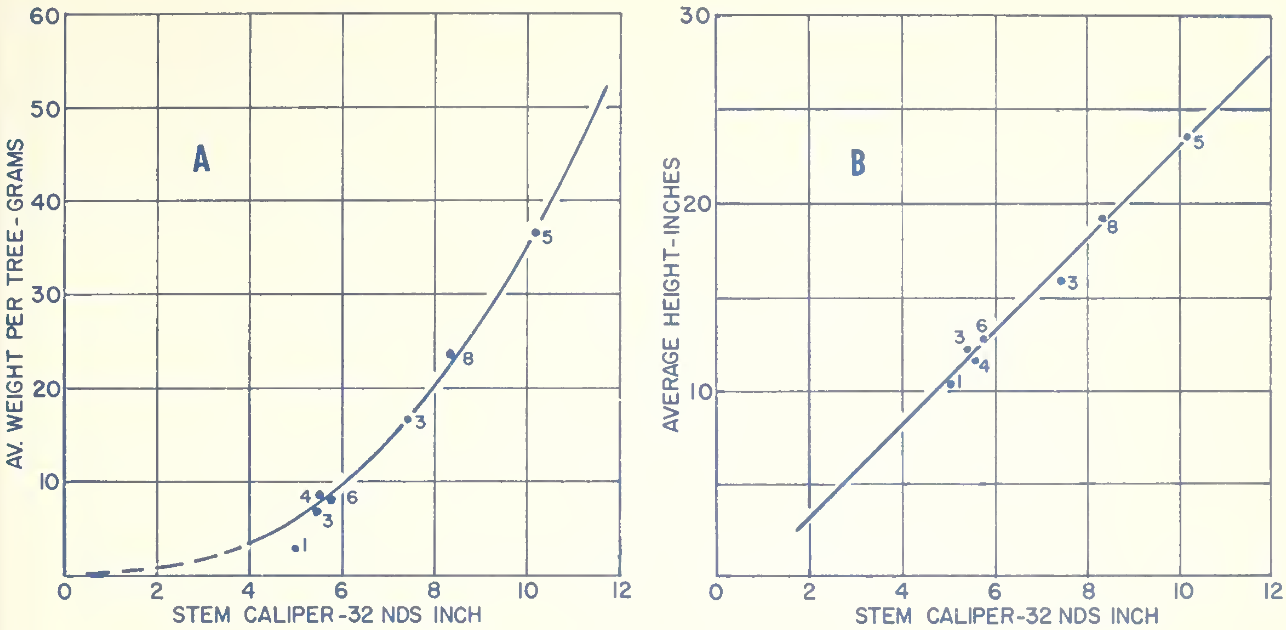

Figure 2.—Relation of stem caliper of 3-0 green ash to: *A*, fresh weight; and *B*, height per tree.

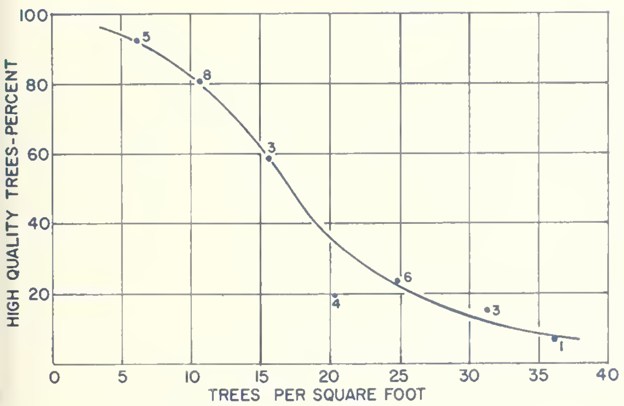

Figure 3.—Relation of stand density of 3-0 green ash to percent of high-quality trees produced (7/32 inch caliper or larger).

Stand Density Effect on Tree Distribution by Stem Caliper

The trees were grouped into three density classes: high, averaging 24.8 trees per square foot; medium, 10.7; and low, 6.1. In the high-density class, 52 percent of the trees were 5/32 inch or less. The respective figures for medium- and low-densities were only 3 and 2 percent; at these low percentages, grading would be a simple matter (fig. 3).

Caliper Versus Height as a Grading Standard

In this study, 51 percent of all trees measured for caliper and height were of 7/32-inch caliper or more, but only 40 percent were at least 16 inches tall. Thus the present Northern Great Plains grading standard for green ash—7/32-inch minimum caliper and 16 inches minimum height—would cause an additional 11 percent or so of the stock measured in this study to be discarded than if the standard were based on caliper size only. For the green ash stock measured here, there was good agreement (i.e., within 2 percent) in two different single criteria of plantability, i.e. between minimum caliper (at least 7/32 inch) and minimum height (at least 13 inches).

Hence, time could be saved by estimating cull on the basis of height alone before lifting the trees. And if 13 inches were considered an acceptable minimum height in subsequent culling, an additional 10 percent or so of the bed run of trees could be saved. In western Oklahoma such short but stocky trees survived well (Engstrom and Stoeckeler 1941).

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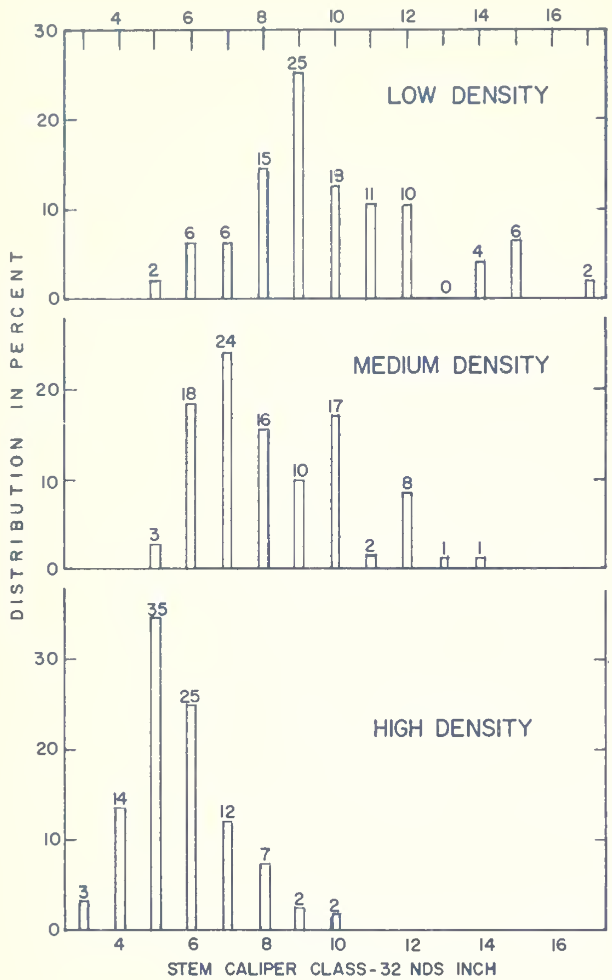

Figure 4.—Distribution of trees by caliper class for three density classes: Low density beds averaged 6.1 trees, medium density 10.7, and high density 24.8 trees per square foot. Figures above each bar are percentages of trees by stem caliper class.

APRIL 1967

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RESEARCH NOTE NC-26

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Lake States Veneer Log Production Shows Increase in 1965

ABSTRACT. — More than 54 million board feet of veneer logs were cut in Michigan, Minnesota, and Wisconsin in 1965, the largest cut since 1956. Oak showed the greatest increase. Eighty-seven percent of the total went for wall panels, doors, etc. The rest went into containers.

Loggers in the Lake States[1] cut 54.3 million board feet of veneer logs in 1965. This is the largest harvest on record since 1956 when 79.0 million board feet were cut. The cut of 24.4 million board feet in Wisconsin and 22.3 million board feet in Michigan far surpassed the 7.6 million board feet cut in Minnesota (table 1).

More than four-fifths of the cut was hard maple, birch, oak, elm, and basswood, in that order of volume. With the exception of oak, these species have long been most in demand by the Lake States veneer industry. Only in recent years has oak taken a prominent position in the industry. The increased cut of oak reflects a shift to the use of a more plentiful species. If present cutting trends continue, oak will soon be the volume leader.

Most of the logs, 47.2 million board feet, went to mills cutting standard grade logs into veneer for wall panels, flush doors, specialty plywoods, and other similar items. The remaining 7.1 million board feet went to mills cutting veneer for boxes, baskets, and other types of containers. An additional 2,400 cords of small logs were cut for container mills in the Lake States. Most of this material is sawed into container covers and consists mainly of aspen, elm, and basswood.

Trees having veneer-quality logs are seldom concentrated in one area. Loggers either select veneer logs while cutting for saw logs and other wood products or search for trees having veneer-quality logs. The widely scattered areas of cutting and keen competition for these high-value logs among buyers result in a widespread movement of logs. Buyers for Lake States mills, especially those in Wisconsin, purchased 7.6 million board feet from areas outside the Lake States. Most of these imports were hard maple and yellow birch logs from Canada. A smaller volume composed of several species came primarily from Illinois, Indiana, and Iowa. In turn, buyers for mills outside the Lake States purchased 5.3 million board feet in the Lake States. An estimated 2.7 million board feet went to Indiana, Ohio, and Iowa mills and the remaining 2.6 million board feet to Canada, eastern United States, and Europe. Most of the exported volume was hard maple and walnut.

More Logs Used in Region Than Are Cut

The 48 Lake States mills, 25 container and 23 standard, received 56.6 million board feet of logs in 1965. Their requirements were 2.3 million board feet more than the cut in the region. Mills using standard grade logs received 49.4 million board feet and container

[1] *Michigan, Minnesota, and Wisconsin; future reports will include all states in the North Central Region.*

Table 1. — *Production and imports of veneer logs, Lake States, 1965*
(Thousand board feet, Int'l 1/4-inch rule)

Species	Destination	Production[1/] Minn.	Wis.	Mich.	Region	Imports Other[2/]	Canada	Total imports	Total receipts
Aspen	Minn.	13	-	-	13	-	-	-	13
	Wis.	12	242	20	274	-	-	-	274
	Mich.	-	-	334	334	-	-	-	334
	Total	25	242	354	621	-	-	-	621
Ash	Minn.	-	-	-	-	-	-	-	-
	Wis.	131	400	7	538	27	-	27	565
	Mich.	-	7	169	176	-	-	-	176
	Exported[3/]	-	-	3	3	-	-	-	-
	Total	131	407	179	717	27	-	27	741
Basswood	Minn.	639	-	-	639	-	-	-	639
	Wis.	1,459	2,562	386	4,407	192	-	192	4,599
	Mich.	-	72	915	987	-	28	28	1,015
	Exported[3/]	-	-	-	-	-	-	-	-
	Total	2,098	2,634	1,301	6,033	192	28	220	6,253
Beech	Minn.	-	-	-	-	-	-	-	-
	Wis.	-	81	52	133	-	-	-	133
	Mich.	-	-	370	370	-	-	-	370
	Total	-	81	422	503	-	-	-	503
Birch	Minn.	225	-	-	225	-	4	4	229
	Wis.	427	2,211	4,870	7,508	3	2,268	2,271	9,779
	Mich.	102	255	3,161	3,518	-	969	969	4,487
	Exported[3/]	-	-	396	396	-	-	-	-
	Total	754	2,466	8,427	11,647	3	3,241	3,244	14,495
Cottonwood	Minn.	77	-	-	77	-	-	-	77
	Wis.	936	71	-	1,007	609	-	609	1,616
	Mich.	-	-	358	358	58	-	58	416
	Total	1,013	71	358	1,442	667	-	667	2,109
Elm	Minn.	88	-	-	88	-	-	-	88
	Wis.	1,294	3,899	66	5,259	49	-	49	5,308
	Mich.	-	15	900	915	-	-	-	915
	Exported[3/]	-	77	-	77	-	-	-	-
	Total	1,382	3,991	966	6,339	49	-	49	6,311
Maple, hard	Minn.	-	-	-	-	-	-	-	-
	Wis.	458	4,220	2,238	6,916	277	2,466	2,743	9,659
	Mich.	-	245	3,327	3,572	-	-	-	3,572
	Exported[3/]	9	635	1,809	2,453	-	-	-	-
	Total	467	5,100	7,374	12,941	277	2,466	2,743	13,231
Maple, soft	Minn.	31	-	-	31	-	-	-	31
	Wis.	191	1,091	107	1,389	80	-	80	1,469
	Mich.	-	28	337	365	-	-	-	365
	Total	222	1,119	444	1,785	80	-	80	1,865
Oak	Minn.	-	-	-	-	-	-	-	-
	Wis.	1,200	7,192	249	8,641	353	47	400	9,041
	Mich.	-	109	150	259	-	-	-	259
	Exported[3/]	-	23	131	154	-	-	-	-
	Total	1,200	7,324	530	9,054	353	47	400	9,300
Walnut	Minn.	-	-	-	-	-	-	-	-
	Wis.	-	1	-	1	-	-	-	1
	Mich.	-	-	9	9	-	-	-	9
	Exported[3/]	99	134	1,636	1,869	-	-	-	-
	Total	99	135	1,645	1,879	-	-	-	10
Misc. species	Minn.	-	-	-	-	-	-	-	-
	Wis.	3	577	49	629	31	-	31	660
	Mich.	-	74	314	388	122	-	122	510
	Exported[3/]	173	184	4	361	-	-	-	-
	Total	176	835	367	1,378	153	-	153	1,170
All species	Minn.	1,073	-	-	1,073	-	4	4	1,077
	Wis.	6,111	22,547	8,044	36,702	1,621	4,781	6,402	43,104
	Mich.	102	805	10,344	11,251	180	997	1,177	12,428
	Exported[3/]	281	1,053	3,979	5,313	-	-	-	-
	Total	7,567	24,405	22,367	54,339	1,801	5,782	7,583	56,609

1/ Vertical columns of figures under box heading "Production" represents the quantity of veneer logs cut in each state.

2/ Central States and small amounts from more distant states.

3/ Veneer logs shipped to mills outside Lake States Region.

mills the remaining 7.2 million board feet. Wisconsin mills, the principal consumers, received 43.1 million board feet. Their needs far exceeded Michigan and Minnesota mills which used 12.4 and 1.1 million board feet, respectively.

Trends in Production Indicate Possible Up-swing

The volume cut in 1965 is the largest in recent years. Future reports on the industry will show whether the increase indicates an upward trend or merely reflects one of the better years in the industry. Partially due to loss of defense contracts, standard grade log production dropped sharply in the late 1940's (fig. 1). Since 1950, production has averaged about 46 million board feet annually. Veneer quality logs are in shorter supply, but improved technology in utilization and continued demand for hardwood veneer have kept this market active. Container veneer log production declined generally from the mid 1940's until 1960. During this time, less costly paperboard and plastic containers made deep inroads in the veneer container market. Since 1960, production has been maintained at 6 to 8 million board feet annually. This indicates the market for veneer containers has apparently stabilized.

Thanks are due the veneer industry in the Lake States and adjacent states for supplying the data in this report. Other sources of information, such as the Department of Commerce, provided an estimate of veneer logs shipped to more distant states and overseas.

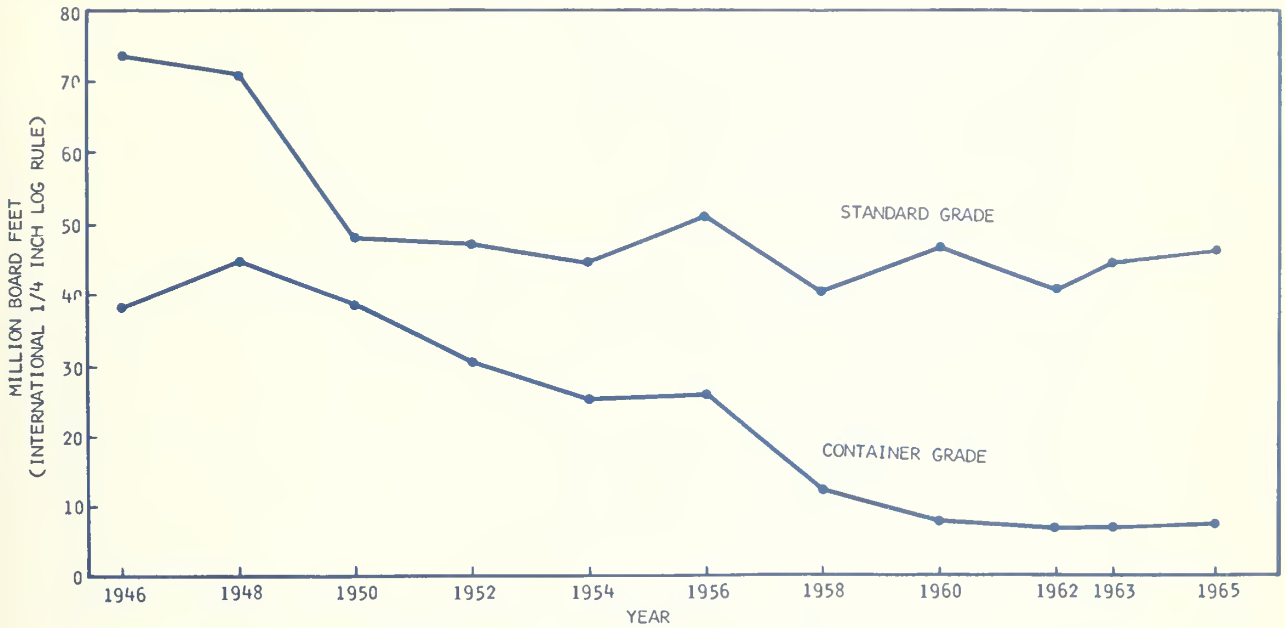

Figure 1.—Veneer log production, Lake States, 1946-1965.

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RESEARCH NOTE NC-27

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Wetland Road Crossings: Drainage Problems and Timber Damage

ABSTRACT. — More than half the 70 wetland road crossings observed in a northeastern Minnesota survey showed timber killed or weakened by a rise in the water table caused by the damming effect of the road.

A common sight in the Lake States and parts of Eastern Canada is dead or dying timber in patches or strips along one side of a wetland forest road (fig. 1). Cause is failure to provide adequate cross drainage. Such damage is especially prevalent on peatland.

The Study and Its Purpose

As a followup of a previous article on this subject citing European experience and practice, defining the hydrological problems, and describing solutions[1], a survey was made of 70 wetland crossings in seven contiguous counties (Cook, Lake, St. Louis, Carlton, Aitkin, Itasca, and Koochiching) in northeastern

[1] *Stoeckeler, Joseph H. Drainage along swamp forest roads—lessons from Northern Europe. J. Forest. 63: 772-776, 1965.*

Figure 1.—Trees at the right on the "uphill" side of this road crossing a black spruce swamp show depressed growth and poor vigor compared with the normal trees at left on the "downhill" side. Because no culvert was used here the water table was raised about 10 inches. Cattails predominate on the flooded side of the crossing showing site retrogression. Alder, fern, and willow make up the ground cover on the other side.

Minnesota. The purpose was to evaluate tree damage and drainage problems caused by the damming effect of the roads. A starting point was selected at random and the first 10 forest wetland crossings found in each county were taken as they came. The forest types involved were largely pure black spruce, tamarack, and mixtures of the two or with northern white-cedar; the swamp hardwood type was also involved, which included black ash, red maple, and associated species. On the better sites many of these wetland tree species are used for pulpwood.

All but one of the 70 wetland crossings examined in this study were built by township or county road agencies, by forestry agencies, or by forest industry. These roads can be generally classified as low-standard truck trails or timberland roads in terms of width, surface quality, foundation, and drainage. Most were graveled, a few were blacktopped, and one had a dirt surface.

Eighty percent of the crossings were on peat; the rest on mineral soil. The gradient on the swamps ranged from nearly level to 4.7 percent. Two-thirds of the sites had 1 percent or less gradient.

Tree Damage

The tree damage observed was classified into three categories: none, trees killed or weakened within 50 feet of road, and trees killed or weakened beyond 50 feet (table 1).

Occurrence of damage was affected by the direction of the road in relation to the contours of the land. All of the 39 crossings that showed damage were within 45 degrees of being parallel to the contour; in other words, they ran across the drainage flow. Nearly two-thirds of the crossings over peatland showed damage compared with about one-fifth of those over mineral soil. A higher percentage of peatland crossings suffered damage than mineral-soil crossings apparently because there was more of a tendency for the water that flowed in the latter to cut a natural channel into which a culvert had to be set. Hence there was less tendency to have a damming action at such sites.

The apparent rise in water table level (in the zone of most serious tree damage) on the 39 crossings showing tree damage averaged about 11 inches, with a maximum of 30 inches.

The damage in acres of adversely affected tree growth per mile of wetland road crossing varies somewhat with average length of crossing: there is more damage where the swamp crossings are short than where they are long (table 2). The reason for this is that the short crossings are more commonly located at the narrowest point in the wetlands, quite sensibly sought out by the road surveyor. In planimetric view they appear in hour-glass shape. The swamps may be three to seven times wider a short distance "upstream" than at the crossing itself, and poor cross drainage has a pronounced damming effect at these places. Also, it was more common to have no culverts at all on short crossings than on long ones, tending to increase the distance back from the road where timber was killed or growth was depressed.

Based on a general average of 14 acres adversely affected per mile of wetland crossing and a count of the total number of crossings on 46,080 acres of land in Minnesota, it was roughly estimated that there may be about 30 thousand acres of wetland in northern Minnesota where trees are actually killed, where crown vigor is markedly affected, or where natural regeneration is inhibited because of periodic or permanent flooding adjacent to road crossings. Not only is valuable timber destroyed but also the esthetic quality of the roadside landscape is degraded.

Drainage Problems

The chief problems were absence of culverts or other cross drainage, culverts set too high, no collector ditch, no discharge ditch, inadequate collector or discharge ditches, and low culvert capacity (table 3, fig. 2). Many sites had a combination of two or three of these deficiencies.

One of the crucial cross-drainage problems is the shallow placement of culverts. When small-diameter culverts are only a few inches below the surface of the road, they invariably fail to adequately drain the area on the higher side of the road; hence, pools of water form and timber may be flooded for prolonged periods and killed. The "high" culverts are

Table 1.—*Frequency of tree damage observed on the wetland sites*

(In percent)

Trees killed or weakened	On 56 peat-soil crossings	On 14 mineral-soil crossings	On all 70 crossings
None	36	79	45
Within 50 feet of road	30	14	24
Beyond 50 feet of road	34	7	31

Table 2. — *Area of forest land adversely affected per mile of wetland crossing*

Length of crossing (feet)	Sites showing damage	Average length of crossing	Area adversely affected per mile of crossing
	Percent	Feet	Acres
0 - 500	63	305	59.1
500 - 1,000	18	740	33.3
1,000 - 2,000	8	1,530	9.8
2,000 - 4,000	5	2,650	6.4
4,000 - 6,000	3	4,800	6.0
6,000 - 8,000	3	6,600	7.2

Table 3. — *Types of wetland road-crossing problems observed on 70 study sites*

(In percent of sites)

Type of problem	Prevalence[1/]	Sites where this factor was most important cause of timber killing
No culvert or bridge	21	21
Culvert set too high	24	17
Poor culvert capacity owing to siltation	7	4
No collector ditch	23	7
Inadequate collector ditch	10	3
No discharge ditch	16	0
Inadequate discharge ditch	11	3
Beaver (dams or plugged culverts)	1	0
No problem that resulted in timber killing	44	--

[1/] Many of the study areas had two or three of these problems present on the same site, hence totals exceed 100 percent.

sometimes damaged by road-grader blades or snowplows. Capacity of such culverts is reduced and potential life span shortened.

Other problems are lack of stability of ditch slopes or road shoulder, sloughing of soil, and subsequent siltation of culverts. Sometimes dry sticks or other debris may plug up the inlet or outlet of culverts. Vegetation such as willow and tall grass or weeds may also reduce culvert capacity.

The remedy for the culvert problem is to set the bottoms of the culverts in most Lake States wetlands about 1½ to 3 feet below the general level of the swamp surface (depending on swamp gradient, drainage area, and culvert size). Also, there should be provided an adequate collector ditch parallel to the road on its "upstream" side, and beyond any zone of spoil deposit or compaction. An adequate discharge ditch, where necessary, should be carried out at about right angles to the road for several hundred feet or more on the "downstream" side of the road, or a sufficient distance to cross two 1-foot contours and thus avoid any backwater effect. If a naturally incised stream channel is already present, the dis-

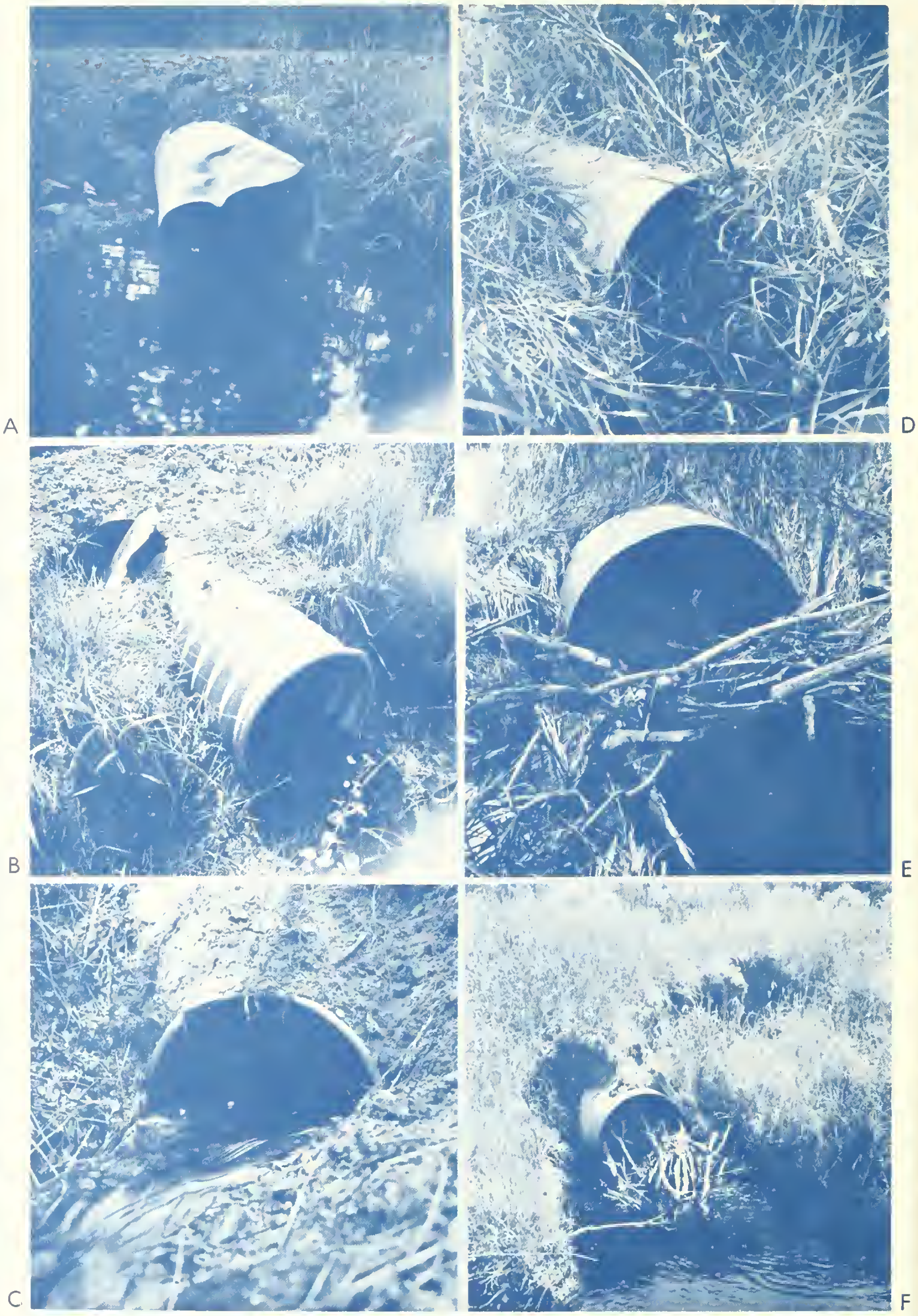

Figure 2.—A, culvert set too high, damaged by road grader; B, culvert intake capacity reduced probably by snowplow damage; C, culvert outlet half filled with gravel that sloughed off the road shoulder; D, grass, willow, and chunks of sod constrict culvert entrance; E, a culvert with about half its intake plugged with dry sticks; F, discharge end of a culvert partially plugged with sticks by beavers.

charge ditch may not be required: and, if the "valley" slopes on both sides toward the stream or drainageway at about a right angle, the collector ditch is probably not necessary.

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RESEARCH NOTE NC-28

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Chemical Weed Control in a Two-Year-Old Walnut Planting

ABSTRACT. — Six herbicide mixtures were sprayed directly on broadleaf weeds and grasses competing with black walnut trees. Mixtures of paraquat (½ lb/acre) with simazine (4 lb/acre) or atrazine (4 lb/acre), and amitrole (2 lb/acre) plus simazine (4 lb/acre) gave satisfactory weed control, which resulted in significantly better tree height and diameter growth.

Grasses and broadleaf weeds compete with young black walnut (*Juglans nigra* L.) trees for moisture and nutrients, and are often the most important site factor affecting tree growth.

In May 1965 we established an experiment to evaluate several combined herbicide treatments for weed control around 2-year-old walnut trees and to learn whether the treatments produced any phytotoxic symptoms on the trees.

The Study

Sixty-three 2-year-old trees grown from nuts that were sown on a cleared forest site in east-central Iowa were studied. The trees are on a northeast slope in a Fayette silt loam soil.

The major weed species present at the time of establishment were: nimblewill (*Muhlenbergia schreberi* Gmel.), Kentucky bluegrass (*Poa pratensis* L.), yellow nut-grass (*Cyperus esculentus* L.), blue violet (*Viola cucullata* Ait.), strawberry (*Fragaria virginiana* Duches.), yellow wood sorrel (*Oxalis europaea* Jord.), silvery cinquefoil (*Potentilla argentea* L.), horse nettle (*Solanum carolinense* L.), daisy fleabane (*Erigeron strigosus* Muhl.), and poison ivy (*Toxicodendron radicans* (L.) Kuntze). Many other annual and perennial weeds, grasses, and small woody plants were also present but they occurred as scattered individuals. The weed species did not overtop even the smallest walnut trees when treatments were applied.

Three quick-killing systemic herbicides that control weeds for short periods were combined with two soil sterilants that control weeds and grasses for longer periods.[1]

1. Amitrole 2 lb/A, and simazine 4 lb/A.
2. Amitrole 2 lb/A, and atrazine 4 lb/A.
3. Paraquat ½ lb/A with Ortho X-77 spreader, and simazine 4 lb/A.
4. Paraquat ½ lb/A with Ortho X-77 spreader, and atrazine 4 lb/A.
5. Dalapon 4 lb/A, and simazine 4 lb/A.
6. Dalapon 4 lb/A, and atrazine 4 lb/A.
7. Control—no herbicide.

Weed control treatments were applied to three size classes of trees (diameters measured 2 inches above ground):

Tree size class	*Height (feet) Av.*	*Height (feet) Range*	*Diam. (32nd inch) Av.*	*Diam. (32nd inch) Range*
I	1.4	1.0-2.3	10	6-17
II	3.1	2.4-3.6	21	18-28
III	4.9	3.7-5.8	33	29-41

Seven weed control treatments were replicated three times for each of the three size classes. Treatments were randomly assigned to individual trees in each size class.

During May 25-28, 1965, the herbicide mixtures in water solutions and suspensions were sprayed on the foliage of the ground vegetation over a 6x6-foot plot around each walnut tree. Two quarts of spray solution at the required concentration were applied with a back-pack sprayer to each plot. The walnut

[1] *The herbicides were (1) amitrole (3-amino-1, 2, 4-triazole), (2) paraquat (1, 1'-dimethyl-4, 4'-dipyridylium dichloride), and (3) dalapon (2, 2-dichloropropionic acid). The soil sterilants were (1) simazine (2-chloro-4, 6-bis (ethylamino)-s-triazine) and (2) atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine). All rates are given in active ingredients. The 80-percent wettable powders of simazine and atrazine were used. Eight ounces of Ortho X-77 Spreader per 100 gallons of spray solution were used with the paraquat treatments.*

foliage was carefully avoided, but not the walnut stems.

Total heights and diameters of trees were measured on May 5 and October 15, 1965, and September 28, 1966. Periodically in 1965 each plot was rated for weed control. Final yields of grasses, broadleaf weeds, and poison ivy were harvested September 11-15 from a 1-foot-square plot on the south side of each tree.

Results

Weeds. — All of the treatments tested were effective in controlling competing vegetation, but there were differences in quickness of kill and length of time weed growth was suppressed (table 1). Treatments with paraquat killed grasses and broadleaf weeds within 4 to 5 days, while treatments with amitrole and dalapon gave a much slower kill. Treatments with atrazine generally gave quicker kills and suppressed weeds longer than treatments with simazine.

September grass yields for all combined treatments except the amitrole-simazine treatment were significantly lower than those for the control treatment (table 2). In mixtures with amitrole, atrazine gave better residual control of grasses than simazine. The amitrole-simazine treatment was effective until August, but thereafter there was considerable regrowth of grass. Nimblewill, a perennial grass that is resistant to amitrole, accounted for most of this grass weight.[2] The amitrole-atrazine mixture apparently was more effective against nimblewill grass than the amitrole-simazine mixture. Planned orthogonal comparisons between chemically treated plots and control plots showed that chemical treatments significantly reduced broadleaf weed and total weed yields.

Treatments with paraquat and amitrole gave effective control of poison ivy initially, but at least one more treatment would be required to eradicate it. The heavy growth of grasses and weeds on control plots apparently restricted the growth of poison ivy.

Most combined treatments held broadleaf weeds and grasses in check until August, but all treatments failed to suppress new weed growth the following spring.

Trees. — Effective control of broadleaf weeds and grasses by the chemicals significantly increased height and diameter growth of black walnut trees in 1965 (table 3). Mean height growth ranged from 1.7 feet on the controls to 3.2 feet for the amitrole-simazine treatment. Mean diameter growth of walnut trees was 6/32-inch better on amitrole-simazine plots and on plots treated with the paraquat mixtures than on control plots.

[2] *Dunham, R. S. Herbicide manual for non-cropland weeds. U.S. Dep. Agr., Agr. Handbook 269, p. 7. 1965.*

Table 1. — *Average weed control around black walnut trees by treatments and 1965 observation date*

Weed control treatments[1/]	Weed control rating on--[2/] June 9	July 1	August 4	September 1
Paraquat ½ lb/A and atrazine 4 lb/A	10.0	10.0	8.6	8.0
Paraquat ½ lb/A and simazine 4 lb/A	10.0	9.2	8.1	6.7
Amitrole 2 lb/A and atrazine 4 lb/A	7.2	9.1	7.4	4.6
Amitrole 2 lb/A and simazine 4 lb/A	6.1	8.2	7.0	3.4
Dalapon 4 lb/A and atrazine 4 lb/A	8.0	8.0	7.6	7.2
Dalapon 4 lb/A and simazine 4 lb/A	5.7	7.3	6.1	4.7
Control--no herbicide	0.0	0.0	0.0	0.0

1/ Includes all herbaceous vegetation and poison ivy averaged over all tree classes. Treatments were applied on May 25-28, 1965.

2/ 0 = No control and 10 = nearly complete control.

Table 2. — *Average grass, weed, and poison ivy yields in September 1965 by weed control treatments*[1]
(In grams)

Weed control treatment	Oven-dry weight per square foot 2/			
	Grass	Weeds	Poison ivy	Total
Paraquat ½ lb/A and atrazine 4 lb/A	.85	.00	2.27	3.12
Amitrole 2 lb/A and atrazine 4 lb/A	.97	.18	2.76	3.91
Dalapon 4 lb/A and atrazine 4 lb/A	1.31	.01	1.42	2.74
Dalapon 4 lb/A and simazine 4 lb/A	1.96	2.03	3.12	7.11
Paraquat ½ lb/A and simazine 4 lb/A	3.64	.06	2.12	5.82
Amitrole 2 lb/A and simazine 4 lb/A	3/ 10.03	.48	1.42	11.93
Control--no herbicide	11.76	15.69	1.39	28.84

1/ All tree classes combined.

2/ Means connected by a bracket are not significantly different from each other at the 5-percent level.

3/ Includes some dead nimblewill foliage.

Table 3. — *Mean height and diameter growth of black walnut trees by weed control treatments and years*[1]

Weed control treatment	Growth 1965 2/		Growth 1966 2/		Total 1966 2/	
	Height	Diameter	Height	Diameter	Height	Diameter
	Feet	32nd inch	Feet	32nd inch	Feet	32nd inch
Amitrole 2 lb/A and simazine 4 lb/A	3.2	16	2.1	12	8.4	49
Paraquat ½ lb/A and atrazine 4 lb/A	3.0	16	2.1	14	8.3	53
Paraquat ½ lb/A and simazine 4 lb/A	2.8	16	2.0	12	7.9	50
Amitrole 2 lb/A and atrazine 4 lb/A	2.3	15	2.3	12	7.7	48
Dalapon 4 lb/A and simazine 4 lb/A	2.3	14	2.0	11	7.5	46
Dalapon 4 lb/A and atrazine 4 lb/A	2.5	13	2.0	10	7.6	45
Control--no herbicide	1.7	10	2.2	9	7.0	39

1/ All tree classes combined. Diameters were measured 2 inches above ground line.

2/ Means connected by a bracket are not significantly different from each other at the 5-percent level.

Height growth in 1966 was similar for chemically released trees and control trees, but previously released trees maintained their initial advantage with respect to total height. Chemically released trees were still growing faster in diameter than were control trees during the second growing season after treatments were applied.

In 1965 trees in the large tree classes (I & II) grew two to three times faster in height and diameter than trees in the smallest class (table 4). During the second year, trees from the largest tree class increased their advantage in both height and diameter over trees in the smallest class.

small trees if there are enough well-spaced, high-quality trees from the larger tree classes available.

3. Of the weed control mixtures studied, paraquat-simazine, paraquat-atrazine, and amitrole-simazine[3] resulted in the best tree height and diameter growth.

4. Spray solutions must be kept off walnut foliage to avoid injury.

5. Best walnut growth responses can be obtained by matching herbicides with weed species and soil conditions in the plantation. Use mixtures with paraquat when both broadleaf weeds and grasses are equally troublesome. Amitrole mixtures are recommended for broadleaf weed and quackgrass control.

Table 4. — *Mean height and diameter growth of black walnut trees by tree classes and years*[1]

Tree class	Growth 1965 2/		Growth 1966		Total 1966	
	Height	Diameter	Height	Diameter	Height	Diameter
	Feet	32nd inch	Feet	32nd inch	Feet	32nd inch
III	3.9	21	3/ 2.6	4/ 15	11.4	69
II	2.5	14	2.1	11	7.6	46
I	1.2	8	1.6	9	4.3	26

1/ Over all weed control treatments. Diameters were measured 2 inches above ground line.

2/ All differences in growth among tree classes are significant at the 5-percent level.

3/ Significantly better (5-percent level) than tree class I.

4/ Significantly better (5-percent level) than tree class I or II.

The best tree (class III tree on an amitrole-simazine plot) grew 11.4 feet in height and 1.5 inches in diameter in 2 years. This tree was 16.8 feet tall and had a diameter of more than 2.6 inches at the end of the 1966 growing season.

There was no evidence of chemical injury to the trees from any of the treatments tested.

Summary and Recommendations

1. Trees released from herbaceous vegetation grew nearly twice as much in height and half again as much in diameter as control trees during the season of chemical application.

2. The smallest trees benefited from release, but they failed to gain on unreleased trees in the next tree class. Obviously, it would not pay to release

Dalapon is useful in mixtures for controlling covers that are predominantly grass.[4]

6. Simazine or atrazine at 4 pounds per acre should be included in mixtures for full season weed control on silt loam soils.[5] Simazine is preferred over atrazine as a residual herbicide because simazine is less subject to leaching.

[3] *Homemade mixtures can be prepared by buying the herbicides separately and mixing them. A combination of amitrole (2 lb/A) and simazine (4 lb/A) is sold under the trade name of Amizine.*

[4] *Byrnes, W. R. Site preparation and weed control. In Black Walnut Culture. U.S. Forest Serv., N. Cent. Forest Exp. Sta., p. 20. 1966.*

[5] *Unpublished data on file at the field office of the North Central Forest Experiment Station in Ames, Iowa.*

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APRIL 1967

U. S. FOREST SERVICE

RESEARCH NOTE NC-29

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Waterline Erosion Control Essential To Streambank Rehabilitation

ABSTRACT. — Tests of streambank erosion control measures on three Michigan streams have shown the key role of waterline stabilization. After undercutting was stopped, the upper banks were revegetated in 1 to 5 years depending on treatment. Without waterline control, all revegetation efforts were ineffective.

Eroding streambanks, which are the obvious source of much of the sediment in Michigan trout streams, have been stabilized by various methods—some expensive, some more economical. Recent tests of cheaper methods have shown that without waterline stabilization, usually by rock rip-rapping, upper bank control methods are of limited value.

These tests of rock rip-rap and various techniques of vegetation establishment were made at three locations in Lower Michigan: the North Branch of the Tobacco River in Clare County, Hersey Creek in Osceola County, and the Pere Marquette River in Newaygo County. The study was done by the North Central Forest Experiment Station in cooperation with the Michigan Department of Conservation, Fish Division, and the Huron-Manistee National Forests.

Rock rip-rap was applied to a bank on the Pere Marquette and to selected banks on the Tobacco River. The remainder of the banks on the Tobacco River and on Hersey Creek had no rock rip-rap. The Tobacco River channel was fenced to exclude cattle from the banks. Fencing was not necessary on the other areas.

All banks were graded before treatment. Some banks were seeded with a mixture of creeping red fescue, perennial rye, and blue grass, and top-dressed with approximately 2 tons per acre of slow-release 16-16-16 fertilizer. The test banks were divided into 10- to 20-foot-wide strips; each strip was sprayed with one of six different asphalt and latex base liquid mulches (fig. 1). The tests on

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Figure 1.—Liquid mulch being sprayed on a bank above rock rip-rap.

Hersey Creek and the Pere Marquette River also included limited comparisons with straw and fibre-net mulches.

All rip-rapped banks were almost completely vegetated within 3 years following treatment and were judged to be stabilized. On the other hand, several of the banks on the Tobacco River and the bank on Hersey Creek that had no rock rip-rap failed soon after the banks were graded and seeded, and have been eroding ever since.

Seeding and fertilizing accelerated revegetation of the banks (fig. 2), but after 2 years vegetation on unseeded rip-rapped banks had nearly caught up with that on seeded, rip-rapped banks. This was possibly due to introduction of seed with rock rip-rap which was obtained from field stone piles.

Mulching had no detectable effect on vegetation establishment.

Consistently, the best results were obtained by placing rock rip-rap along the waterline and sloping the upper bank. Seeding and fertilizing the upper bank aided in quick establishment of vegetation.

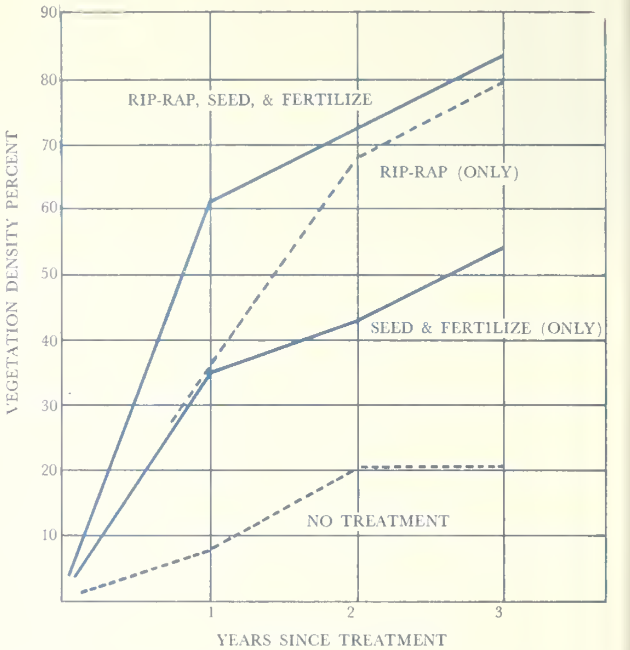

Figure 2.—Effect of bank treatment and time on vegetation density.

APRIL 1967

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U. S. FOREST SERVICE

RESEARCH NOTE NC-30

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Northern Minnesota Lumber Production Declines From 1960 to 1965

ABSTRACT. — Shows lumber production by species in three Survey Districts of northern Minnesota and by county for softwoods, aspen, and other hardwoods. Compares lumber production in 1960 with 1965.

Lumber production in 23 northern Minnesota counties (fig. 1) dropped 15 percent between 1960 and 1965 (tables 1 and 2). According to a recent sawmill survey by the Office of Iron Range Resources and Rehabilitation in cooperation with the Station, the amount of lumber sawn decreased from about 120 million board feet in 1960 to 102 million board feet in 1965. Since the survey covered only northern Minnesota these results cannot be directly compared with the 1960 cut in all of Minnesota of 162 million board feet. However, as about 74 percent of the State's lumber is normally sawn in the northern area, it is probable that lumber output for the entire State decreased in these 5 years.

In three Survey Districts (Northeast, Central Pine, and Rainy River) the lumber manufactured from all species was 112 million board feet in 1960 and 95 million board feet in 1965, a reduction of about 15 percent (table 1). The decrease was 24 percent in the Northeast District, and 11 percent in the Central Pine District. Almost no change in lumber production occurred in the Rainy River District. In these three districts 18 percent less softwood lumber and 28 percent less aspen lumber was sawn in 1965 than in 1960. Production of lumber from other hardwoods increased 30 percent. The decline in aspen production parallels the decline in the market for wooden boxes. At the same time a growing pallet market has furnished an outlet for the increased lumber production from other hardwood species.

Itasca, St. Louis, and Clearwater Counties lead in lumber manufacturing (table 2). Between the two surveys lumber output in-

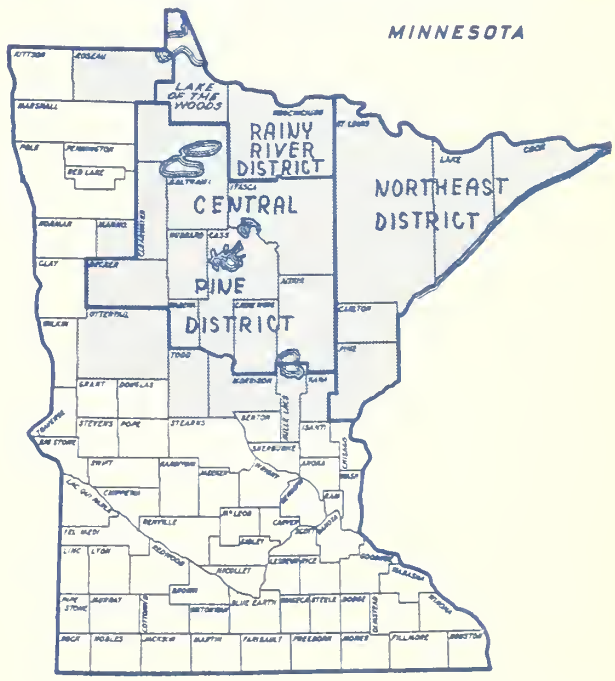

Figure 1.—Study counties are shaded. Districts are outlined with heavy lines.

Table 1. — *Production of lumber by species and districts, Northern Minnesota, 1965 (Thousand board feet lumber tally)*

Species	Northeast District	Central Pine District	Rainy River District	Other1/	Total	Percent of total
Balsam fir	237	512	74	30	853	0.8
White-cedar	1,024	59	45	14	1,142	1.1
Jack pine	1,360	6,046	399	1,896	9,701	9.5
Red pine	4,194	10,696	1,791	176	16,857	16.5
White pine	13,173	9,269	2,138	65	24,645	24.1
Spruce	1,159	971	72	63	2,265	2.2
Tamarack	-	52	-	89	141	0.1
Total softwoods	21,147	27,605	4,519	2,333	55,604	54.3
Ash	158	1,391	13	431	1,993	1.9
Aspen	3,866	17,987	2,355	1,189	25,397	24.8
Basswood	400	1,910	-	1,298	3,608	3.5
Birch	2,431	1,633	2	61	4,127	4.0
Cottonwood	-	43	-	-	43	-
Elm	314	4,160	-	501	4,975	4.9
Hard maple	17	191	-	376	584	0.6
Soft maple	-	186	-	-	186	0.2
Red oak	499	1,852	-	765	3,116	3.1
White oak	-	788	261	232	1,281	1.3
Balsam poplar	-	1,439	-	-	1,439	1.4
Total hardwoods	7,685	31,580	2,631	4,853	46,749	45.7
ALL SPECIES	28,832	59,185	7,150	7,186	102,353	100.0
Percentage change from 1960	- 24	- 11	None			

1/ Includes Kanabec, Mahnomen, Mille Lacs, Morrison, Otter Tail, Roseau, and Todd Counties.

creased 12 percent in Itasca County, decreased 29 percent in St. Louis County, and increased about 86 percent in Clearwater County. Several mills specializing in pallet lumber manufacturing accounted for much of the increase in Clearwater County.

Several interrelated factors contributed to the decline in lumber produced. First, there was a scarcity of good woods workers. Industrial growth was accelerating in the Lake States in 1965, and several taconite developments began on the Minnesota Iron Range. Accordingly, some woods workers switched to other industrial occupations offering promise of greater fringe benefits, or more job security, or higher pay. In addition, the number of farm laborers, a traditonal source of part-time woods employees, shrank from 1960 to 1965 in northern Minnesota. Secondly, a shortage of good-quality saw logs occurred in 1965. Part of the shortage resulted from insufficient woods labor, but poor weather conditions for logging operations was a major cause also. Thirdly, competition from lumber shipped in from southern and western states has depressed the margin of profit for some local mills. This competition has not allowed sawmill operators to raise lumber prices enough to offset rising labor and capital expenses. Thus, the profit squeeze idled many

Table 2. — *Lumber production for specified counties, Northern Minnesota, 1965 (Thousand board feet lumber tally)*

County and district	Production by species groups: All species	Softwoods	Aspen	Other hardwoods	Percentage change since 1960 (all species)
Carlton	654	400	161	93	- 66
Cook	5,733	3,824	1,284	625	+ 6
Lake	4,517	4,129	54	334	- 23
Pine	1,138	-	-	1,138	+ 5
St. Louis	16,790	12,794	2,367	1,629	- 29
Northeast District	28,832	21,147	3,866	3,819	- 24
Aitkin	4,284	479	1,200	2,605	- 44
Becker	1,534	1,030	138	366	- 64
Beltrami	7,035	3,898	1,393	1,744	- 44
Cass	7,381	4,703	1,779	899	- 21
Clearwater	11,048	928	5,668	4,452	+ 86
Crow Wing	5,608	2,731	2,591	286	- 1
Hubbard	3,232	2,103	941	188	- 23
Itasca	18,276	10,946	4,277	3,053	+ 12
Wadena	787	787	-	-	- 35
Central Pine District	59,185	27,605	17,987	13,593	- 11
Koochiching	6,682	4,103	2,305	274	+ 15
Lake of the Woods	468	416	50	2	- 65
Rainy River District	7,150	4,519	2,355	276	None
Kanabec	711	40	279	392	*
Mahnomen	754	124	61	569	*
Mille Lacs	563	57	144	362	*
Morrison	832	39	10	783	*
Otter Tail	1,307	327	249	731	*
Roseau	1,554	1,380	166	8	*
Todd	1,465	366	280	819	*
TOTAL ALL COUNTIES	102,353	55,604	25,397	21,352	

*Production for 1960 not available on individual county basis.

marginal operations. Approximately one-third of the 733 mills active in 1960 were idle in 1965. Most idled mills were small; nearly three-fourths of them had been producing less than 100,000 board feet annually. Some mills were closed because the operators could make more money in mining or construction work. If economic activity remains high in northern Minnesota, additional marginal mill closings are probable.

The survey method was as follows: Personal interviews were conducted at sample mills selected from the "Directory of Northern Minnesota Sawmills and Other Wood-using Industries." Incuded in the canvass were all mills producing over 500,000 board feet annually, 31.8 percent of the mills producing 250,000 to 499,000 board feet, 16.8 percent of the mills producing 100,000 to 249,000 board feet, and 10.6 percent of the mills producing under 100,000 board feet. Samples were selected at random within each production class in each county wherever possible. Total production and percentages by species were recorded for each mill visited. The total volume of lumber sawed was obtained by expanding the sample tally in each production class by the number of mills in each class for every county. Species volume percentages were determined for all sample mills in each county. Production for each species in a county was found by multiplying the total production in that county by each species percentage for that county.

The actual sampling error is ± 2.9 percent for total lumber production, ± 4.2 percent for softwood lumber production, and ± 5.1 percent for hardwood lumber production.

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JULY 1967

U. S. FOREST SERVICE

RESEARCH NOTE NC-31

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

RISING PULPWOOD PRICES STIMULATE LARGEST LAKE STATES PULPWOOD HARVEST, 1966

ABSTRACT. The 1966 Lake States pulpwood harvest climbed to 4¼ million cords, an 18 percent increase from 1965. Woods labor continued to be scarce, but a better logging season coupled with the higher prices provided the incentive for reaching the record harvest.

After several years of minor fluctuations, the 1966 Lake States pulpwood harvest climbed sharply to 4,280,000 cords, an 18-percent increase over 1965 (table 1 on back of page). Cutting increased with rising pulpwood prices in the region. Woods labor continued to be scarce; but a better logging season, coupled with higher prices and increased mechanization in logging, provided the incentive for reaching the record harvest. The greater demand for pulpwood resulted from additions to regional pulping capacities, high levels of economic activity throughout the country, and a growing population.

All three states shared the pulpwood production gains. Wisconsin led with a 23-percent advance over 1965; Minnesota and Michigan were each ahead by 15 percent.

Roundwood pulpwood cut in the region was 4.1 million cords, about 96 percent of the total and 600,000 cords above the 1965 cut. Approximately 400,000 more cords of aspen were cut than in 1965. Half of the additional aspen cords were harvested in Wisconsin where average delivered mill prices for rough and peeled aspen apparently have climbed about 13 percent and 27 percent, respectively, since 1963.[1] Cutting of Minnesota aspen was up almost 150,000 cords from 1965. Average Minnesota aspen pulpwood prices (f.o.b. cars) are more than one-fifth higher than in 1963 for both rough and peeled cords.[2] Hemlock cutting increased by more than one-third; all of the gain occurred in Wisconsin. The delivered Wisconsin mill price of rough hemlock has risen about 14 percent since 1963.[1] The harvest of pine and miscellaneous hardwoods increased by 100,000 and 80,000 cords respectively. Most of the additional pine was cut in Minnesota. Wisconsin and Michigan shared equally the added harvest of hardwoods.

Not all species shared in the larger cut, however. Lake States loggers produced 17 percent less spruce pulpwood than in 1965; Minnesota accounted for all of the decline. Birch and tamarack production was down also.

Wood chips, slabs, and veneer cores used for pulping amounted to 4 percent of the total Lake States production. Local primary wood-using firms shipped 175,000 cords of such material to local and Central States pulpmills in 1966, an increase of 31,000 cords over 1965. However, less local softwood residues were used for pulping than in 1965.

Pulpwood receipts at Lake States mills in 1966 were approximately 4¾ million cords, ¾ million cords above 1965. Receipts were up 22 percent in Michigan, 18 percent in Wisconsin, and 16 percent in Minnesota. Lake States forests supplied 91 percent of the roundwood, Canada 7 percent, and western states 2 percent (table 2). A striking shift occurred in spruce procurement. Although the regional mills received 45,000 fewer cords of native spruce, purchases from Canada increased by 65,000 cords. As a result, 5 percent more spruce was consumed in regional mills than in 1965. Changes in receipts of other species closely paralleled their production changes in the Lake States.

June 1967

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Market Analyst

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[1] *Based on data from Wisconsin Forest Products Review, University of Wisconsin Extension Service, July 1963 and April 1967.*

[2] *Based on data from Minnesota Forest Products Marketing and Pricing Review, Office of Iron Range Resources and Rehabilitation, 1963 and 1966.*

Table 1.--*Production and imports of pulpwood, Lake States, 1966*
(In standard cords, unpeeled)

Species and destination	Production by states[1]				Imports			
	Minnesota	Wisconsin	Michigan	Region	Other U. S.[2]	Canada	Total imports	Total receipts
Aspen								
Minn.	577,874	4,000	-	581,874	-	5,585	5,585	587,459
Wis.	33,973	802,553	275,634	1,112,160	-	238	238	1,112,398
Mich.	-	3,166	500,837	504,003	255	21,565	21,820	525,823
Total	611,847	809,719	776,471	2,198,037	255	27,388	27,643	2,225,680
Balsam fir								
Minn.	59,601	-	-	59,601	-	139	139	59,740
Wis.	20,339	55,004	63,006	138,349	428	47	475	138,824
Mich.	-	-	24,747	24,747	-	19,322	19,322	44,069
Total	79,940	55,004	87,753	222,697	428	19,508	19,936	242,633
Birch, white								
Minn.	1,098	-	-	1,098	-	-	-	1,098
Wis.	21	39,302	4,640	43,963	-	-	-	43,963
Mich.	-	-	7,615	7,615	-	-	-	7,615
Total	1,119	39,302	12,255	52,676	-	-	-	52,676
Hemlock								
Minn.	-	-	-	-	-	-	-	-
Wis.	-	68,672	93,623	162,295	-	-	-	162,295
Mich.	-	-	5,302	5,302	-	-	-	5,302
Total	-	68,672	98,925	167,597	-	-	-	167,597
Pine								
Minn.	198,401	-	-	198,401	-	8,378	8,378	206,779
Wis.	56,746	215,383	107,650	379,779	91,783	1,279	93,062	472,841
Mich.	268	-	143,041	143,309	-	-	-	143,309
Total	255,415	215,383	250,691	721,489	91,783	9,657	101,440	822,929
Spruce								
Minn.	90,183	-	-	90,183	2,468	62,415	64,883	155,066
Wis.	71,974	17,458	53,164	142,596	3,783	154,205	157,988	300,584
Mich.	48	-	21,157	21,205	-	56,477	56,477	77,682
Exported[3]	9,954	-	-	9,954	-	-	-	-
Total	172,159	17,458	74,321	263,938	6,251	273,097	279,348	533,332
Tamarack								
Minn.	231	-	-	231	-	-	-	231
Wis.	7,071	3,186	601	10,858	-	-	-	10,858
Mich.	-	-	-	-	-	-	-	-
Total	7,302	3,186	601	11,089	-	-	-	11,089
Misc. dense hdwds.								
Minn.	30,843	-	-	30,843	-	-	-	30,843
Wis.	48	234,465	35,591	270,104	-	-	-	270,104
Mich.	-	-	158,640	158,640	754	-	754	159,394
Exported[3]	133	8,040	-	8,173	-	-	-	-
Total	31,024	242,505	194,231	467,760	754	-	754	460,341
Total roundwood								
Minn.	958,231	4,000	-	962,231	2,468	76,517	78,985	1,041,216
Wis.	190,172	1,436,023	633,909	2,260,104	95,994	155,769	251,763	2,511,867
Mich.	316	3,166	861,339	864,821	1,009	97,364	98,373	963,194
Exported[3]	10,087	8,040	-	18,127	-	-	-	-
Total	1,158,806	1,451,229	1,495,248	4,105,283	99,471	329,650	429,121	4,516,277
Residues, softwood								
Minn.	-	-	-	-	-	-	-	-
Wis.	1,825	6,624	2,539	10,988	88,975	-	88,975	99,963
Mich.	-	-	-	-	-	-	-	-
Exported[3]	-	5,069	1,693	6,762	-	-	-	-
Total	1,825	11,693	4,232	17,750	88,975	-	88,975	99,963
Residues, hardwood								
Minn.	11,637	8,451	1,353	21,441	-	-	-	21,441
Wis.	793	58,444	29,760	88,997	494	-	494	89,491
Mich.	-	-	40,046	40,046	1,190	-	1,190	41,236
Exported[3]	768	5,997	-	6,765	-	-	-	-
Total	13,198	72,892	71,159	157,249	1,684	-	1,684	152,168
All wood material								
Minn.	969,868	12,451	1,353	983,672	2,468	76,517	78,985	1,062,657
Wis.	192,790	1,501,091	666,208	2,360,089	185,463	155,769	341,232	2,701,321
Mich.	316	3,166	901,385	904,867	2,199	97,364	99,563	1,004,430
Exported[3]	10,855	19,106	1,693	31,654	-	-	-	-
Total	1,173,829	1,535,814	1,570,639	4,280,282	190,130	329,650	519,780	4,768,408

1/ Vertical columns of figures under box heading "Production by States" present the amount of pulpwood cut in each State.
2/ Mostly Western States.
3/ Pulpwood shipped to mills outside of Region.

Table 2. — *Geographic origin and destination of pulpwood received by Lake States mills, 1966*

Species	Percent of pulpwood originating from:					Percent of pulpwood received by mills in:		
	Minn.	Wis.	Mich.	Canada	Other U. S.	Minn.	Wis.	Mich.
Aspen	28	36	35	1	*	26	50	24
Balsam fir	33	23	36	8	*	25	57	18
Birch	2	75	23	-	-	2	83	15
Hemlock	-	41	59	-	-	-	97	3
Pine	31	26	31	1	11	25	58	17
Spruce	31	3	14	51	1	29	56	15
Tamarack	66	29	5	-	-	2	98	-
Misc. hardwoods 1/	7	51	42	-	*	7	59	34
Residues	6	29	29	-	36	9	75	16
All wood material	24	32	33	7	4	22	57	21
Previous year (1965)	25	31	34	7	3	23	57	20

1/ Mostly dense hardwoods.
* Less than ½ of one percent.

U. S. FOREST SERVICE

RESEARCH NOTE NC-32

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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ANNUAL SOIL TEMPERATURE WAVE AT FOUR DEPTHS IN SOUTHWESTERN WISCONSIN[1]

ABSTRACT. — Soil temperature was measured for a year on a southeast-facing slope of 25 percent, latitude 43° 50′ N. The spring-summer cover was unmowed alfalfa-bluegrass meadow, the fall-winter cover, meadow stubble. Snow cover was light or absent. The soil was Fayette silt loam, valley phase. The annual temperature wave at all depths followed the air temperature wave. The annual range in soil temperature varied from 30° C. at 15 cm. to 17° C. at 120 cm. The lowest soil temperature was —7° C.

Temperature of the soil at different depths during different periods of the year is often of interest to research workers in the plant sciences and in watershed hydrology. The interest of hydrologists lies chiefly in soil heat transfer during the winter, when soil freezing may become an important element in the snowmelt-runoff relationship.

Among the important factors (besides latitude and insolation) that affect soil temperature are slope, aspect, and soil cover. The temperature wave for one year under one set of conditions in southwestern Wisconsin (latitude 43° 50′ N.) is presented here.

Temperature was measured by means of thermistors and a resistance bridge. The thermistors were buried at 15-cm. intervals to a depth of 120 cm. in three replications. The site was a southeast-facing slope of about 25 percent on the Coulee Experimental Forest near LaCrosse, Wis. The plant cover, of medium density, was alfalfa meadow interspersed with Kentucky bluegrass. It was mowed and raked in the fall but was left to grow undisturbed in the spring and summer. Snow cover was light or absent during the winter of measurement. The soil was Fayette silt loam, valley phase—a deep, well-drained loessal soil. Readings were made at weekly intervals during late fall and winter (the period of greatest interest to us) and at approximately monthly intervals the rest of the year. The data are for the year beginning with April 1964 and ending with March 1965. All values are means of the three replications.

Although temperature was measured at eight depths, data for only four (30, 60, 90, and 120 cm.) are shown (fig. 1). Readings at the other depths not shown generally fall between the values plotted in figure 1. As would be expected, the readings at 15 cm. showed greater short-term variation.

The annual wave at all depths followed the general shape of the air temperature wave quite closely. The air temperatures plotted in figure 1 are 7-day averages of the mean daily temperature from U.S. Weather Bureau (La Crosse Airport) data. The November rise in soil temperature was caused by a warm spell during the last week of October and the first part of November. Temperature rose at all depths except the two lowest during this period. The low point in the soil temperature wave occurred about a month later than the low in the air temperature wave. Data from St. Paul, Minn., showed a similar lag.[2] The temperature range at a given depth varied from 30° C. at 15 cm. to 17° at 120 cm.

The soil began to freeze during the latter part of December, and by February 8 frost had penetrated to a depth of 75 cm., the lowest depth reached that

[1] *This research was done in cooperation with the Wisconsin Conservation Department.*

[2] *Baker, Donald G. Factors affecting soil temperature. Minn. Farm and Home Sci. 22: 11-12, illus. 1965.*

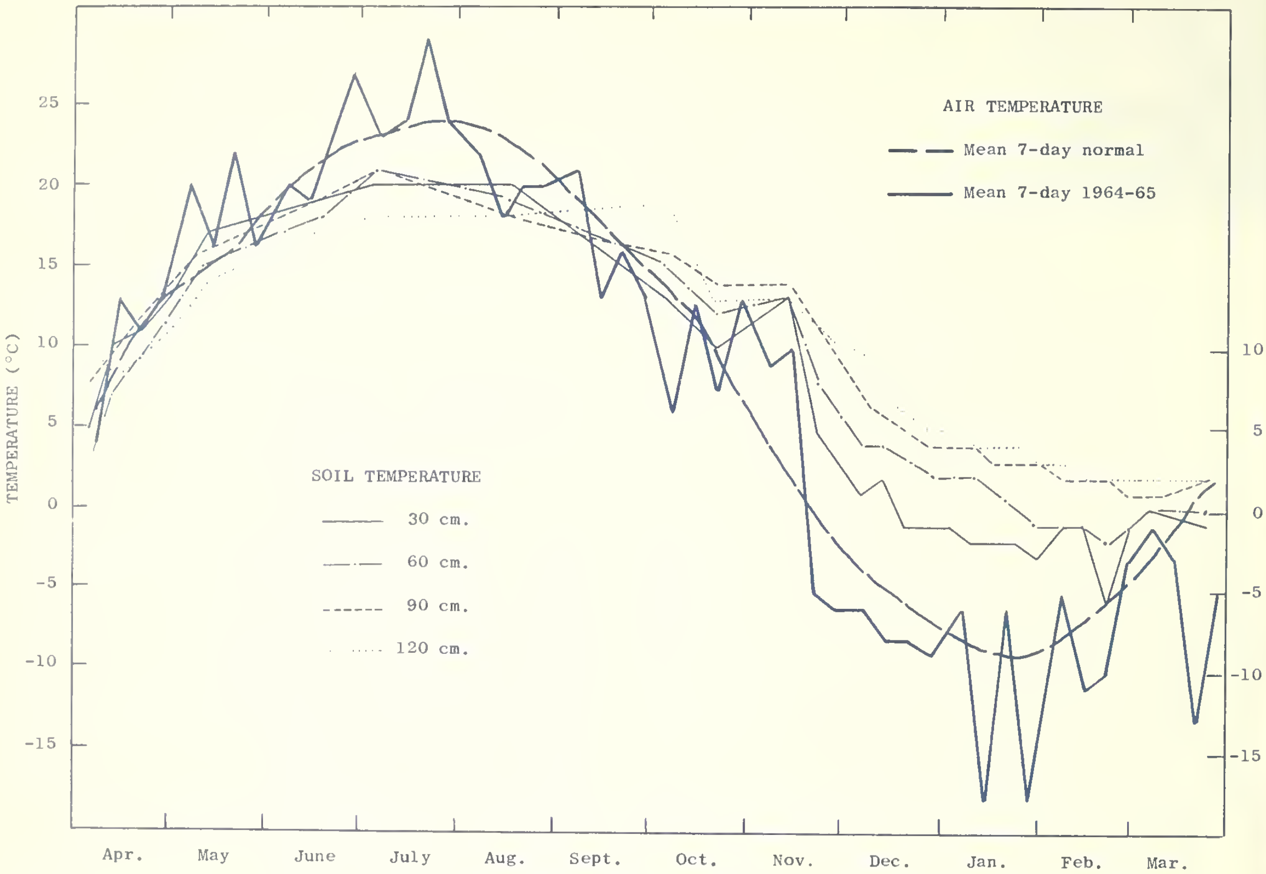

Figure 1.—Air and soil temperatures, April 1964 to March 1965.

Table 1.—Temperature (°C.) of frozen soil[1]

Date	Depth (centimeters)				
	15	30	45	60	75
12-21-64	-1	-1			
12-28-64	-1	-1			
1- 4-65	-1	-1			
1-11-65	-3	-2			
1-18-65	-3	-2	-2		
1-25-65	-1	-2	0	0	
2- 1-65	-4	-3	-2	-1	
2- 8-65	-1	-1	-1	-1	-1
2-15-65	0	-1	-1	-1	-1
2-23-65	-7	-6	-3	-2	-1
3- 1-65	1	-1	-1	-1	-1
3- 8-65	1	0	0	-1	-1
3-26-65	0	-1	0	0	
4- 5-65	1	0			

1/ Blank spaces indicate unfrozen soil.

winter. (An article describing the method of measuring frost depth will be published this year in *Soil Science.)* The soil in the upper 30 cm. of the profile was continuously frozen from December 21 through March; yet its temperature varied from 1° to —7° C. (table 1). Temperature of the soil below the frost line diminished gradually to a minimum of about 1° C. at the end of February (fig. 1).

This information will help guide our research on how land use and slope climate affect the depth, type, and incidence of soil freezing — all key factors to springtime floods and ground water accretion in the Upper Midwest's unglaciated region.

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August 1967

U. S. FOREST SERVICE
RESEARCH NOTE NC-33

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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A COMPUTER PROGRAM FOR PRELIMINARY DATA ANALYSIS

ABSTRACT. — A computer program written in FORTRAN has been designed to summarize data. Class frequencies, means, and standard deviations are printed for as many as 100 independent variables. Cross-classifications of an observed dependent variable and of a dependent variable predicted by a multiple regression equation can also be generated.

A preliminary look at a set of measurements is often desirable before settling on a particular analytical technique. Questions of possible interest at this stage include how well the measurements represent the range of field conditions and what relationships apparently exist between variables. Values predicted by a series of estimating equations might be compared so that the "best" such equation can be chosen.

The NCBREAKS computer program discussed here is designed to summarize distributions so that checks for apparent relationships and rough comparisons can be quickly and easily made. Measurements on each variable of interest are subdivided into several classes. The numbers of observations and their means and standard deviations are then printed in a series of tables for each of these classes.

An illustrative application of the NCBREAKS program is provided by the problem of predicting gross cubic-foot volume growth in natural and planted jack pine stands, given measurements made in 480 sample stands. A standard 80-column Hollerith card is punched with the basic data for each stand: the past gross growth in cubic feet, the number of trees per acre, and a code indicating whether the stand is natural or planted. To determine the spread of the sample stands, stocking classes were established by providing their upper limits, the class "breaks," as program input.

Break specified as program input	*Interval code and no. of trees per acre*
	1. 0
0	
	2. 1- 200
200	
	3. 201- 400
400	
	4. 401- 600
600	
	5. 601- 850
850	
	6. 851-1100
1100	
	7. 1101-1400
1400	
	8. over 1400

If the data were summarized at this point, all stands would be lumped together. To separate the planted from the natural stands, a special *trans-generation* option of the program was utilized. Variables could be generated through common arithmetic operations on the observed variables; or logarithms, powers, or inverses of the observations could be taken. For the jack pine problem, the additional option of creating "zero-one" dummy variables (as occasionally used in multiple regression equations) was used to separate the stands. The result of this manipulation is that three variables occur in the printed tables: (1) the stocking level of the 480 stands, (2) the stocking level of just the natural stands, and (3) the stocking level of the planted stands.

A frequency table shows the number of each kind of stand by stocking classes (table 1). For example, while 30 natural stands with less than 200 trees per

Table 1. —NUMBER OF OBSERVATIONS ASSOCIATED WITH INTERVALS

INDEPENDENT VARIABLE	INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
1	0	32.	115.	104.	91.	46.	29.	63.
2	125.	30.	101.	87.	53.	27.	13.	44.
3	355.	2.	14.	17.	38.	19.	16.	19.

Table 2. —INTERVAL MEANS OF INDEPENDENT VARIABLES

INDEPENDENT VARIABLE	INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
1	0	.1574E+03	.3025E+03	.4818E+03	.7231E+03	.9742E+03	.1212E+04	.2899E+04
2	0	.1556E+03	.3016E+03	.4845E+03	.7297E+03	.9581E+03	.1206E+04	.2928E+04
3	0	.1850E+03	.3084E+03	.4678E+03	.7139E+03	.9971E+03	.1217E+04	.2832E+04

Table 3. —INTERVAL MEANS OF OBSERVED DEPENDENT VARIABLE

INDEPENDENT VARIABLE	INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
1	0	.5543E+02	.7749E+02	.9464E+02	.9778E+02	.1221E+03	.1371E+03	.1026E+03
2	.1173E+03	.5677E+02	.7963E+02	.9695E+02	.9080E+02	.1009E+03	.1211E+03	.8011E+02
3	.8681E+02	.3525E+02	.6211E+02	.8282E+02	.1075E+03	.1523E+03	.1500E+03	.1546E+03

acre (interval 2) were sampled, that stocking level is represented by only 2 planted stands. Note that the first interval must be carefully interpreted. It is rather awkwardly defined as the number of stands that do not fit under a given variable. There are 125 stands with zero naturally occurring trees, i.e. there are 125 planted stands.[1]

To determine the relationships between stocking levels and gross growths, two sets of tables were generated. The first set includes the means and standard deviations (only the means are shown in table 2) of the independent variables — the stocking levels — for the specified classes. The second set lists the means and standard deviations of the gross growths of the stands in each of these classes (table 3). Combining the three tables tells us, for example, that the 19 planted stands in the highest stocking class (interval 8 of the third variable) average 2,832 trees and an annual gross increment of 155 cubic feet per acre.[2] (Interval 1 states that the 125 not-natural stands averaged about 30 cubic feet per acre more growth than did the 355 not-planted stands.)

The most direct way to consolidate this information is through a graph (fig. 1). While all of the minor irregularities in the 480 stands will not appear, this loss of detail is more than offset by the speed of plotting just the class means. Such smoothed plots can often suggest whether a linear or logarithmic or some other curve form would be appropriate — or, in terms of the present example, whether there is a significant or important difference between the growth-stocking level relationships of planted and natural stands.

Suppose that the single quadratic equation

$$\text{gross growth} = 0.26\ (\text{No. trees/A}) - 0.00013\ (\text{No. trees/A})^2$$

seems to be worth investigating. By entering the appropriate coefficients into the program and transgenerating the required squared term, mean predicted values of gross growth corresponding to the stocking level classes of the independent variables will be generated in the usual tabular form. A rough test of the prediction equation can then be made by plotting the results (fig. 2).

The preceding discussion has emphasized the most common uses of the program. An unlimited number of observations on as many as 100 variables, each divided into appropriate intervals, can be summarized. Any single variable will be cross-classified with

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[1] *For convenience, the stocking classes for all three variables were defined by the same set of breaks. Additional breaks ordinarily would be specified for other stand characteristics, such as site index, that might be examined.*

[2] *The symbol E+xx following a number indicates that the number is to be interpreted after moving the decimal point xx places to the right.*

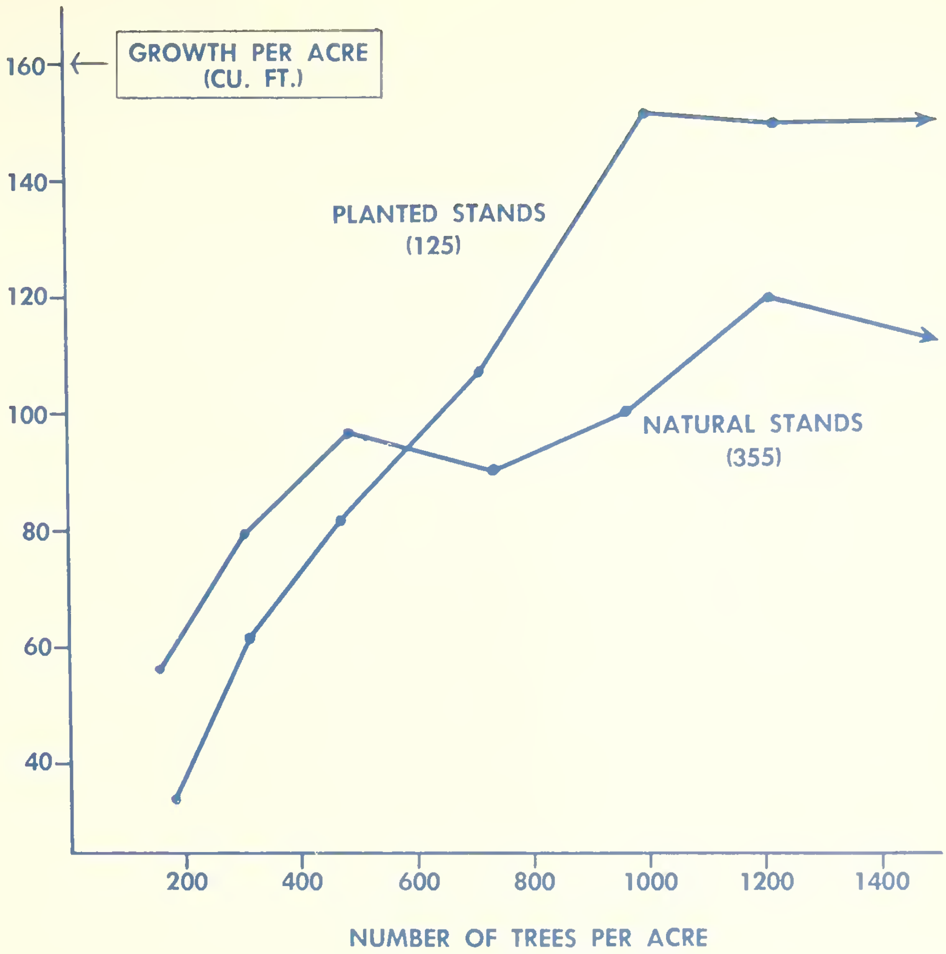

Figure 1.—Observed annual gross growth per acre on 480 jack pine stands by mean stocking per acre.

all others if it is designated as the dependent variable. Entering a constant and coefficients for any subset of the independent variables, perhaps in combination with one of the transgeneration options, results in a similar cross-classification of predicted values. The tables of standard deviations are also useful, for example, to test the reasonableness of an assumption of constant variance. In all these instances, graphs intended to give a preliminary indication of the nature of a set of data can be quickly prepared from the interval means.

The NCBREAKS program was written in FORTRAN 60, specifically for the Control Data Corporation 1604 computer of the Numerical Analysis Center of the University of Minnesota, but is adaptable to most computers with the following characteristics:

(1) A FORTRAN 60 or FORTRAN II or compatible compiler capable of utilizing
  (a) two-dimensional arrays,
  (b) a variable data format (not in source program);
(2) Core storage of 16,000 data words in addition to the compiler storage requirement.

Complete program documentation and a punched copy of the source deck are available from the Biometrical Section of the Station.

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August 1967

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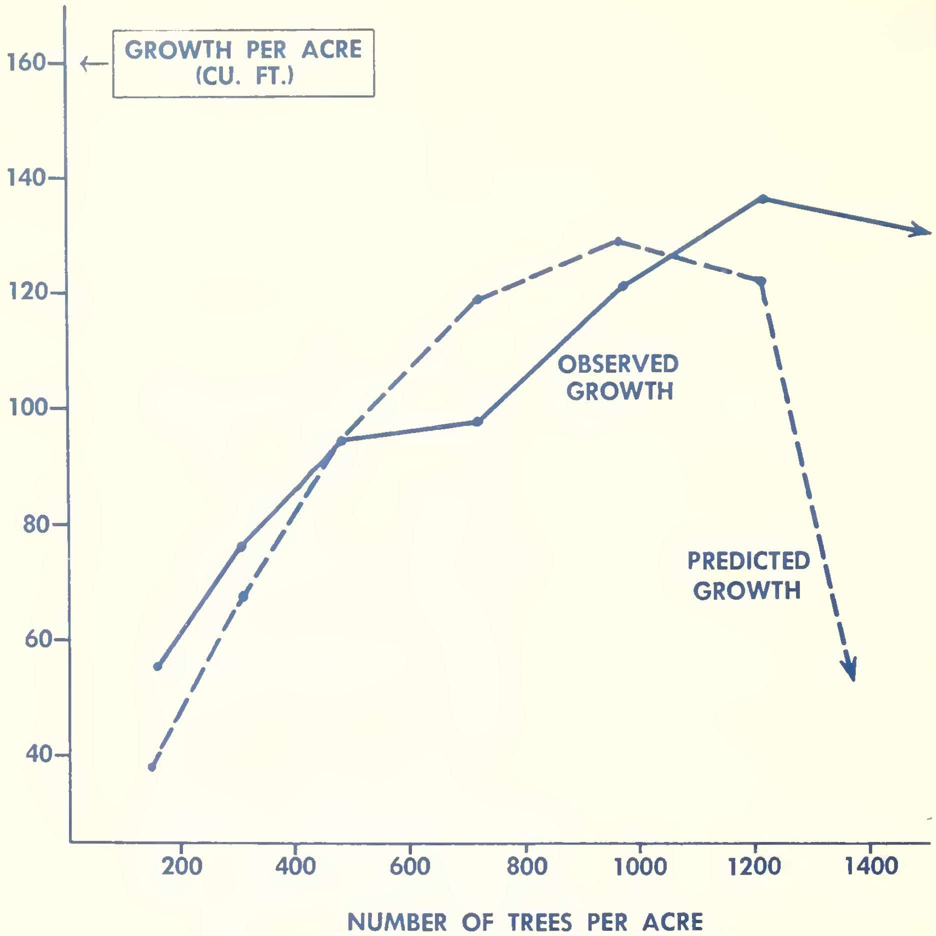

Figure 2.—Observed and predicted annual gross growth per acre on 480 jack pine stands by stocking per acre.

U. S. FOREST SERVICE

RESEARCH NOTE NC-34

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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CHEMICAL WEED CONTROL INCREASES SURVIVAL AND GROWTH IN HARDWOOD PLANTINGS

ABSTRACT. — In a plantation of four hardwood species on a silt loam soil planted to 1-0 stock, 4 pounds of active atrazine or simazine controlled weeds effectively without injuring the trees. Chemical weed control was better on plowed and disked ground than on unprepared ground. Yellow-poplar and white ash grew faster on prepared ground. Black walnut and red oak did not respond to ground preparation treatments. Guides are presented for proper use of the chemicals in establishing hardwood plantations.

Weed competition can seriously reduce survival and growth of newly established hardwood plantations in Iowa. Weeds and grasses compete strongly with planted trees for moisture, light, and nutrients, especially during the period of establishment. Dense weed patches also provide food and cover for rodents, which often injure or destroy newly planted trees.

Machine cultivation, mowing, and scalping around individual trees have effectively controlled weeds in the past. Newer chemical weed control methods are cheaper than mechanical methods but require more knowledge and skill to use safely and effectively.

In April 1963 we established a study on an abandoned old-field site in east-central Iowa. At that time smooth brome grass *(Bromus inermis* Leyss) was the main ground cover. The soil is classified as Clinton silt loam. Two ground preparation and six weed control treatments were applied to determine the most effective combination of treatments as evaluated by survival and height growth of black walnut *(Juglans nigra* L.), red oak *(Quercus rubra* L.), yellow-poplar *(Liriodendron tulipifera* L.), and white ash *(Fraxinus americana* L.). Besides presenting study results, this Note outlines procedures for proper application of the weed control chemicals.

Methods

A split-split-plot design in randomized blocks was used. Each of five blocks was divided into two main plots. Ground preparation treatments assigned to main plots were:

1. Fall plowing plus spring disking and harrowing.
2. No ground preparation (brome grass sod cover).

Main plots were divided into six weed control sub-plots each 12x42 feet. The six weed control treatments were:

1. Simazine,[1] 4 pounds per acre.
2. Simazine, 2 pounds per acre.
3. Atrazine,[1] 4 pounds per acre.
4. Atrazine, 2 pounds per acre.
5. Black plastic mulch (26½-inch squares).
6. No weed control.

The weed control plots were separated from each other by 3-foot isolation strips, and the ground preparation blocks by 12-foot isolation strips.

Early in April, the herbicides were uniformly sprayed over each sub-plot. Then, with a Lowther tree planter, 14 one-year-old, uniformly graded seedlings of each species were planted in each sub-plot at 3x3-foot spacing.

The herbicides were activated by 1 inch of rain, which fell within 11 days after herbicide application.

In each mulching sub-plot, black polyethylene tree mulch squares (26½x26½x.022-inch thick)

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[1] *The chemical name for simazine is 2-chloro-4, 6-bis (ethylamino)-s-triazine; for atrazine it is 2-chloro-4-ethylamino-6-isopropylamino-s-triazine. Sprays were made from the 80-percent wettable powder, but all rates are given in pounds of active ingredients.*

Figure 1.—Weed control 110 days after treatment was applied on prepared ground. Note the dense weed growth on the check plot (no herbicide) as compared to the plot where simazine was applied. Atrazine at the 4-lb. rate gave results similar to the simazine treatment.

were placed around 56 seedlings (560 trees total) in a manner such that the plastic did not touch the stems. Soil was used to anchor the plastic on tilled plots, and wire pins held the plastic in place over the sod on untilled plots.

Chemicals Successfully Controlled Weeds

The four species grew best on plots treated with 4 pounds per acre of simazine or atrazine. At the 4-pound rate, atrazine provided a full season of weed control, but when the herbicides were applied to prepared ground, simazine was as good (fig. 1). On unprepared ground, atrazine, which is absorbed through the foliage and roots, was more effective against established brome grass than was simazine, which is absorbed only through the roots (Davis *et al.* 1959).

For both chemicals, the 2-pound rate did not result in as effective or long lasting control as the 4-pound rate. Most weed control treatments improved second-year height and two-year basal diameter growth of hardwood trees (table 1). No symptoms of chemical injury to any of the trees were visible.

Neither weed control nor ground preparation treatments affected 2-year survival of black walnut or red oak trees. At least 80 percent of the walnut trees and 71 percent of the oak trees survived regardless of treatment. However, in plots without herbicides trees died back repeatedly, were stunted, and probably will be gradually eliminated by weed competition and by rabbits and mice that thrive in the weed cover. Significant differences in mean survival rates among treatments were found for white ash and yellow-poplar trees (table 2).

Even the best weed control treatments failed to provide any residual weed control during the second growing season. Spring herbicide applications at the beginning of the second season probably would have increased tree growth.

Survival and growth of plastic-mulched trees generally were the same as for control trees. Apparently, the 26½-inch squares of black plastic were not large enough to be effective. Black plastic is expensive and requires more time to install than herbicide treatments.

Responses to ground preparation and weed control treatments varied by species. Where weeds were eliminated, yellow-poplar, white ash, black walnut, and red oak grew 44, 33, 17, and 11 inches, respectively, in 2 years compared to 2 inches or less growth on plots with no weed control. Yellow-poplar and white ash seedlings grew rapidly in height, but black walnut and red oak were slower starters.

Most walnut trees died back the first year, but the amount of dieback was less severe where weeds were chemically controlled than on plots with less effective control. Furthermore, during the second growing season, the trees showed large height growth responses to chemical weed control.

Red oak trees grew faster during the second growing season on plots treated with 4 pounds per acre of atrazine than on untreated plots. Growth probably would have been greater had larger stock been used. Stem diameters of our planting stock averaged only 4/32 inch. This is 3/32 inch smaller than the preferred planting stock grade for red oak (Limstrom 1963).

Ground Preparation Was Important

Better chemical weed control was obtained on prepared ground than on unprepared ground. Where no herbicide was applied, ragweed and foxtail grasses rapidly invaded prepared ground. On mulch plots, where only a 26½-inch square around

Table 1.—Average 2-year basal diameter growth and second-year height of planted hardwood trees by weed control treatment[1]

Weed control treatment	Yellow-poplar Height	Yellow-poplar Diameter	Black walnut Height	Black walnut Diameter	Red oak Height	Red oak Diameter	White ash Height	White ash Diameter
	Inches	32nds	Inches	32nds	Inches	32nds	Inches	32nds
Atrazine 4 lb/A	48*	19*	40*	16*	17	2	31*	12*
Simazine 4 lb/A	37*	12*	32*	12*	14	2	26*	10*
Atrazine 2 lb/A	29*	7	29*	8*	13	1	20*	7
Simazine 2 lb/A	29*	7	23	4	11	1	17	5
Plastic mulch	17	1	14	0	8	0	13	3
No weed control	16	0	13	0	8	0	8	0
All treatments2/	2.0	1.2	1.4	1.0	0.5	0.1	1.4	0.8

1/ Basal diameter was measured in 32nds of an inch at a point 1 inch above ground line.

2/ Standard error for each mean in a column.

* Significantly different (.05 level) from the no weed control and plastic mulch treatments, using Keuls test as explained by Snedecor (1956). Mean is based on 140 planted trees.

Table 2.—Average second-year survival of white ash and yellow-poplar seedlings by ground preparation and weed control treatment

Ground preparation treatment	Weed Control treatment	Percent survival: White ash	Percent survival: Yellow-poplar
Plow and disk	Plastic mulch	80*	54*
Plow and disk	Simazine 4 lb/A	76*	76*
Plow and disk	Simazine 2 lb/A	74*	67*
None	Atrazine 2 lb/A	72*	56*
Plow and disk	None	67*	39*
None	Atrazine 4 lb/A	64*	59*
Plow and disk	Atrazine 4 lb/A	63	77*
None	Simazine 4 lb/A	63	61*
Plow and disk	Atrazine 2 lb/A	61	71*
None	Simazine 2 lb/A	56	61*
None	None	29	16
None	Plastic Mulch	10	20
All treatments1/		5.5	5.5

1/ Standard error for each mean in a species column.

* Significantly different (.05 level) from the last two treatments in a column (Snedecor 1956).

each tree was protected from weed invasion, weed growth was almost as dense as on check plots.

Plowing and disking stimulated rapid height growth of yellow-poplar and white ash seedlings but not of black walnut or red oak seedlings (table 3). After 2 years yellow-poplar was the only species that showed significantly better (8/32-inch more) basal diameter growth on prepared than unprepared ground.

Table 3.—Average second-year height of planted hardwood trees on prepared and unprepared ground
(In inches)

Ground preparation treatment	Yellow-poplar	Black walnut	Red oak	White ash
Plow and disk	37*	28	12	25*
None	20	23	12	14
All1/	4.0	2.5	1.1	2.5

1/ Standard error for each mean in the species column.

* Significantly different from the number below (Snedecor 1956). Each mean based on 420 planted trees.

Recommendations and Precautions

Information gained from this study has been added to that of others to provide the following guides.

The planting site should be thoroughly prepared by fall plowing and spring disking and harrowing so that the herbicides can be applied on bare soil. Simazine and atrazine kill newly germinating annual broadleaf weeds and grasses, but perennial weeds and established plants may be unaffected. Simazine generally will not give satisfactory weed control without prior ground preparation, but atrazine gives good control of smooth brome grass without preparing the ground.

Simazine or atrazine (wettable powder forms) must be applied in early spring so that sufficient moisture is available to move the herbicides into the weed seed zone before the seeds germinate. One-half to one inch of rainfall within 15 days after atrazine and simazine applications is required to move 4-pounds-per-acre rates into the zone where weed seeds germinate (Splittstoesser and Derscheid 1962).

Simazine can be applied before, simultaneously with, or after planting without injury to the tested species, but atrazine should be applied before planting; otherwise some injury can be expected. Both herbicides kill by their adverse effect on photosynthesis but since atrazine is 14 times more soluble than simazine (Crafts 1961), it is absorbed not only through the roots but also through the foliage. Simazine is absorbed only through the roots.

Four pounds per acre of active simazine or atrazine should be applied on silt loam soils, but only 2 to 2½ pounds per acre of active simazine on sandy soils. Higher rates of simazine and atrazine must be applied to control weeds on heavy soils (clay) and soils high in organic matter than on sandy soils. Soils high in organic matter or clay content reduce simazine phytotoxicity more than do soils low in these components (Burnside and Behrens 1961). We have used as much as 16 pounds per acre of simazine on a silty clay loam soil without injuring black walnut seedlings.

Atrazine cannot be applied safely on sandy soils because it is leached more rapidly (Rodgers 1962) and to greater depths than simazine. Seedlings may be injured or killed if the herbicides come in contact with tree roots. Simazine and atrazine remained in the upper inch of soil following furrow irrigation on a silt loam soil (Ashton 1961), but with heavy rainfall and increasing amounts of sand even small amounts of simazine are leached to greater depths (Burschel 1961).

Atrazine or simazine can be applied safely at recommended rates on 1-year-old black walnut, red oak, white ash, and yellow-poplar seedlings, but younger seedlings may be injured or killed. Older seedlings may escape injury because their roots are below soil containing toxic amounts of herbicides (Kozlowski and Kuntz 1960).

The manufacturer's instructions should be followed, and your equipment should be calibrated so that the herbicides are uniformly applied. Even the most resistant tree species may be injured or killed if either herbicide is applied in sufficient quantity. Broadcast treatments are most effective on level planting sites, and 6- to 8-foot treated contour bands are recommended on sites subject to erosion.

The trees must be planted in an unright position and the soil packed firmly about the tree so that the herbicide cannot get to the tree's roots through cracks.

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August 1967

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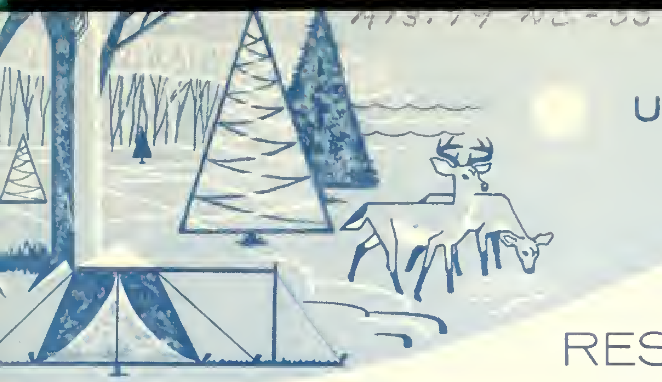

U. S. FOREST SERVICE

RESEARCH NOTE NC-35

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

WINTER THAWS CAN RAISE GROUND WATER LEVELS IN DRIFTLESS AREA[1]

ABSTRACT. — Springflow and ground water levels both rose with winter thaws, even when the ground was frozen. A high soil water content suggests that water moved to the water table through a continuous column of soil water rather than as a wetting front.

Winter or early spring thaws occur frequently in the lower Lake States region. They may last for one or more days and are usually followed by an extended period of freezing before the normal springtime thaw. Since the ground is generally frozen at the time, they may produce snowmelt runoff. Sometimes they even cause an out-of-season flood.

Recent springflow studies on the Coulee Experimental Forest in southwestern Wisconsin show that winter thaws can also help recharge the ground water system, even during a period of deep soil frost. Three late winter thaws in 1965 produced sharp rises in springflow and corresponding rises in the water table above the spring (fig. 1). The spring, which had flowed continuously during a 5-year period of record, dried up in November 1964. It remained dry until February 6, when a 3-day thaw produced the rise shown. A 1-day thaw on February 20 produced a smaller rise; and then a third thaw that began on February 27 and lasted for 10 days produced another larger rise. Thereafter, flow receded normally until the regular springtime rise began on March 31.

The increases in flow were roughly proportional to the amounts of heat during the respective thaw periods. Expressed as degree-hours above 32° F., the values were: 340 (February 4 to 7), 110 (February 20), and 950 (February 27 to March 8). The repeated thaws prevented accumulation of a continuous snowpack, and there was never much snow on the ground at one time. Had a deeper snowpack existed, the same thaws might not have released meltwater, since more heat would have been needed to "ripen" the snowpack.

Water table changes, measured at a well 500 feet from the springhead, show that the ground water table responded rapidly to relatively small amounts of melting snow. The water level during the period was about 50 feet below the ground surface. Flumes on the Experimental Forest recorded surface flow during the thaws; so we know that the melting snow produced water at the ground surface. We infer from the marked springflow rises that this resulted in infiltration as well as surface flow. The almost instantaneous response suggests that the infiltrating water recharged the water table through a continuous capillary column rather than a wetting front. Soil water measurements tend to

[1] *This work was done at the Station's field office in La Crosse, Wis., where research in runoff and erosion reduction is done in cooperation with the Wisconsin Conservation Department.*

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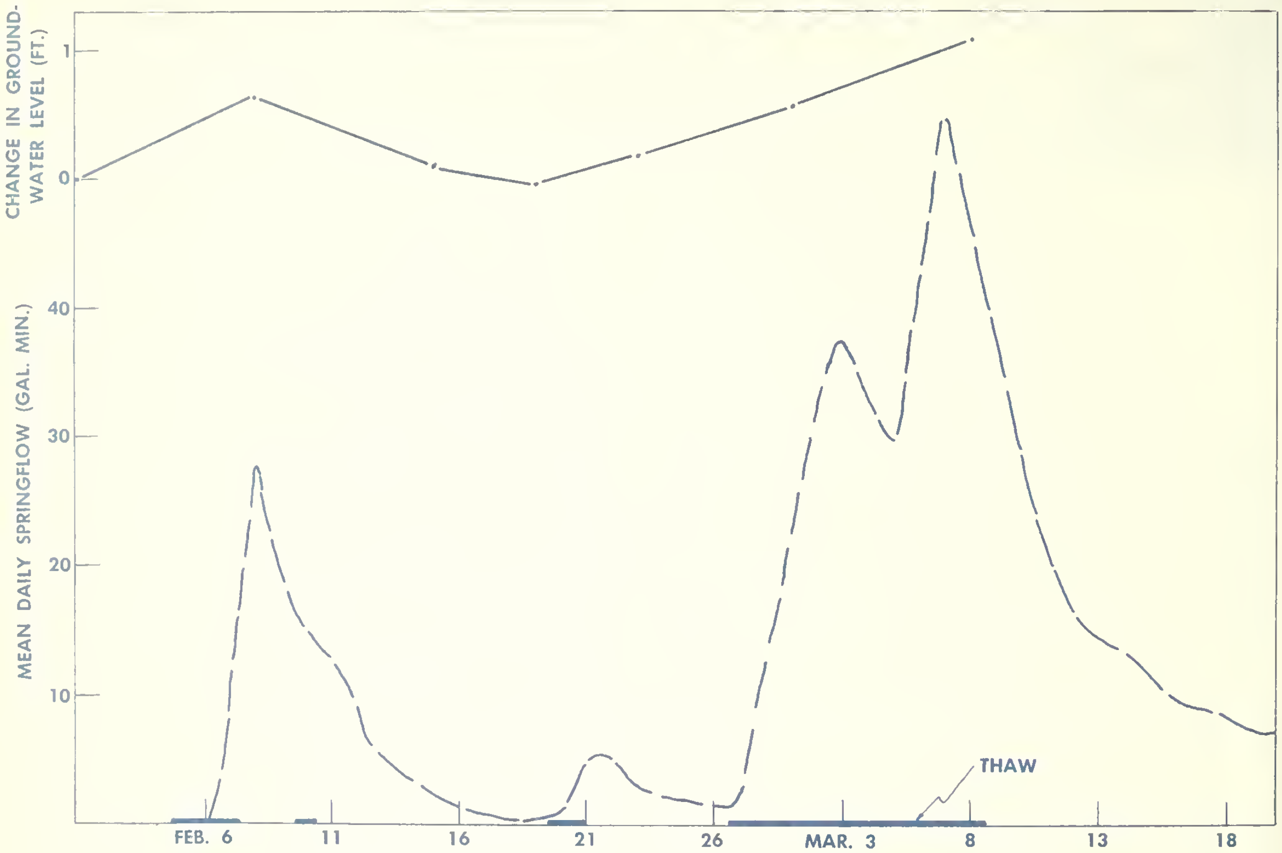

Figure 1.—Effect of winter thaws on springflow and ground water levels, 1965. The plotted points of the upper chart show the dates when well depth was measured. Minor changes probably occurred between these dates.

support this. Water content in a 5-foot profile (determined from periodic readings with a neutron meter) near the spring averaged about 38 percent by volume (Pv.), with less than one Pv. variation during the period. This approximates field capacity for the loessal silt loam soils of the Experimental Forest.

Schneider[2] ascribed the rise of water tables following winter thaws to percolation of soil water from a thawing frost layer, rather than to infiltration. However, frost measurements on open land (alfalfa meadow, southeast slope) taken concurrently with this study showed that the thaws did not affect the thickness of the frozen layer. Frost depth ranged from 2.0 to 2.6 feet. On the wooded north slope above the spring, however, frost depth averaged one-half foot on February 15, with 90 percent of sample points falling on frozen ground. This is a relatively thick frozen layer for forest soils, which normally have much less frost than open-land soils. Most of the watershed is forested; so most of the water must have come from forest land. Was the 10 percent of unfrozen ground the major source of infiltration, or was the frozen ground also permeable enough to take in water from slowly melting snow? We hope to find out from planned studies.

[2] *Schneider, Robert. Correlation of ground water levels and air temperatures in the winter and spring in Minnesota. U.S. Geol. Surv. Water-Supply Pap. 1539-D, 14 pp., illus. 1961.*

August 1967

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U. S. FOREST SERVICE

RESEARCH NOTE NC-36

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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SPRUCE BUDWORM DEFOLIATION IS REDUCED MOST BY COMMERCIAL CLEAR CUTTING

ABSTRACT. — A pilot study in three northern Minnesota spruce-fir stands showed that as cutting intensity increased, defoliation by the spruce budworm decreased. Commercial clear cutting reduced defoliation most.

It has been proposed that forest management has considerable promise in combating epidemics of the spruce budworm. Recommendations made by various authors for reducing susceptibility and vulnerability of spruce-fir stands to spruce budworm have been summarized by Prebble and Morris (1951) and Turner (1952). Two general approaches are proposed: (1) to expedite harvesting of overmature timber as a presalvage measure, and (2) to reduce hazard in young merchantable stands and increase resistance to budworm attack through selection cutting. The first recommendation is consistent with good silviculture because of the high incidence of decay in older stands. The second, however, has been inadequately tested. Partially cut stands have often been subject to excessive windthrow (Morris *et al.* 1955). A test in which "vulnerable" trees were cut to reduce losses from an impending spruce budworm attack in Maine failed when the infestation did not develop (Hart 1956).

In 1956 the impending budworm outbreak in northeastern Minnesota permitted a test of cutting as a management technique to reduce damage. One characteristic in which Lake States spruce-fir stands differ from those in the Northeast and New Brunswick is stand area. Most of the balsam fir in the Lake States is found in blocks of about 5 to 100 acres. These are separated by nonhost types; *i.e.,* aspen, birch, and jack pine. This attribute enhanced the cutting test because: (1) small blocks can be logged in a single season, thereby eliminating treatment time as a variable, and (2) the lack in continuity of the forest type reduces the chance of budworm invasion from adjacent untreated areas.

Methods

The method of study was to compare, within each of three spruce-fir stands, two levels of thinning with an undisturbed check area.

Several criteria were used in selecting the stands: (1) They must have no more than light defoliation so that a budworm population could build up "in place" — an established budworm population might mask the effect of treatment. (2) A stand must be large enough to contain three adjoining 20- to 25-acre blocks of fairly uniform timber; in smaller blocks larvae might move from one treatment to another. (3) Stocking must be dense enough to permit a commercial operation in the area to be partially cut and still leave enough growing stock to minimize windthrow and allow a future cut. (4) Average age at breast height must be less than 60 years to ensure that the remaining growing stock would be relatively free of defect.

All stands selected were predominantly balsam fir but had components of other species. Little defect occurred in any of the stands.

The first one (Stand I), near International Falls on the west end of the Kabetogama Peninsula, had balsam fir averaging 50 years of age, with some trees as old as 103 years; white spruce averaging 82 years, with some trees up to 105 years; some paper birch; and a scattered overstory of aspen and balsam poplar, remnants of a 102-year-old age class. The stand had been lightly defoliated in 1956, and egg surveys indicated a potential medium infestation of budworm in 1957. Treatments were applied the winter of 1956-57.

The second stand (Stand II), located about 9 miles north of Grand Marais and bisected by the Gunflint Trail, had balsam fir averaging 47 years, with some trees as old as 67 years; white spruce averaging 54 years, with some trees as old as 77 years; occasional upland black spruce, aspen, and paper birch; and a scattered overstory of overmature white pine. No noticeable defoliation had occurred in 1957, but eggs collected that summer indicated a possible light-to-medium infestation the next year. A heavy infestation was present about 9 miles west of the area. Treatments were applied during the winter of 1957-58.

The third stand (Stand III), about 1¼ miles east of Isabella, had essentially even-aged, 35-year-old balsam fir and white spruce, although about five balsam fir trees per acre were in the 80-year age class. There were also occasional upland black spruce and a scattered overstory of overmature paper birch, the snags of which were conspicuous throughout the area. In 1958, the area had not been noticeably defoliated by the budworm, but some infestation was present about 15 miles to the north. Egg-mass collections indicated a possible light infestation for 1959. Treatments were applied during the winter of 1958-59.

The treatments, randomly assigned to the three 20- to 25-acre blocks with each stand, were: (1) commercial clear cutting — removing all host trees having two or more 8-foot bolts, (2) partial cutting — removing 30 percent of the basal area in host species by cutting from above, and (3) no cutting — check (fig. 1). No vulnerability rating scheme was used in marking trees for cutting because none was felt to be adequate.

Within each block, 9 to 12 circular 1/10-acre plots were located on a 4x5-chain grid. Every year after the season's defoliation had been completed, the amount of defoliation for each tree was estimated with the aid of binoculars. Detailed records were kept for 5 years by individual trees.

Analysis and Results

During the study, defoliation in each area gradually increased for 3 years and then declined. During the fifth year there was no noticeable defoliation.

Very little mortality and top killing occurred in any of the plots. Inasmuch as defoliation is a precursor to tree mortality and the defoliation index for balsam fir is highly correlated with the percentage basal area of the stand in dead and damaged trees,[1] defoliation index was used as a measurement of treatment effects.

The average weighted defoliation index for each block was computed as follows:

1. The current defoliation for each of the 5 years was summed for each balsam fir tree. Defoliation was coded as 0, 50, 88, 150 (100 percent of the current foliage removed plus

[1] *Unpublished information from another study made by the author at the same time as the one reported here.*

25 to 75 percent of the previous year's foliage), or 188 (100 percent of the current foliage plus 76 to 100 percent of the previous year's foliage removed).

2. The cumulative defoliation value for each tree was multiplied by its basal area.

3. The cumulative weighted defoliation values for all balsam fir trees on a plot were summed.

4. Each summed value was divided by the total basal area in balsam fir on the plot, giving an average cumulative weighted defoliation index per square foot of basal area.

5. An average was struck for all plots in each block. This defoliation index permitted comparison of blocks having unequal numbers of trees and different basal areas.

The defoliation index values (table 1), when analyzed by a randomization test (Kempthorne 1952), indicated that the treatment effect was significant at the .028 level of probability. One standard error about each block mean indicates no overlapping among treatments of the first two stands, but this was not so for the third stand. There was a trend toward reduced defoliation with increased cutting at all locations. This was evident even though the intensity of defoliation at the different locations was not the same.

Conclusions

The undisturbed, mature, spruce-fir forest represents the maximum potential for spruce budworm injury in the northern Lake States. Various factors such as the intensity and duration of an outbreak, size of the area concerned, and other considerations not accounted for in this study could influence the degree of absolute damage that might be expected. It is clear, however, that as cutting intensity increased there was a corresponding reduction in the amount of defoliation on the residual stands. Though partial cutting did reduce defoliation somewhat, commercial clear cutting reduced it much more.

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Figure 1.—Spruce-fir stands in the study area. Top to bottom: uncut, partial cut, clear cut.

Table 1.—Pilot cutting study: average cumulative weighted defoliation index per square foot of balsam fir basal area by cutting intensity levels.

Stand and treatment	Percent cut	Defoliation index and standard error
Stand I		
Commercial clear cut	83	103 ± 39
Partial cut	27	176 ± 20
Uncut	0	270 ± 11
Stand II		
Commercial clear cut	70	48 ± 12
Partial cut	29	84 ± 12
Uncut	0	144 ± 10
Stand III		
Commercial clear cut	72	87 ± 20
Partial cut	31	98 ± 4
Uncut	0	109 ± 10
Average, all stands		
Commercial clear cut	75	79
Partial cut	29	119
Uncut	0	174

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U. S. FOREST SERVICE

RESEARCH NOTE NC-37

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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SIZE AND PLACEMENT OF METAL CULVERTS CRITICAL ON PEATLAND WOODS ROADS

ABSTRACT. — Culverts too small in diameter or poorly placed were major causes of timber flooding and tree damage. Placement problems were poor culvert slope, poor hydraulic approach, lack of gravel bedding, and too little soil covering the culverts.

A recent 7-county survey on roads used for logging and other woods work in northern Minnesota peatlands showed that backwater on 56 percent of wetland crossings had killed the timber or depressed its growth rate (Stoeckeler 1967). Furthermore, at high-water stages runoff water sometimes flowed over the road and eroded it. High levels of impounded water caused some road surfaces to become too soft and rut deeply after only a few passes of vehicles. Such roads are difficult for traffic and sometimes impassable, and require excessive maintenance. Lack of any culverts or poor placement of culverts were major reasons for this damage.

As a supplement to the survey, 41 metal culverts on 39 sites were studied to determine the factors that reduced their effectiveness. Thirty-seven sites had single culverts, and two had double culverts. Topography was such that the contours were somewhat parallel to, or within about 45 degrees of being parallel to, the road on 33 sites. These sites had considerable tree damage. There was no tree damage on the other 6 sites where contours were more nearly at right angles to the road so that drainage was less likely to be impeded (Stoeckeler 1965).

Culvert Size and Condition

Culvert size was related to tree damage from backwater and to the degree of siltation. Sites with culverts 21 inches or less in diameter had an especially high incidence of tree damage (table 1). Of these smaller culverts, 30 percent showed serious siltation; they were either plugged completely or silted up to one-third or more of their diameter. Plugged culverts contribute to a permanent backwater. Those partially plugged have a reduced capacity, and prolong temporary flooding from backwater. None of the culverts 24 inches or more in diameter were plugged, nor was their capacity seriously impaired.

Many factors affect the condition of culverts, but the number of years since installation is probably the more important one in culvert deterioration. Mueller (1955) cites 57 years as the average expected life of corrugated iron culverts in the United States. This life span, however, can be drastically shortened by various factors such as highly acid waters, the presence of organic reducing or oxidizing soils (Beaton and Stratfull 1959, 1962), or the presence of hydrogen sulfide (Lehmann 1964).

Table 1.--Tree damage on 33 sites with contours of the land somewhat parallel to the road

Culvert diameter group (inches)	Number of sites	Percent of sites with--[1]			
		Undamaged stands	Damaged stands		
			Light to moderate	Severe	Total
12	5	0	20	80	100
15-21	15	20	40	40	80
24-30	6	67	0	33	33
36-60	7	71	15	14	29

[1] See Stoeckeler (1967) for damage class definitions.

Field tests, based on the method of Beaton and Stratfull (1962), indicate that the pH of the water on 21 of the 33 sites with water flowing through the culverts is acid enough (5.0 or less) to reduce culvert life below the 57-year average. According to Forest Engineer Peter Meyer on the Chippewa National Forest in Minnesota, the average life of culverts in that area is only about 25 years. There, acid waters, which come mostly from certain types of peatlands, are probably a major factor in culvert deterioration. Asphalt coating would seem to offer a means of prolonging the service life of metal culverts in peatlands and should be tested.

In overall condition 53 percent of all 41 culverts in the study were rated as good, and 37 percent as fair. Ten percent were rated as poor owing to serious corrosion, severe bowing from frost lift, or other causes.

Culvert condition was also rated by the Mueller system, which deals with condition of the metal and its degree of corrosion. By this rating, only one culvert needed immediate replacement. Two more were rather close to the replacement stage.

Seven percent of the culverts were bowed and out of alignment, probably due to frost action; and another 7 percent had been damaged by road graders and snowplows — 4- to 12-inch pieces had been torn out, thereby accelerating rusting and weakening the culverts. Such breaks serve as entry points for surface gravel or soil and can thus reduce culvert capacity.

Installation Problems

About one-fourth of the culverts were classed as poor in the quality of hydraulic approach. Many inlets protruded too far, were choked by grass, brush, or siltation, or had large rocks impeding inflow of water.

The Minnesota Highway Department recommends a maximum slope of 1.0 percent and a minimum slope of 0.2 percent for culverts. For 34 culverts where slope was recorded, 27 percent were below the minimum and 44 percent were above the maximum:

Percent of slope	*Percent of culverts*
—0.1 to —1.0	6
0 to 0.1	21
0.2 to 1.0	29
1.1 to 1.5	26
1.6 to 3.0	9
3.1 and over	9

The culverts with slopes below the minimum standard averaged —0.7 percent slope — that is, they sloped *toward* the supposed inlet. Such culverts are especially prone to siltation. Twenty-six percent were in the 1.1 to 1.5 slope percent; although this is slightly greater than the maximum slope standard, it is not excessive for small-diameter culverts in narrow woods roads. Too little slope was a greater problem than too much.

Many factors can change the slope of a culvert after its installation. Some important ones are unequal soil subsidence and buoying (the lifting action by water) (Frederickson 1963) and frost heaving. Excessive projection of the intake side of the culvert probably accentuates both frost heaving and buoying.

Experts in soil mechanics and road construction (Casagrande 1936, 1938; Edgerton 1961) have emphasized the use of coarse gravel bedding under and at the sides of metal culverts to reduce frost heaving. Of the 41 culverts studied, only 48 percent were set on gravel or crushed rock. The lack of such bedding in the others undoubtedly caused some of the frost lifting, tilting, unequal subsidence, or culvert bowing. To reduce tilting or unequal subsidence, Davis (1961) suggests putting culverts in shallower peat on coarse bedding material extending to the mineral soil below, and for deeper peats (4 to 5 feet or more) placing the culvert on brush mat "corduroy," which holds up the mineral soil road surface fill.

Of the 41 culverts, 28 percent were not stabilized by rock or sod near the inlet. Sixteen percent had considerable sloughing on the road shoulder — a particularly serious problem near the smaller diameter metal culverts, which tended to get silted in. Seventeen percent had considerable erosion at the outlets, and 20 percent had some erosion at the inlets. Rock riprap or rock channel liners at inlets, or graded gravel and rock at outlets could serve as energy dissipators and reduce this erosion very substantially (Smith and Hallmark 1961).

The average soil depth over the top of the culverts was 1.1 feet. The depth of soil cover was especially thin (0.5 foot or less) on 35 percent of the culverts and rather meager (0.6 to 1.0 foot) on an additional 32 percent. Eighteen percent had a soil depth of 1.1 to 2.0 feet, and 15 percent had 2.1 feet or more. Deeper placement of culverts would seem highly desirable to increase the depth of soil over culverts and reduce culvert damage by traffic and by roadgraders and snowplows.

Apparently more care was taken in placing the larger diameter, more expensive culverts than the 12- to 21-inch size where most of the cross drainage and maintenance problems occurred.

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THE FOREST SERVICE CREED

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U. S. FOREST SERVICE

RESEARCH NOTE NC-38

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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FOREST AREA IN MICHIGAN COUNTIES, 1966

ABSTRACT. — In 1966, Michigan had 19.4 million acres of forest land. Almost half of the 18.9 million acres classified as commercial forest land was in Upper Michigan. Since 1955 commercial forest land has increased from 2.4 million to 2.8 million acres in Southern Lower Michigan, and decreased from 7.7 million to 7.0 million acres in Northern Lower Michigan.

The recently completed Third Forest Survey of Michigan shows that 19.4 million acres, or more than half of Michigan's 36.4 million acres, are forested (table 1). Forest land comprises nine-tenths of the total land area in the Upper Peninsula, three-fifths of the land area in the northern half of Lower Michigan, but only one-fifth the land area in the southern half (fig. 1, see p. 4).

About 18.9 million acres or 98 percent of the total forest area is useable for production of industrial timber and is therefore classified as commercial forest land. Almost half of it, 9 million acres, is in the Upper Peninsula. Of the 15 counties in that area, Marquette County alone has more than 1 million acres, and 12 other counties have at least 500,000 acres each. In Lower Michigan the northern unit has 7 million acres and the southern unit 3 million acres of commercial forest land.

Although the total of commercial forest land has changed less than 2 percent between this survey and the one dated 1955, we can note some significant changes in certain sections of the state. In the 35 counties in Southern Lower Michigan, commercial forest land has increased from 2.4 million to 2.8 million acres. This increase reflects the idle cropland and pastureland that is returning to forest, widespread tree planting on open land, and the decreasing use of farm woodlots for pasture.

In the 33 counties in Northern Lower Michigan, commercial forest land decreased from the 7.7 million acres reported in 1955 to 7.0 million acres in 1966, a difference of about 10 percent. Comparisons of the two surveys show a large reduction of nonstocked forest land in these counties. About 500,000 of the nonstocked forest acreage reported in 1955 cannot be accounted for in the present seedling and sapling acreage; apparently most of this is now being used for nonforest purposes.

In the Upper Peninsula commercial forest land has remained about the same, with small increases showing up in the western part and small decreases in the eastern part.

(text cont. on p. 4)

Table 1.—Area of land and forest land, by counties, Michigan, 1966

Survey district & county	All land[1/]	All forest	Forest Land[2/] Non-commercial[3/]	Commercial[4/]	Commercial forest as a percent of land area
	Thousand acres	Thousand acres	Thousand acres	Thousand acres	Percent
E. UP. PEN.:					
Alger	584.3	540.6	4.7	535.9	91.7
Chippewa	1,011.2	805.1	38.6	766.5	75.8
Delta	755.2	638.3	14.4	623.9	82.6
Luce	585.0	543.3	17.1	526.2	89.9
Mackinac	649.0	572.0	10.1	561.9	86.6
Menominee	660.5	527.5	14.2	513.3	77.7
Schoolcraft	767.4	654.5	13.1	641.4	83.6
Total	5,012.6	4,281.3	112.2	4,169.1	83.2
W. UP. PEN.:					
Baraga	578.6	543.3	8.2	535.1	92.5
Dickinson	484.5	454.0	6.3	447.7	92.4
Gogebic	711.7	666.4	22.3	644.1	90.5
Houghton	659.2	576.9	16.1	560.8	85.1
Iron	766.1	708.7	12.6	696.1	90.9
Keweenaw	348.2	341.2	128.5	212.7	61.1
Marquette	1,178.2	1,108.6	11.5	1,097.1	93.1
Ontonagon	845.3	784.2	56.9	727.3	86.0
Total	5,571.8	5,183.3	262.4	4,920.9	88.3
NO. LOWER PEN.:					
Alcona	433.3	324.1	1.3	322.8	74.5
Alpena	363.5	212.2	1.8	210.4	57.9
Antrim	305.3	186.4	0.8	185.6	60.8
Arenac	235.5	106.4	1.0	105.4	44.8
Bay	285.4	48.3	0.6	47.7	16.7
Benzie	202.2	124.7	2.7	122.0	60.3
Charlevoix	265.0	162.6	0.9	161.7	61.0
Cheboygan	464.0	340.3	3.1	337.2	72.7
Clare	366.1	230.3	1.3	229.0	62.6
Crawford	360.3	313.6	10.0	303.6	84.3
Emmet	295.0	189.4	6.7	182.7	61.9
Gladwin	321.9	189.7	2.8	186.9	58.1
Grand Traverse	297.0	161.7	0.6	161.1	54.2
Iosco	350.1	243.9	1.7	242.2	69.2
Isabella	366.1	97.9	0.8	97.1	26.5
Kalkaska	361.0	271.1	0.4	270.7	75.0
Lake	366.1	297.1	0.2	296.9	81.1
Leelanau	223.4	114.2	1.0	113.2	50.7
Manistee	357.1	221.3	1.1	220.2	61.7
Mason	315.5	160.1	1.5	158.6	50.3
Mecosta	360.3	149.6	1.2	148.4	41.2
Midland	332.8	171.7	1.6	170.1	51.1
Missaukee	361.6	227.4	0.3	227.1	62.8
Montmorency	355.2	287.5	0.5	287.0	80.8
Newaygo	548.5	311.7	1.5	310.2	56.6
Oceana	343.0	152.3	2.1	150.2	43.8
Ogemaw	367.4	241.4	1.9	239.5	65.2
Osceola	371.8	176.1	1.4	174.7	47.0
Oscoda	361.6	302.3	1.0	301.3	83.3
Otsego	339.2	251.8	0.8	251.0	74.0
Presque Isle	418.5	290.8	1.6	289.2	69.1
Roscommon	333.4	271.9	2.0	269.9	81.0
Wexford	360.3	221.9	1.5	220.4	61.2
Total	11,387.4	7,051.7	57.7	6,994.0	61.4

Survey district & county	All land[1/]	All forest	Forest Land [2/]: Non-commercial[3/]	Forest Land [2/]: Commercial[4/]	Commercial forest as a percent of land area
	Thousand acres	Thousand acres	Thousand acres	Thousand acres	Percent
SO. LOWER PEN.:					
Allegan	530.6	150.7	0.6	150.1	28.3
Barry	351.4	94.4	0.8	93.6	26.6
Berrien	371.2	71.0	1.6	69.4	18.7
Branch	323.8	56.6	0.2	56.4	17.4
Calhoun	453.8	99.7	0.7	99.0	21.8
Cass	312.3	69.7	0.3	69.4	22.2
Clinton	365.4	45.0	-	45.0	12.3
Eaton	362.9	55.9	0.1	55.8	15.4
Genesee	411.5	56.2	0.2	56.0	13.6
Gratiot	362.2	49.4	-	49.4	13.6
Hillsdale	384.6	70.3	0.3	70.0	18.2
Huron	526.1	62.7	1.1	61.6	11.7
Ingham	357.8	58.6	0.3	58.3	16.3
Ionia	368.0	63.5	0.1	63.4	17.2
Jackson	451.2	96.2	0.5	95.7	21.2
Kalamazoo	362.9	79.9	1.4	78.5	21.6
Kent	551.7	129.3	0.6	128.7	23.3
Lapeer	420.5	83.8	3.8	80.0	19.0
Lenawee	482.5	64.8	0.9	63.9	13.2
Livingston	365.4	92.5	0.7	91.8	25.1
Macomb	307.8	46.5	1.5	45.0	14.6
Monroe	359.7	35.1	0.1	35.0	9.7
Montcalm	455.7	134.4	0.7	133.7	29.3
Muskegon	322.6	170.0	1.0	169.0	52.4
Oakland	561.3	154.6	17.4	137.2	24.4
Ottawa	361.0	89.1	0.7	88.4	24.5
Saginaw	519.7	99.0	0.3	98.7	19.0
St. Clair	473.6	79.4	0.9	78.5	16.6
St. Joseph	325.1	57.7	0.5	57.2	17.6
Sanilac	615.0	70.4	0.2	70.2	11.4
Shiawassee	345.6	42.5	-	42.5	12.3
Tuscola	522.2	105.7	0.2	105.5	20.2
Van Buren	388.5	100.1	0.5	99.6	25.6
Washtenaw	458.2	84.2	1.1	83.1	18.1
Wayne	388.5	38.2	1.6	36.6	9.4
Total	14,520.3	2,857.1	40.9	2,816.2	19.4
State Total	36,492.1	19,373.4	473.2	18,900.2	51.8

1/ 1960 Bureau of the Census.

2/ Land at least 10 percent stocked by forest trees of any size, or formerly having such tree cover; excludes lands currently developed for nonforest use such as urban or thickly settled residential or resort areas, city parks, orchards, improved roads, or improved pasture lands. The minimum area classified as forest land was 1 acre. Roadside, streamside, and shelterbelt strips of timber with crown width of at least 120 feet and all unimproved roads and trails, streams, and clearings in forest areas were classified as forest.

3/ Unproductive forest land incapable of yielding crops of industrial wood because of adverse site conditions and productive public forest land withdrawn from commercial timber use through statute or administrative regulation.

4/ Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization.

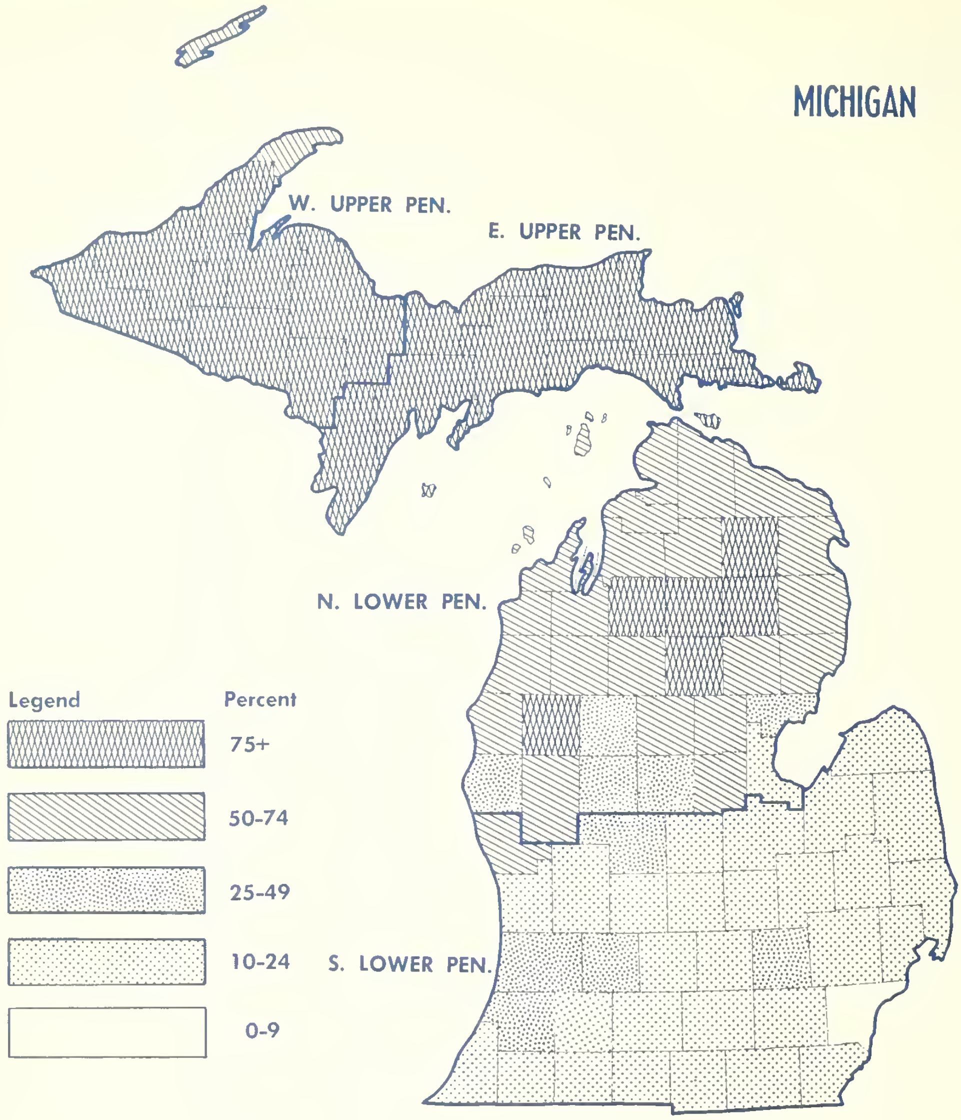

Figure 1.—Commercial forest area as a percent of all land area.

Noncommercial forest land totals 473,000 acres. Of this area, 268,000 acres are reserved, primarily in state parks and Isle Royale National Park. The remaining 205,000 acres is unproductive forest land, found primarily in conifer swamps and bogs in the Upper Peninsula.

The forest area information reported here is part of the results of the Third Michigan Forest Survey made during 1964-1966 by the North Central Forest Experiment Station and the Michigan Conservation Department. Other publications giving details of Michigan forest areas, timber volumes, and growth and cut are being prepared and will be available in the near future.

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Associate Mensurationist

August 1967

U. S. FOREST SERVICE

RESEARCH NOTE NC-39

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

FOREST STAND-SIZE TRENDS IN UPPER MICHIGAN, 1955-1966

ABSTRACT. — Sawtimber and poletimber acreage was half again as large in 1966 as in 1955; seedling and sapling acreage had decreased about one-third; and nonstocked area had dropped from 1.2 million acres to 100,000.

The forests of Upper Michigan have changed rapidly in stand-size composition since 1955. By 1966 the acreage of poletimber and sawtimber stands combined had increased more than 57 percent. These stands had their origin in an era of repeated, unchecked fires that followed wholesale logging, first for old-growth pine and then for northern hardwoods. Gradually improved fire protection in the 1920's sparked the resurgence of second-growth stands, which are now maturing. This background partially explains the current large shifts in stand structure. Stand sizes for 1955 and 1966 were as follows:

Stand-size class	*Million acres in— 1955*	*1966*	*Percent increase (+) or decrease (—)*
Sawtimber	1.5	2.6	+73
Poletimber	2.7	4.0	+48
Saplings and seedlings	3.5	2.4	—31
Nonstocked	1.2	.1	—92
Total	8.9	9.1	+ 1

Nonstocked forest area decreased 1.1 million acres during the 10 years. This acreage became stocked with larger size classes. Nevertheless, seedling and sapling stands decreased by 1.1 million acres; evidently considerably more than half of the 1955 acreage in this size class now has pole-size and larger stands. Poletimber stands increased the most in acreage, but sawtimber had the largest percentage increase.

In 1966 nearly 29 percent of the commercial forest supported sawtimber. More than 43 percent was poletimber. The Western Unit of Upper Michigan has more of these larger stand sizes than the Eastern Unit has (table 1).

These changes in stand size reflect not only higher volumes in larger trees but also an expanding acreage where commercial cutting operations can be considered, especially in types that generally mature as poletimber. They also suggest that land managers can shift the emphasis of their forestry programs from tree planting and restocking of non-stocked land (only about 100,000 acres in 1966) to care and improvement of existing stands.

Procedures used to determine stand size in the Survey of 1966 differed slightly from those used in 1955. The newer procedures gave a better sample of small trees. Had they been used in 1955 less non-stocked acreage

Table 1.—Area of commercial forest land by county, unit, and stand-size class, Upper Michigan, 1966

(In thousand acres)

County	All stands	Sawtimber stands	Poletimber stands	Saplings & seedling stands	Nonstocked areas
Alger	535.9	174.8	226.3	131.8	3.0
Chippewa	766.5	169.7	336.9	250.5	9.4
Delta	623.9	126.9	281.4	210.4	5.2
Luce	526.2	154.9	199.7	169.2	2.4
Mackinac	561.9	125.0	271.6	160.6	4.7
Menominee	513.3	128.7	222.1	157.5	5.0
Schoolcraft	641.4	159.5	262.4	211.3	8.2
EAST. UPPER MICH.	4,169.1	1,039.5	1,800.4	1,291.3	37.9
Baraga	535.1	213.1	219.0	98.3	4.7
Dickinson	447.7	124.8	210.1	111.1	1.7
Gogebic	644.1	176.0	291.0	162.2	14.9
Houghton	560.8	187.2	232.5	133.3	7.8
Iron	696.1	196.7	315.3	170.7	13.4
Keweenaw	212.7	90.9	84.0	37.4	.4
Marquette	1,097.1	381.2	446.3	255.6	14.0
Ontonagon	727.3	189.6	358.8	166.2	12.7
WEST. UPPER MICH.	4,920.9	1,559.5	2,157.0	1,134.8	69.6
ALL UPPER MICH.	9,090.0	2,599.0	3,957.4	2,426.1	107.5

would have been reported. Another effect of the change was to understate the true increase in acreages of poletimber and sawtimber stands.

These statistics are from a Forest Survey of Michigan made between 1963 and 1966 by the North Central Forest Experiment Station, the Michigan Conservation Department, and the National Forests in Michigan and a previous survey made between 1946 and 1957. The sampling errors per million acres of forest land were ±1.6 percent for the latest survey and ±1.1 percent for the previous survey.

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August 1967

U. S. FOREST SERVICE

RESEARCH NOTE NC-40

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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RATE OF PERIMETER INCREASE RELATED TO TIMBER SPREAD INDEX AND NORTHEASTERN FUEL TYPES

ABSTRACT. — Gives the average rates of perimeter increase for fires in four broad fuel type groups by four spread index classes.

Information on how fast fires spread in different fuels is limited. Acquiring data under controlled conditions is costly and time consuming. Yet, fire control organizations need to associate spread indexes with real rates of spread to make efficient use of the National Fire Danger Rating System. As a step in that direction, individual fire report forms from the Eastern Region (formerly Region 7), U.S. Forest Service, were analyzed to obtain rates of perimeter increase from time of discovery to attack. Data from 1950 to 1958 are summarized here.

Rates of spread were computed by Timber Spread Index classes for four fuel type groups (table 1). Each group includes fuel types that had similar average rates of spread under all burning conditions. These groupings avoid perpetuating the use of a complex fuel classification system that does not reflect differences in spread characteristics. Users should associate their fire problem areas with one of four broad fuel type groups.

Fuel type group A, which had the slowest spreading fires, is associated with northern conifers, hardwood and hemlock hardwood, and conifer slash (Eastern Region fuel types 1, 2, 3, and 8).[1] Group B is a summary of fires in southern pine and hardwood-southern pine slash fuels (fuel types 6, 7, and

[1] *Banks, W. G. and H. C. Frayer. Rate of forest fire spread and resistance to control in the fuel types of the Eastern Region, U.S. Forest Serv. Fire Control Notes 27(2): 10-13. 1966.*

Table 1.—Average and standard deviation of perimeter increase rate at time of initial attack

Fuel type group[1/]	Spread index class							
	0-10		11-20		21-30		31-40	
	Average and standard deviation	Obser-vations	Average and standard deviation	Obser-vations	Average and standard deviation	Obser-vations	Average and standard deviation	Obser-vations
	Chains/hour	Number	Chains/hour	Number	Chains/hour	Number	Chains/hour	Number
A	9.3 ± 8.9	6	11.2 ± 11.3	15	6.5 ± 4.9	3	16.0 ± 16.6	3
B	10.5 ± 9.8	32	23.7 ± 26.5	92	30.4 ± 26.9	70	36.7 ± 29.4	24
C	15.8 ± 19.0	21	19.5 ± 23.1	85	25.1 ± 23.2	277	29.3 ± 26.2	142
D	20.9 ± 11.9	155	28.8 ± 19.0	465	33.2 ± 23.2	43	46.2 ± 48.1	17

[1/] A = Northern conifers, hardwood cutover, hemlock-hardwood cutover, and new conifer slash.
B = Southern pine reproduction and hardwood and southern pine slash.
C = Northern and Appalachian hardwoods and hardwood reproduction.
D = Grass, fern, and weeds.

10). Group C represents northern and Appalachian hardwood fires (fuel types 4 and 5). Group D, the fastest spreading fires, represents flashy fuels such as grass, weeds, and ferns (fuel type 11).

Fires reported as zero rate of spread were not included. Burning Index (model 8-200) values as given on the report forms were converted to Timber Spread Index values on the basis of a relation between the two measures. This step added to the large variation evident in the standard deviations.

Average spread rates ranged from 9 chains per hour perimeter increase to 46 chains per hour (table 1). Spread rates increased steadily with increase in spread class for each fuel type group.

These spread rates may be useful in planning. It must be pointed out that the large standard deviations associated with the average spread values mean it is not possible to accurately predict actual spread rates for individual fires. Factors not included in the Spread Index computation, such as slope and aspect, influence spread rates. Also fires occurring at a different time or place from the danger-rating observation have introduced error. However, based on the currently used fuel type classification and Timber Spread Index, values shown are a best estimate of the actual perimeter spread rate that initial attack crew will encounter.

The next step is to collect sufficient data to determinte rates of spread for specific fuel types, or fuel types classified by a system based on rate of spread. In the meantime, these data give a first approximation of these values.

August 1967

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RESEARCH NOTE NC-41

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Forest Cover Types by Counties, Michigan, 1966

ABSTRACT. — Presents 1966 forest type areas by counties and shows trends in forest type areas since 1955, by survey units.

Statistics from the recently completed Third Forest Survey of Michigan show that over three-fourths of the 18.9 million acres of commercial forest land in Michigan support hardwood forest types. Four major hardwood types are found: maple-beech-yellow birch, aspen-paper birch, oak-hickory, and elm-ash-cottonwood.

Maple-beech-yellow birch, locally called northern hardwoods, is the largest forest type in Michigan and covers over one-fourth (5.2 million acres) of the commercial forest land (table 1). Although scattered over the entire state, the type is found most commonly in the western and northern parts of the Upper Peninsula. These species reproduce well when they are protected from fire. The recent Survey bears this out by showing large acreages of the type now moving into poletimber-size stands. These poletimber stands probably originated in the 1920's with the coming of organized forest fire protection.

Aspen-paper birch, the State's second largest type, accounts for almost 25 percent (4.7 million acres) of the total commercial forest. Found in most parts of the State, the type covers large blocks of land in the northeastern part of the Lower Peninsula and in the southern part of the Upper Peninsula. This forest type needs fire and clear-cutting to perpetuate itself. Increased cutting of aspen, lack of recent fires, and mortality of aspen may account for the 19-percent decrease in the type since the last survey about 10 years ago (fig. 1).

The oak-hickory type is composed primarily of several species of oak in the Upper Peninsula and of hickory as well as oak in the south. It constitutes 13 percent (2.4 million acres) of the State's commercial forest, and is found chiefly on sandy soils in southern Lower Michigan. This type increased 12 percent in the last decade, primarily due to natural conversion of idle cropland and pasture to the oak-hickory type in southern Michigan.

The elm-ash-cottonwood type is sometimes called the lowland hardwoods type. It constitutes 10 percent (1.9 million acres) of Michigan's commercial forest. Found throughout most of the State, it is most common on the fertile soils and along the streams of southern Lower Michigan. This type, the smallest major type in 1955, increased rapidly (66 percent) in the last decade. The natural conversion from other forest types in the north and from idle farmland to forest in the south accounts for this change.

Stands in which softwoods are a major component constitute the remaining 24 percent (4.6 million acres) of commercial forest. The spruce-fir type, which occupies 15 percent (2.9 million acres), includes the white-cedar, balsam fir-white spruce, black spruce, and tamarack local types (listed in descending order by acreage). Balsam fir-white spruce occurs chiefly in the western Upper Peninsula, and the swamp conifer types in the eastern Upper Peninsula. The area of spruce-fir types in the State increased by 12 percent since the last Survey, probably due to natural conversion following the cutting of other forest types.

The white-red-jack pine type makes up almost 10 percent (1.8 million acres) of the State's commercial forest. The jack pine sub-type makes up over half of the major type. The major blocks of pine timber are on the sandy lands of the eastern Upper Peninsula and north-central Lower Peninsula; however, pine has been planted in all sections of the State. The pine type has decreased 9 percent during the last decade probably due to natural conversion to other forest types following harvesting of the pine.

The sampling error for the State's total commercial forest area of 18.9 million acres is ± 0.46 percent at one standard error (the 67-percent confidence limit). For 20,000 acres the error would be ± 14.0 percent. Very small acreages may be considerably in error since sampling error increases as the size of the area decreases.

These statistics are from the Third Forest Survey of Michigan, made between 1964 and 1966 by the North Central Forest Experiment Station and the Michigan Department of Conservation. Detailed information on present forest resources and trends will be published as results become available.

Table 1. — *Commercial forest land by forest cover types, survey units, and county; Michigan, 1966*

(In thousand acres)

County	Total commercial forest land area[1]	Forest type[2]: White-red-jack pine[3]	Spruce-fir[4]	Oak-hickory[5]	Elm-ash-cottonwood[6]	Maple-beech-birch[7]	Aspen-birch[8]
EASTERN UPPER MICHIGAN UNIT							
Alger	535.9	51.7	95.8	3.0	54.4	241.1	89.9
Chippewa	766.5	92.1	256.8	2.0	48.8	200.3	166.5
Delta	623.9	90.1	178.6	3.2	46.3	139.6	166.1
Luce	526.2	82.8	198.2	1.8	33.0	153.9	56.5
Mackinac	561.9	38.4	159.9	3.0	38.9	155.0	166.7
Menominee	513.3	23.7	191.4	4.8	50.1	134.8	108.5
Schoolcraft	641.4	93.9	178.7	2.0	67.2	179.8	119.8
Unit total	4,169.1	472.7	1,259.4	19.8	338.7	1,204.5	874.0
Percent	100.0	11.3	30.2	0.5	8.1	28.9	21.0
WESTERN UPPER MICHIGAN UNIT							
Baraga	535.1	27.7	105.9	5.7	34.1	275.3	86.4
Dickinson	447.7	29.7	126.4	6.1	21.7	104.6	159.2
Gogebic	644.1	12.1	116.8	5.7	34.0	356.0	119.5
Houghton	560.8	27.6	57.3	7.6	21.4	330.7	116.2
Iron	696.1	24.9	160.9	6.5	26.2	285.1	192.5
Keweenaw	212.7	5.7	40.6	5.7	11.8	117.3	31.6
Marquette	1,097.1	118.9	279.4	27.2	62.2	397.5	211.9
Ontonagon	727.3	21.6	83.6	8.1	36.0	358.5	219.5
Unit total	4,920.9	268.2	970.9	72.6	247.4	2,225.0	1,136.8
Percent	100.0	5.5	19.7	1.5	5.0	45.2	23.1
NORTHERN LOWER MICHIGAN UNIT							
Alcona	322.8	28.3	38.0	72.3	31.5	36.7	116.0
Alpena	210.4	8.2	49.7	17.3	28.8	28.6	77.8
Antrim	185.6	25.5	10.8	31.8	12.0	50.4	55.1
Arenac	105.4	6.7	8.6	12.2	20.2	11.5	46.2
Bay	47.7	3.8	4.0	2.7	8.9	7.9	20.4
Benzie	122.0	9.6	8.4	14.4	15.2	37.2	37.2
Charlevoix	161.7	5.3	14.5	16.7	11.4	63.7	50.1
Cheboygan	337.2	49.3	38.2	46.5	30.5	59.2	113.5
Clare	229.0	9.7	15.8	30.1	25.9	55.6	91.9
Crawford	303.6	84.6	18.2	92.4	16.3	33.7	58.4
Emmet	182.7	11.0	18.3	17.7	17.0	64.6	54.1
Gladwin	186.9	8.8	12.7	13.7	29.6	24.1	98.0
Grand Traverse	161.1	30.5	7.0	42.1	12.7	40.7	28.1
Iosco	242.2	60.0	20.1	38.6	24.9	22.0	76.6
Isabella	97.1	4.5	6.1	12.4	16.2	17.9	40.0
Kalkaska	270.7	72.4	29.6	43.1	18.3	53.9	53.4
Lake	296.9	49.6	4.1	145.7	14.7	21.8	61.0
Leelanau	113.2	12.1	6.9	10.2	6.6	42.6	34.8
Manistee	220.2	26.9	6.3	66.2	15.5	41.1	64.2
Mason	158.6	24.5	3.0	51.6	9.4	31.4	38.7
Mecosta	148.4	9.7	5.7	32.3	12.8	32.6	55.3
Midland	170.1	5.6	11.0	13.4	26.1	20.6	93.4
Missaukee	227.1	11.1	34.5	17.5	17.3	57.5	89.2
Montmorency	287.0	47.1	32.5	34.9	19.1	64.2	89.2
Newaygo	310.2	29.9	12.9	93.1	31.3	47.2	95.8
Oceana	150.2	16.1	3.4	40.3	12.2	37.5	40.7
Ogemaw	239.5	34.6	14.9	58.1	20.4	43.4	68.1
Osceola	174.7	11.2	8.2	20.1	17.8	47.7	69.7
Oscoda	301.3	97.5	24.5	59.0	20.5	24.2	75.6
Otsego	251.0	30.9	27.2	20.4	13.8	56.4	102.3
Presque Isle	289.2	23.6	51.1	33.6	37.2	46.1	97.6
Roscommon	269.9	37.3	40.6	67.7	23.8	29.1	71.4
Wexford	220.4	36.3	9.7	28.0	12.6	62.3	71.5
Unit total	6,994.0	922.2	596.5	1,296.1	630.5	1,313.4	2,235.3
Percent	100.0	13.2	8.5	18.5	9.0	18.8	32.0

Table 1 cont'd.

(In thousand acres)

County	Total commercial forest land area[1]	Forest type[2]: White-red-jack pine[3]	Spruce-fir[4]	Oak-hickory[5]	Elm-ash-cottonwood[6]	Maple-beech-birch[7]	Aspen-birch[8]
SOUTHERN LOWER MICHIGAN UNIT							
Allegan	150.1	7.5	1.9	55.8	35.9	30.3	18.7
Barry	93.6	3.2	1.7	40.1	23.0	14.5	11.1
Berrien	69.4	0.9	1.1	27.1	18.3	13.4	8.6
Branch	56.4	1.5	1.0	22.0	14.6	9.5	7.8
Calhoun	99.0	2.1	2.4	35.4	31.3	13.9	13.9
Cass	69.4	1.9	1.1	28.1	16.1	13.8	8.4
Clinton	45.0	0.6	0.2	15.2	11.4	11.8	5.8
Eaton	55.8	1.4	0.9	13.4	14.7	15.3	10.1
Genesee	56.0	1.1	0.9	20.5	16.5	8.5	8.5
Gratiot	49.4	0.6	0.7	11.4	11.4	8.5	16.8
Hillsdale	70.0	1.1	1.1	28.4	18.2	12.5	8.7
Huron	61.6	0.6	1.1	8.9	26.5	9.0	15.5
Ingham	58.3	0.7	0.8	18.3	16.4	14.4	7.7
Ionia	63.4	1.7	0.5	18.6	14.6	17.4	10.6
Jackson	95.7	4.5	2.3	42.1	22.4	13.2	11.2
Kalamazoo	78.5	3.3	1.9	31.9	18.1	12.3	11.0
Kent	128.7	7.8	1.9	42.7	30.2	27.3	18.8
Lapeer	80.0	1.9	1.2	26.9	22.7	13.9	13.4
Lenawee	63.9	1.7	0.8	32.7	14.1	9.7	4.9
Livingston	91.8	5.1	2.2	43.3	19.3	12.6	9.3
Macomb	45.0	1.3	0.6	21.2	10.4	7.7	3.8
Monroe	35.0	0.3	0.8	8.0	15.4	5.5	5.0
Montcalm	133.7	8.5	2.3	46.1	33.4	24.6	18.8
Muskegon	169.0	10.1	1.7	82.3	29.0	27.1	18.8
Oakland	137.2	4.2	3.7	55.6	35.9	19.4	18.4
Ottawa	88.4	12.6	1.3	39.7	14.4	13.2	7.2
Saginaw	98.7	2.0	1.3	24.1	30.2	16.5	24.6
St. Clair	78.5	1.8	1.3	24.3	19.1	16.8	15.2
St. Joseph	57.2	1.5	1.1	22.6	18.0	6.5	7.5
Sanilac	70.2	1.2	1.6	10.8	22.9	9.8	23.9
Shiawassee	42.5	0.8	0.1	13.5	10.2	12.7	5.2
Tuscola	105.5	2.5	1.4	26.0	27.1	17.3	31.2
Van Buren	99.6	3.4	2.0	29.7	30.8	19.3	14.4
Washtenaw	83.1	2.3	1.3	36.8	18.6	15.6	8.5
Wayne	36.6	0.9	0.5	13.0	8.3	7.8	6.1
Unit total	2,816.2	102.6	46.7	1,016.5	719.4	501.6	429.4
Percent	100.0	3.6	1.7	36.1	25.6	17.8	15.2
State total	18,900.2	1,765.7	2,873.5	2,405.0	1,936.0	5,244.5	4,675.5
Percent	100.0	9.4	15.2	12.7	10.2	27.8	24.7

1/ Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization. Forest tracts of less than 1 acre and isolated strips of timber less than 120 feet wide are excluded.

2/ A classification of forest land based upon the species forming a plurality of live-tree stocking.

3/ Forests in which eastern white pine, red pine, scotch pine, or jack pine, singly or in combination, comprises a plurality of the stocking.

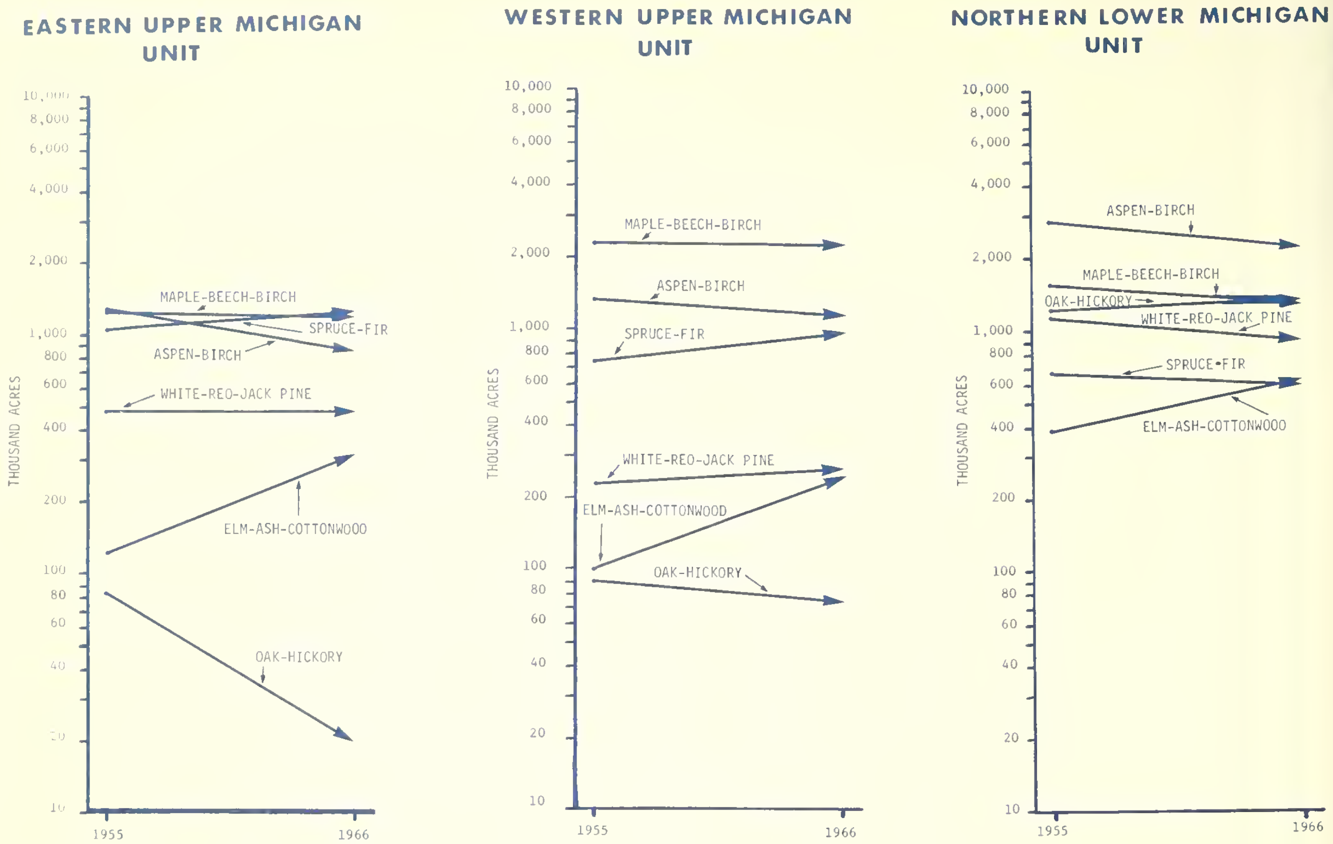
4/ Forests in which spruce or true firs, singly or in combination, comprise a plurality of the stocking.

5/ Forests in which upland oaks or hickory, singly or in combination, comprises a plurality of the stocking.

6/ Forests in which elm, ash, or cottonwood, singly or in combination, comprises a plurality of the stocking.

7/ Forests in which maple, beech, or yellow birch, singly or in combination, comprises a plurality of the stocking.

8/ Forests in which aspen, balsam poplar, paper birch, or gray birch, singly or in combination, comprises a plurality of the stocking.



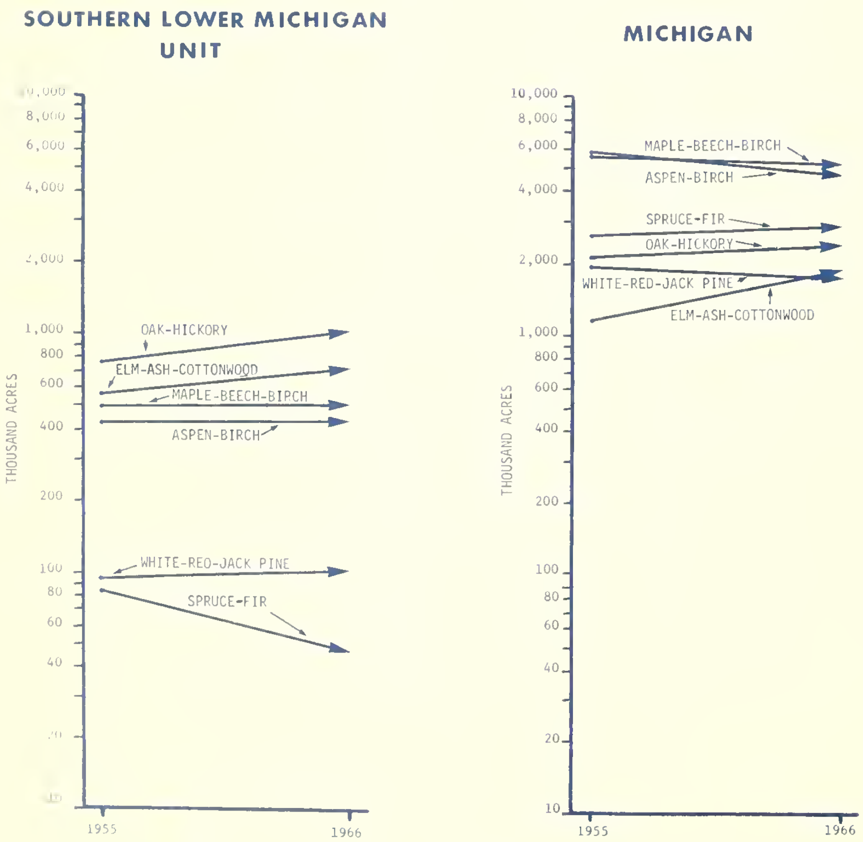


Figure 1. — Trends in forest cover type area between 1955 and 1966. Charts (semi-logarithmic) show data for the four Survey units and for the entire State. Acreages for 1955 have been adjusted to include nonstocked forest land.

ARNOLD J. OSTROM
Associate Mensurationist

U. S. FOREST SERVICE

RESEARCH NOTE NC-42

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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The Changing Recreational Use of the Boundary Waters Canoe Area

ABSTRACT. — Although data on use for 1961 and 1966 are not always comparable, a bare-minimum estimate of the increase in number of visitors between those years is 19 percent. The greatest increase was in number of canoeists and boaters, which rose on the average 9 or 10 percent a year.

An opportunity has arisen for examining use trends in a major recreation area—the Boundary Waters Canoe Area (BWCA). For most other areas, only attendance totals are available, and changes in types and patterns of use are hidden. Now information from BWCA visitor permits, which were first issued by the Superior National Forest in 1966, can be compared to the use patterns shown by the North Central Forest Experiment Station's BWCA study in 1961.

The data hint at a number of interesting shifts in use, most of them indicating increased importance of the Canoe Area as a wilderness resource. Comparisons must be made with caution, however. Use definitions for the 2 years were not always identical, and the data for both years are subject to error. In 1966, the registration system was new, and some visitors, unaware of the requirement, failed to register. Spot checks by the Superior National Forest indicated 72 percent compliance, and the permit figures have been expanded on this basis. The expansion is conservative, however; lakes around the edges of the BWCA were not checked as closely, and it is likely that a larger proportion of visitors in these areas did not have permits.

Most of the 1961 figures came from traffic counters and from estimates of the make-up of the traffic based on roadside interviews with about 5 percent of the departing drivers. Thus some sampling error was to be expected. However, numerous cross-checks showed good accuracy, generally within plus or minus 5 percent.

Amount and Types of Use

The totals for visitors (a person is counted as a "visitor" each time he takes a trip to the canoe country, rather than every time he crosses the BWCA boundary during a visit to the general area) are 72,400 for 1961 and 86,000 for 1966. This 19-percent increase is a bare-minimum estimate of growth because of the likely underestimate of marginal area users.

The figures for the main types of use are:

Type of visitor	*1961*	*1966*	*Percent change*
Paddling canoeists	22,300	34,400	+54
Motor canoeists	8,400	12,100	+44
Boat campers	7,800	12,200	+56
Visitors not staying overnight in BWCA[1]	33,900	27,300	—19
Total	72,400	86,000	+19

[1] Auto campers, resort guests, private-cabin users, local people, etc.; data are combined because of differences in definitions for the two surveys.

The picture, if we take these numbers at face value, is of a great increase in the use of the wilderness core area and its isolated, primitive campsites by canoeists and boaters. Nearly 59,000 of them camped overnight in the BWCA in 1966, half again as many as in 1961. They constituted half the BWCA visitors in 1961, two-thirds in 1966. In both years, our data for these types of visitors are more reliable than for other types, and we can be reasonably sure that the numbers of canoeists and boaters combined have grown at an average rate of 9 or 10 percent a year. This continues the long record of rapid growth of wilderness use.

On the other hand, there seems to be a decline in use by the types of visitors who stay on the edges of the BWCA and go in and out daily for the more general sorts of recreation that are not unique to wilderness. The data indicate that 6,600 fewer people used the BWCA in this way, a drop of one-fifth from 1961. It seems likely, however, that more marginal users failed to register in 1966 than did canoeists and boaters. If we assume that their numbers actually did not change from 1961 to 1966, a 28-percent increase in total visitors is indicated. This is still a very conservative estimate, and, in my opinion, 40 percent is a more likely figure.

In 1961, visitors travelling by canoe barely outnumbered those using boats. This is apparently no longer true. In 1966, over two-thirds of the visitors using water craft canoed, and paddlers alone made up half of the total. On a visitor-day basis, boaters (excluding canoeists) accounted for about one-fifth of the use.

Geographic Distribution of Use

Most visitor types are still crowded into a few popular places — and in even greater numbers than in 1961. Some spreading out has taken place, however, by the paddling canoe-trippers, over half of whom used one access point — Moose Lake — in 1961. These are the people who value solitude most highly, according to past studies, and maybe this is part of the reason for the spread. Although the number of groups of paddling canoeists starting from Moose Lake in 1966 was 2,000 more than in 1961, they constituted a considerably smaller proportion of the total paddling canoeists:

Starting point	*Percent of total groups* *1961*	*1966*
Most used point (Moose Lake)	52	39
2nd most used (Fall Lake)	8	17
3rd most used [1]	5	10
Total	65	66

[1] Saganaga in 1961; Lake One in 1966

The top five spots still received about 75 percent of all use in each year, however. In fact, only 12 accesses had at least 1 percent of the paddling groups in 1966 compared to 15 in 1961 (65 access points received some use in 1966).

The two other BWCA overnight-user types are crowded into fewer places. Motor canoeists have become more concentrated and now are the most unevenly distributed type of visitor. The top location (also Moose Lake) had 44 percent of all groups in 1961 and 48 percent in 1966. Boat campers used access points more evenly than motor canoeists, but their concentration has also increased: The share of use accounted for by the top five access points rose from 56 to 76 percent.

The fringe area users all became more bunched up. Auto camper use of the BWCA appears slightly more concentrated in 1966 than in 1961. Resort guests used BWCA access points fairly evenly, but also were more concentrated than in 1961. Private cabin use of the BWCA became slightly more uneven (this distribution would be expected to change slowly because of the fixed location of cabins). Fall Lake led in other day-use (mostly use by local residents) both years and increased its share to one-third of all day-use in 1966. Elsewhere, there was some spreading out.

The proportion of visitors going to Canada apparently fell substantially, but just how much is in doubt. Seasonal permit holders were not asked if they had visited Canada, so only individual trip permits could be used for this comparison. Attendance at Quetico Park, across the Canadian border, has been nearly constant since 1961. Altogether, the data strongly indicate that the BWCA has become more a major destination and less a travel route through to the Canadian wilderness. The relative shift away from Moose Lake, the main route to Canada, also is consistent with this view.

Visitors' Places of Residence

The comparison of where BWCA visitors came from must also be made only on the basis of the individual trip permits. These included over half of all visitors during the 1966 study period.

With these data restrictions in mind, it appears that proportionately more BWCA visitors of almost every type came from outside Minnesota in 1966 than in 1961. Just over half of all visitors in 1966 were Minnesotans compared to 61 percent in 1961. Paddling canoeists were the only type that remained unchanged.

Local northeastern Minnesota people made up a slightly smaller proportion of total visitors in 1966 — that is, most of the growth in use has come from outside the local area, as would be expected from population trends. More visitors from Minneapolis and St. Paul were paddling canoeists in 1966 than in 1961, and fewer were resort guests. The Twin Cities' share of other types stayed about the same. Chicago contributed nearly as many visitors as northeastern Minnesota. Michigan, Ohio, and Indiana increased their share of most types of use, and the total of visitors from other distant regions — Missouri, Kansas, Nebraska, the Northeast, the South, and the West — also increased.

Party Size

Groups averaged a little larger in 1966 for all visitor types except paddling canoeists, who averaged 5.0 persons per group both years. The overall group average rose from 3.9 to 4.3 persons, about a 10-percent increase.

Length of Stay

Average group length of stay declined from 4.4 days to 3.6. This was partly due to the increase in the number of day-users. Average length of stay for every other type of use declined:

	Number of days		
Type	*1961*	*1966*	*Change*
Paddling canoeists	5.1	4.8	—.3
Motor canoeists	4.2	3.9	—.3
Boat campers	3.9	3.6	—.3
Auto campers	4.3	3.8	—.5
Resort guests	5.1	4.5	—.6
Private cabin users	5.7	5.5	—.2
Day-users	1.0	1.0	...
Total	4.4	3.6	—.8

Conclusions

These changes, taken together, suggest the growing importance of the BWCA as a wilderness resource of national significance. This conforms to past trends and recent projections. BWCA use is already ahead of projections made only 7 or 8 years ago. More people are coming, especially for the unique recreational opportunities provided by the area. They are more often coming to visit the BWCA itself rather than just hurrying through it to Canada. And they are coming from farther away. The canoe-trippers are also using the area somewhat more fully, apparently seeking out some of the less crowded lakes. The slightly shorter length of stay is the only shift that seems to go against this trend toward enhanced value of the wilderness aspects of the area. This may be part of a general trend to more frequent but shorter visits to National Parks, National Forests, and State Parks all around the nation, perhaps related mainly to the increasing mobility of Americans. Conceivably, dissatisfaction by some visitors with increasing crowding, or maybe with the fishing (which some people think is declining) might lead to shorter stays. Part of the apparent drop in some types of general "non-wilderness" recreation would more likely be connected with lack of fishing success than crowding.

Some of the increased prominence of the area's role as wilderness may result from policy changes. Resorts and cabins were purchased and removed from the BWCA, some of the canoe routes were zoned for unmechanized use only, and boat storage on interior lakes was prohibited. The policy changes cannot reasonably account for the magnitude of the shifts in use, however. Only about 2 percent of the 1961 outboard motor use would have violated the zoning regulations in force in 1966. It may be fairer to say that the policy shifts reflect changes in the use of the Canoe Country and in the way it is valued by citizens and public officials.

The trends seem strong enough and consistent enough to be indicative, despite the shortcomings of some of the data. As the visitor registration system becomes more widely known and more complete and accurate, the trends will become clearer, and more definite conclusions can be drawn. But even this blurred view shows an interesting picture of a fascinating and more and more significant region.

October 1967

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Principal Geographer

[1] Recently transferred to Intermountain Forest and Range Experiment Station at Missoula, Montana.

U. S. FOREST SERVICE

RESEARCH NOTE NC-43

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Buildup Index as an Expression of Moisture Content in Duff

ABSTRACT.—The relation between Buildup Index and moisture content of grouped litter and duff samples from beneath four medium-site forest stands closely approximated the relation between Buildup Index and moisture equivalent of 5-day timelag fuels having an equilibrium moisture content of 15 percent.

Moisture content is one of the most important factors affecting the rate at which forest fuels will burn. Generally, moisture content varies with weather conditions, but it also varies with volume and compactness of the fuels and whether they are green or cured.

The Buildup Index of the National Fire Danger Rating System, a cumulative numerical index derived from daily weather data, presumably indicates the moisture content in medium-drying forest fuels. Buildup Index is a component of Spread Index and is often used separately for fire control planning.[1] The fuels to which Buildup Index primarily applies are forest litter (L) and duff (F) averaging 3 to 4 inches in depth.[2] The amount of moisture in these forest floor fuels largely determines how deep a fire will burn and is therefore particularly useful for predicting the effects of both wild and prescribed fires.

During 1963, we compared the Buildup Index with the actual moisture content of forest floor fuels commonly found in the Lake States to see how consistently it predicted fuel moisture. Samples of litter and duff from well-stocked pine and hardwood stands were collected between 1:00 p.m. and 2:30 p.m. on 56 irregularly scheduled days from mid-May to mid-August. On each scheduled day, one composite L and F sample was collected from five randomly located plots in each of four medium-site stands. Three stands—45-year-old and 90-year-old natural red pine and uneven aged aspen-oak — were in northern Minnesota. The fourth—a 25-year-old red pine plantation—was near Cadillac, Mich. The 90-year-old red pine stand and the aspen-oak stand had an understory of hazel brush and herbaceous vegetation and a well-developed[3] forest floor. The 45-year-old red pine stand also had a well-developed forest floor but very little subordinate vegetation. The 25-year-old red pine plantation had a shallow, poorly developed floor and no understory vegetation.

The moisture content of the samples was determined by ovendrying. For each sampling date the Buildup Indexes were computed from data taken daily at 1:00 p.m. with

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[1] *Ralph M. Nelson. The National Fire Danger Rating System. U.S Forest Serv. Res. Pap. SE-13, 44 p. Southeast. Forest Exp. Sta., Asheville, N. C. 1964.*

[2] *U.S. Forest Service. National Fire-Danger Rating Handbook, FSH2-5123.3. Feb. 1964.*

[3] *Litter, duff, and humus present and readily identifiable.*

hygrothermographs and recording rain gauges near the sampling areas.

The highest Buildup Index computed during the sampling period in northern Minnesota was 53, at which time the average fuel moisture was 15 percent in the 45-year-old pine and 36 percent in the aspen-oak and 90-year-old pine stands. At the Michigan site the highest Buildup Index computed was 107; the average fuel moisture at that time was 18 percent.

There was no significant difference in the mean values and rates of change for the fuel moisture-Buildup Index relationship between

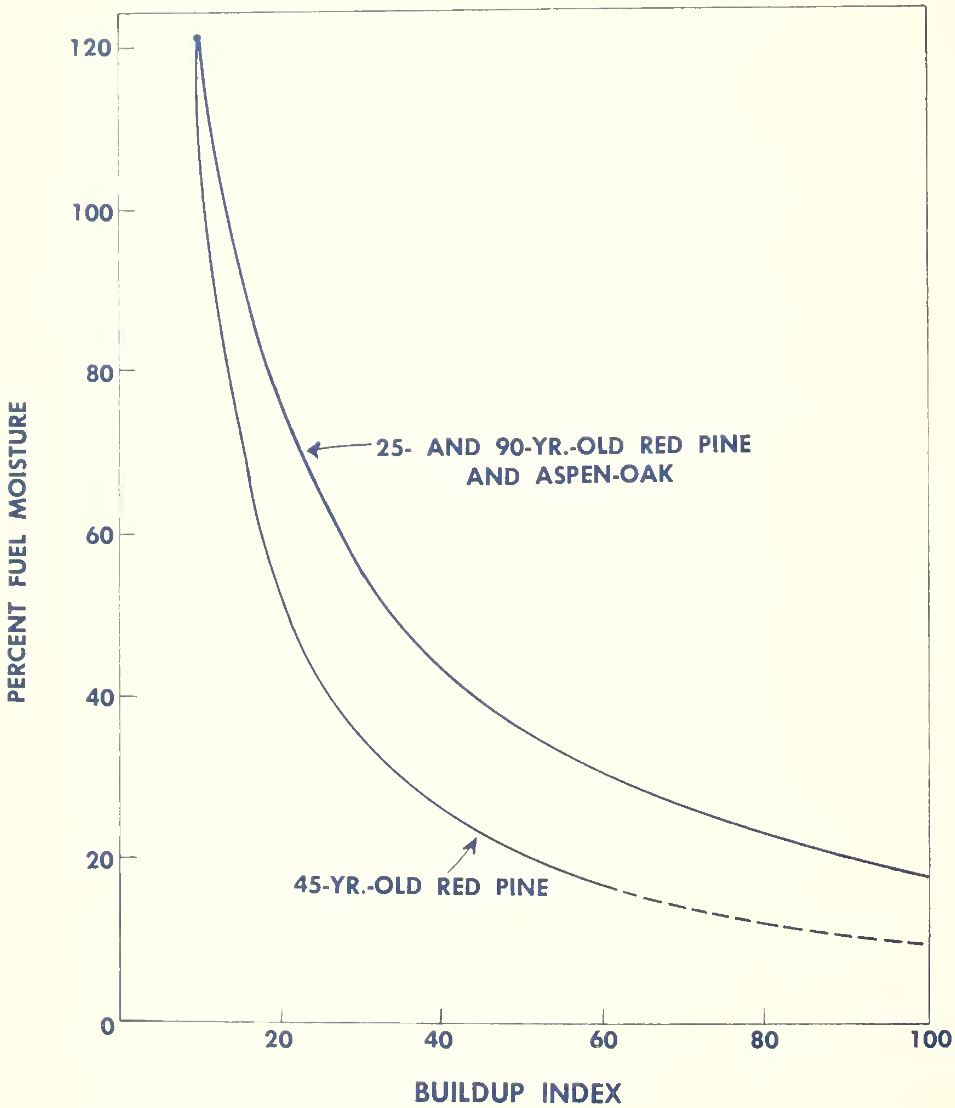

Figure 1.—Buildup Index (BUI) compared to moisture content (MC) of duff. The equations for the trend lines are:

25- and 90-year-old red pine and aspen-oak:

$1/\%MC = .0032 + .0005\ BUI.\quad r^2 = .45,\ N = 91$

45-year-old red pine:

$1/\%MC = -.0006 + .0010\ BUI.\quad r^2 = .46,\ N = 35$

The broken line for the 45-year-old red pine indicates a projection beyond the limit of the field data.

the hardwood and the 25- and 90-year-old pine stands. These data were therefore grouped and plotted separately from those for the 45-year-old red pine (fig. 1). The more rapid change in fuel moisture in 45-year-old pine duff with changes in the Buildup Index is more apparent than real. This response was partially due to the absence of understory vegetation and less compact litter.

Grouped data from all four stands did not compare favorably to the fuel moisture equivalent of 10-day timelag[4] fuels from which Buildup Index was derived[5] (fig. 2). However, the data closely approximated the fuel moisture equivalent of 5-day timelag

[4] *Timelag is the interval of time required for a fuel, under standard drying conditions where the dry bulb temperature is 80° F. and the wet bulb temperature is 57° F., to lose approximately two-thirds of its moisture content above equilibrium.*

[5] *John J. Keetch. Development of the National Fire-Danger Rating System: Basic Structure and Spread Phase. U.S. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N. C. 1965. Unpublished report.*

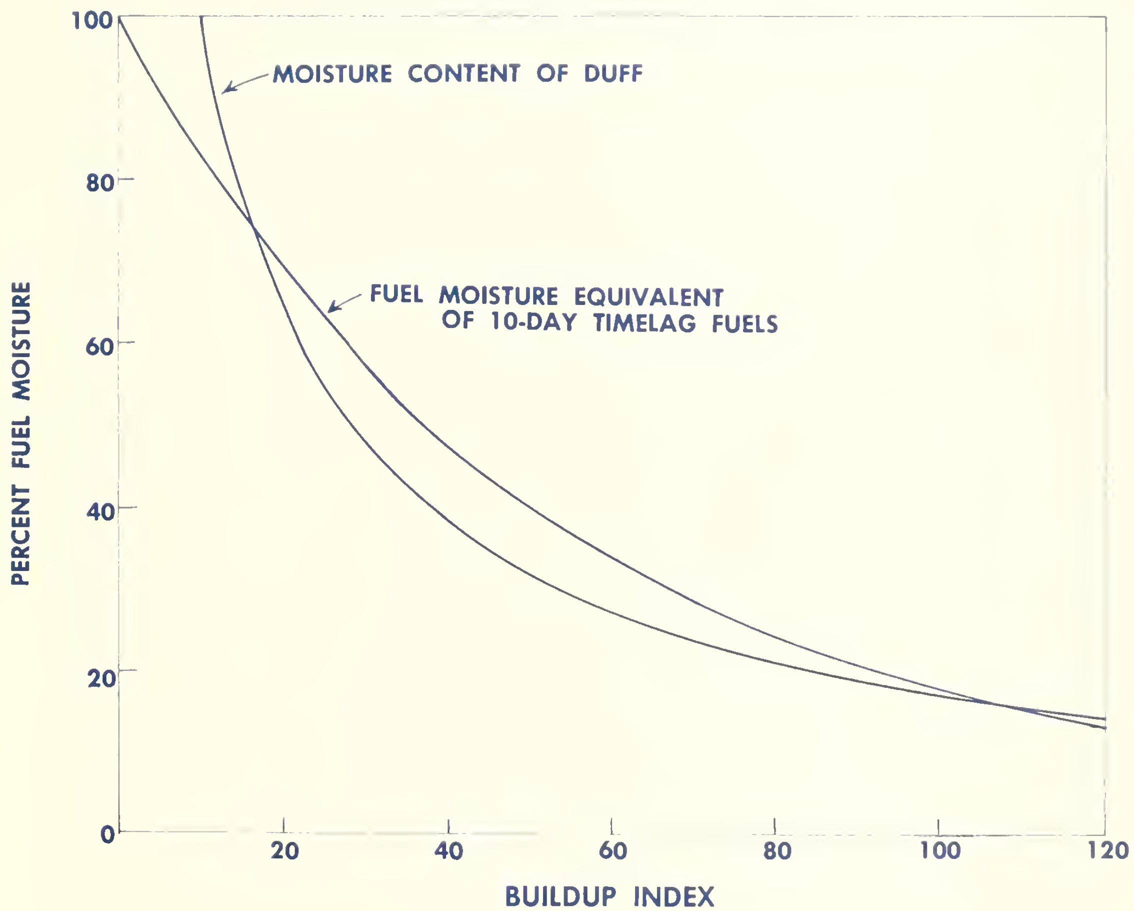

Figure 2.—(1) The moisture content (MC) of duff compared to the (2) fuel moisture equivalent of 10-day timelag fuels (see text footnote 5 for source of data) when both are plotted over Buildup Index. The equations for the trend lines are:

(1) $1/\%\ MC = .0047 + .00053\ BUI. \quad r^2 = 36,\ N = 126$

(2) $MC = (100 - 5) \,/\, \left[(2.71825)^{\frac{BUI}{50}}\right] + 5$

fuels having a saturated moisture content of 145 percent and drying to an equilibrium moisture content of 15 percent.

This study did not establish that there is a reliable relationship between the full range of litter and duff moisture and the higher values of Buildup Index. The equation for 25- and 90-year-old red pine and aspen-oak (fig. 1) may be used, however, in similar stands as an indicator of the trend in moisture content of litter and duff fuels during late spring and summer. The indicated relationship becomes less reliable as the litter and duff approach the estimated 15-percent equilibrium moisture.

We still do not know precisely what fuel moisture levels are needed for controlled fire to remove specific quantities of forest floor material, nor do we know how various physical and chemical characteristics of fuel influence fuel moisture. Continued use of Buildup Index and fine fuel moisture[6] for describing burning conditions will, however, strengthen our understanding of the relationship between fuel moisture and fire effects.

[6] *Table 1.—Fine Fuel Moisture. U.S. Forest Serv. Form 5100-24 (2/64).*

1968

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U. S. FOREST SERVICE

RESEARCH NOTE NC-44

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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A Dual-Range Strain Gage Weighing Transducer Employing Automatic Switching

ABSTRACT.—Describes a dual-range strain gage transducer which has proven to be an excellent weight-sensing device for weighing trees and tree-length logs; discusses basic principles of the design and operation; and shows that a single transducer having two sensitivity ranges with automatic internal switching can sense weight with good repeatability and that one calibration curve serves the entire ambient temperature range in which it is used.

The Station's Forest Engineering Laboratory at Houghton, Mich., is engaged in research to promote the mechanization of woods harvesting operations. Current mechanization efforts involve the use of harvesting machines that handle full trees or tree-length logs and can perform several processing and handling operations.

To improve the design of these machines, information is needed on the weight and location of the center of gravity of the various forest tree species. To the author's knowledge, only one report has been published on the subject.[1]. The Laboratory is now cooperating with the Department of Forestry at Michigan Technological University on a study to obtain this type of information.

This Note reports on a unique transducer which is being used as the weighing device in the cooperative study[2].

The Problem

The basic problem was to design a transducer with adequate sensitivity for weighing full trees and tree-length logs which have a wide range of weights due to variability of tree size, form, and specific gravity within and between species. Furthermore, the transducer had to function with satisfactory repeatability (give the same readings for any given weight) and accuracy within tolerable limits over a temperature range of 10° to 90° F.

The expected maximum and minimum loads were established as 8,000 pounds and 100 pounds respectively. Because a single-range transducer designed for the maximum expected load would not be sensitive enough at the low end of the weight range, a transducer with two weight ranges, 0 to 2,000 and 2,000 to 8,000 pounds, was designed.

A dual-range transducer was chosen rather than two transducers (one for each weight range) to reduce rigging and hookup time in the field. Depending on the equipment being used, the hourly field costs could range from $20 to $30 per hour. Although the dual-range transducer is more complex than a single-range transducer, the combined cost of its construction and calibration was estimated to be only slightly more than that for two single-range transducers. The potential savings for in-the-field operation made the dual-range transducer a logical choice. The machining and assembly time for the transducer, including mounting the strain gages and wiring, was approximately 35 hours.

The Design

The dual-range transducer employs a tension rod with two different sized sections on which strain gages are mounted (fig. 1). Separating the two strain gage sections is an enlarged section that serves as the automatic switching device and controls the proportion of straining between the strain-gaged sections.

The transducer rod is housed in a steel capsule with a rigid surface on which the shoulder of the

[1] *Keen, R. E. Weights and centres of gravity involved in handling pulpwood trees. Pulp Pap. Res. Inst. Can., Woodlands Res. Index 147, 93 p. 1963.*

[2] *Gary Viegelahn of the Engineering Mechanics Department, Michigan Technological University, made a number of helpful suggestions in the design of the transducer.*

rod comes to bear for loads greater than the maximum low-range load. The transducer rod and the containing capsule were made from the same material to insure equal thermal expansion. This point is critical if the transducer is used under varying ambient temperatures. If two different materials were used, the transducer calibration would be subject to change with temperature because of the differences in thermal expansion. Different materials having equal coefficients of thermal expansion are satisfactory.

The basic operational concept is that loads in the low-weight range are measured mainly in the small-diameter section (section A in fig. 1) and those in the high-weight range are measured mainly by the large-diameter section (section B). For any given load in the low-weight range, the small-diameter section elongates more than the larger section. This causes a greater change in resistance of the strain gages mounted on the small-diameter section and thereby a greater detectable change in the Wheatstone bridge output.

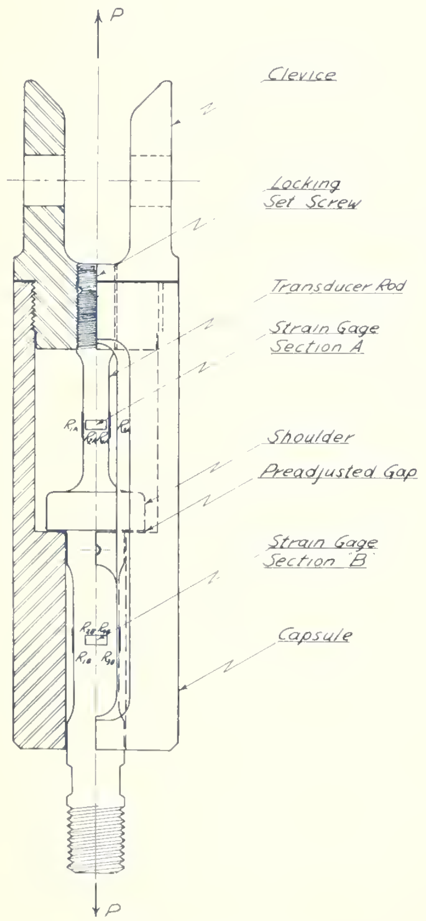

Figure 1.—Transducer assembly.

For loads in excess of the low-weight range, the transducer rod shoulder bottoms out within the transducer capsule and prevents the small-diameter section from being strained any further. Due to small imperfections in machining and alignment and the elasticity of the steel, bottoming out does not occur at a finite load but rather as a gradual transition between the two ranges (fig. 2).

The transducer capsule was designed so that the location of the zone of transition could be controlled by setting a predetermined gap between the bottom of the shoulder and the rigid bearing surface. This gap was set with a feeler-gage, and the transducer rod was locked in place with a set screw (fig. 1). This method for setting the predetermined gap may seem relatively crude; however, Section A of the transducer was sized so that it would be strained to only about one-third of the yield point at a gap setting of .0015 inch. Even if the gap were set at .003 inch (variations of .001 inch are detectable with feeler gages), the strain level would still be well below the yield point.

The gap was determined by making use of the following basic relationships between stress and strain for uniaxial loading.

$$\varepsilon_{y.p.} = \sigma_{y.p.} / E$$

where

$\varepsilon_{y.p.}$ = strain at the yield point,
$\sigma_{y.p.}$ = stress at the yield point,
E = modulus of elasticity.

To prevent overstraining and hysteresis effects, a safety factor of three was used, thus the allowable strain level is given by:

$$\varepsilon_{allow} = \varepsilon_{y.p.} / 3$$

The magnitude of the gap setting is obtained by multiplying the allowable strain by the gage length of Section A of the transducer rod.[3]

$$\text{Gap} = \varepsilon_{allow} \times \text{Gage Length}$$

As previously indicated, it is *not* required that the gap be set such that the strain will be *exactly* one-third of the yield point strain, but only approximately that value. The important point is that once the approximate gap has been set, there *must* be a positive means to lock the transducer rod in the capsule so that the no-load gap does not change with handling. This is required to provide repeatability.

[3] *Gage length in this case is taken as the net length of the small-diameter section.*

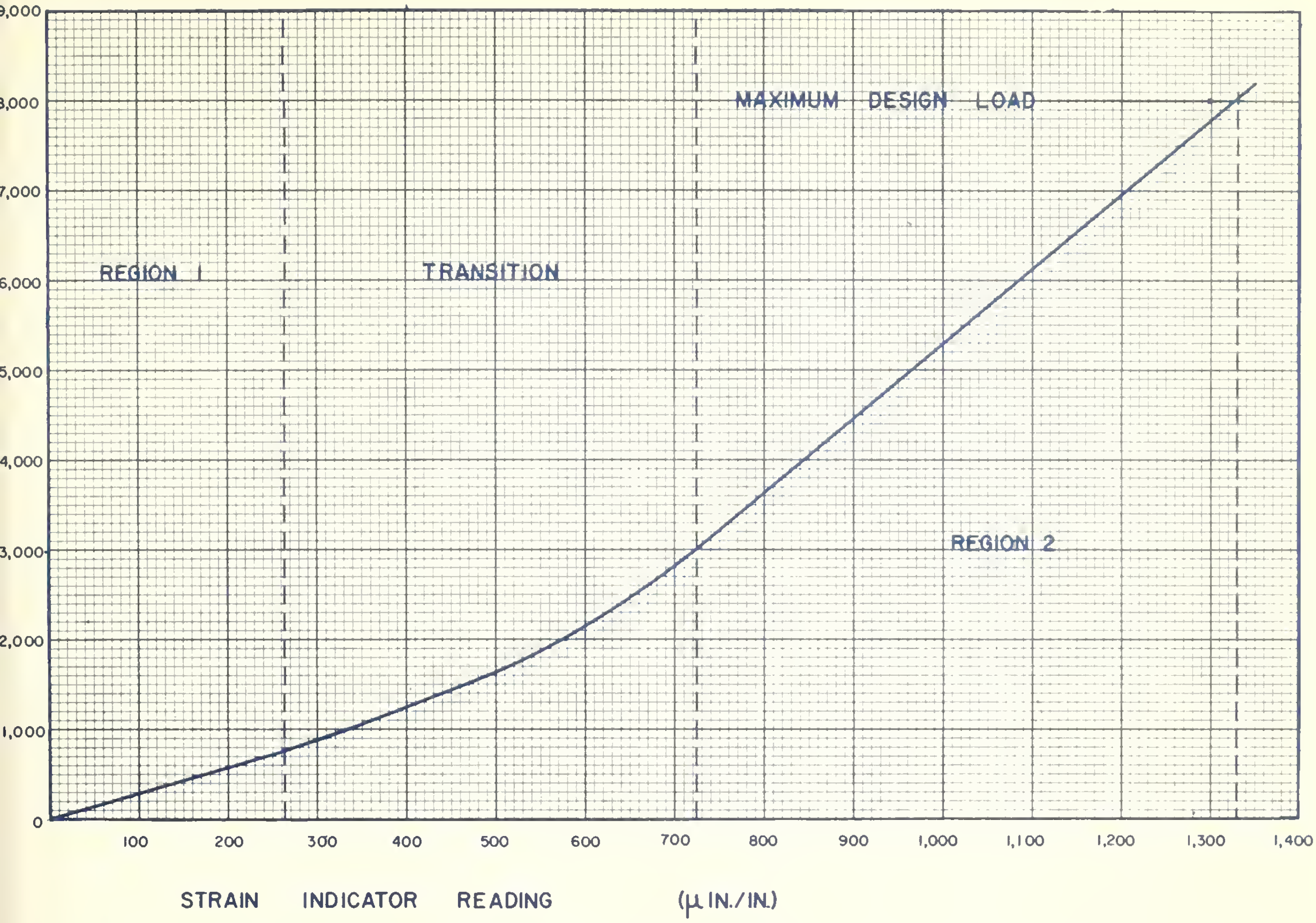

Figure 2.—Calibration curve for dual-range weighing transducer. The low-weight range falls within the area designated above as Region 1, the high-weight range in Region 2.

The diameter for each of the transducer rod sections is obtained by using the following formula,

$$d = 2\sqrt{\frac{P}{\pi E \varepsilon_{allow}}}$$

where

d = diameter of section (inches)
P = maximum design load of section (pounds).

Circuitry

Four 120-ohm SR-4 strain gages were mounted on each reduced diameter section of the transducer rod. Two of the gages in each section are mounted parallel to the longitudinal axis of the transducer rod and the other two are mounted at 90° to the longitudinal gages (Poisson arrangement). The longitudinal gages in Sections A and B are labeled R_{1A}, R_{3A}, and R_{1B} and R_{3B} respectively. Similarly the Poisson gages are R_{2A}, R_{4A}, and R_{2B} and R_{4B} (fig. 3). This gage arrangement provides for automatic temperature compensation and eliminates the effects of bending. Observation of the physical arrangement in the bridge circuit shows that the total output of the bridge is affected by the amount of axial strain in both Sections A and B.

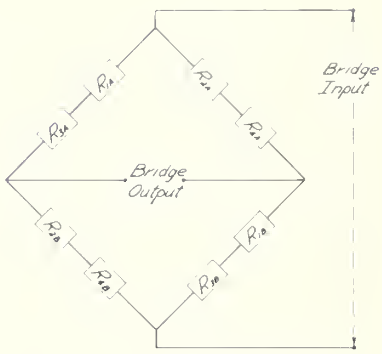

Figure 3.—Wheatstone bridge arrangement of strain gages.

The transducer was calibrated on a standard Tinus Olsen testing machine. The transducer output is linear in the low- and high-weight ranges and nonlinear in the transition region (fig. 2). The chronology of the bridge output is as follows. In the low range both gage sections are strained and therefore both contribute to the bridge output—the largest contribution coming from the more heavily strained Section A. At the transition load there is a knee in the load-strain curve. During the transition stage the small-diameter section takes less of any additional load on the transducer. After complete bottoming out occurs, the gages in Section A are strained a constant amount since no further increases in load will be carried by the small-diameter section. The large-diameter section, however, continues to be strained with increasing loads, and all further changes in the bridge output are a result of straining the gages in Section B.

The change in strain per unit of load in the low-weight range is greater than the change in strain per unit of load in the high-weight range (fig. 2). For the calibration curve shown, the sensitivity in the low-weight range was 0.349 (μ inch/inch)/pound as compared to a sensitivity in the high-weight range of 0.144 (μ inch/inch)/pound;[4] the first being about 2.5 times more sensitive than the second. This transducer design therefore has greater accuracy for weights in the low range than would a transducer employing only a single diameter tension rod capable of measuring weights up to 8,000 pounds. If a single diameter rod (Section B) were used, the entire calibration curve would have a constant slope equal to that shown in the high-weight range (fig. 2).

The transducer was tested under laboratory controlled conditions in the temperature range of 16° to 65° F., and the same calibration curve as shown in figure 2 was obtained over this range of temperatures. This was expected, however, since the transducer was temperature compensated; and it was therefore concluded that one calibration curve would be satisfactory for the entire temperature range, 10° to 90° F., in which it would be used.

Typical results from the log weight study for which the transducer was designed are shown in figure 4. A battery-operated portable strain indicator was used to monitor the indicated strain readings. The individual components of the transducer are shown in figure 5.

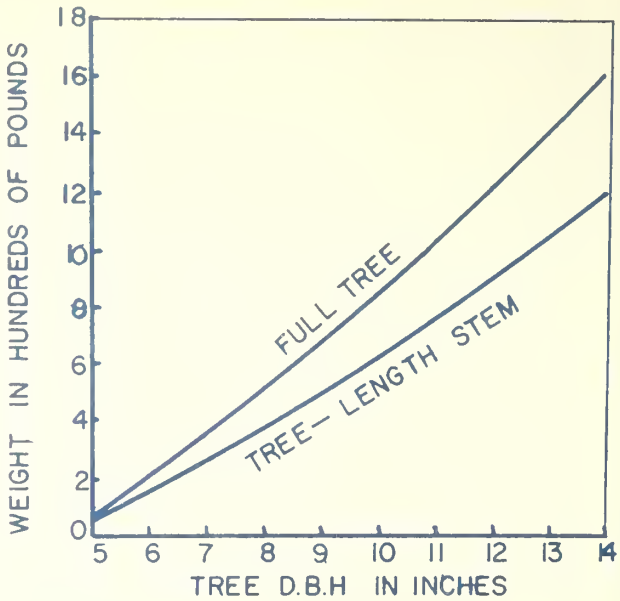

Figure 4.—Weight of full trees and tree-length stems versus tree DBH for 39 aspen trees.

F-516677

Figure 5.—Transducer components.

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Forest Engineering Laboratory
Houghton, Michigan (field office maintained in cooperation with Michigan Technological University)

[4] *1 μ inch = 10^{-6} inches.*

U. S. FOREST SERVICE

RESEARCH NOTE NC-45

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

A Computer Program for Displaying Forest Survey Type Information

ABSTRACT.—Presents a computerized procedure for displaying forest type information from inventory plots. Although the development of general forest type maps is emphasized, the program can be used to display any locational data having rectangular coordinates.

Forest type maps of large areas are generally made from aerial photographs by skilled photo-interpreters. This method is fast, efficient, and fairly low in cost. However, photo quality and the skill of photo-interpreters vary, and some forest types change between the time of photo-flight and mapping. Therefore, forest type information collected by field crews would generally provide a more accurate type map.

For this reason, a computer program to display forest type data collected by field crews has been written. Although the use of a computer as a mapping aid is not a new idea,[1] this program is unique in that it locates plots so that the computer run can easily be used by Forest Survey in developing general forest type maps.

Description of Program

Program AUTOMAP (Automatic Mapper) operates on the rectangular coordinate system used to identify all Forest Survey plots.[2] Each plot is identified by specifying its section number, township, range, and principal meridian; and the forest type is identified by a standard two-digit numeric code. A punched card containing this information is entered into the computer and located to the nearest quarter township. The program internally converts each numeric code into a single alphabetic character code which is displayed on the printed page. A single page of output represents 10 ranges in width (60 miles) and 8 townships in length (48 miles).

Prior to processing, the cards must be ordered from the most northwestern township and range to the most southeastern township and range referenced by a particular principal meridian. Plots referenced by different principal meridians must be processed separately.

Program AUTOMAP is written in Fortran IV (E Level) for an IBM 360/30. Input to

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[1] *For additional references on automatic mapping techniques, see two papers by E. Amidon published by the Pacific Southwest Forest and Range Experiment Station: A computer-oriented system for assembling and displaying land management information, U.S. Forest Serv. Res. Pap. PSW-17, 34 pp., 1964; and MIADS2—An alphanumeric map information assembly and display system for a large computer, U.S. Forest Serv. Res. Pap. PSW-38, 12 pp., 1966.*

[2] *A description of the rectangular coordinate system can be found in the Manual of Instructions for the Survey of the Public Lands of the United States issued by the General Land Office of the Department of the Interior in 1939, and revised in 1947 by the Bureau of Land Management. The system is applicable in most of the United States.*

MAINTAINED IN COOPERATION WITH THE UNIVERSITY OF MINNESOTA

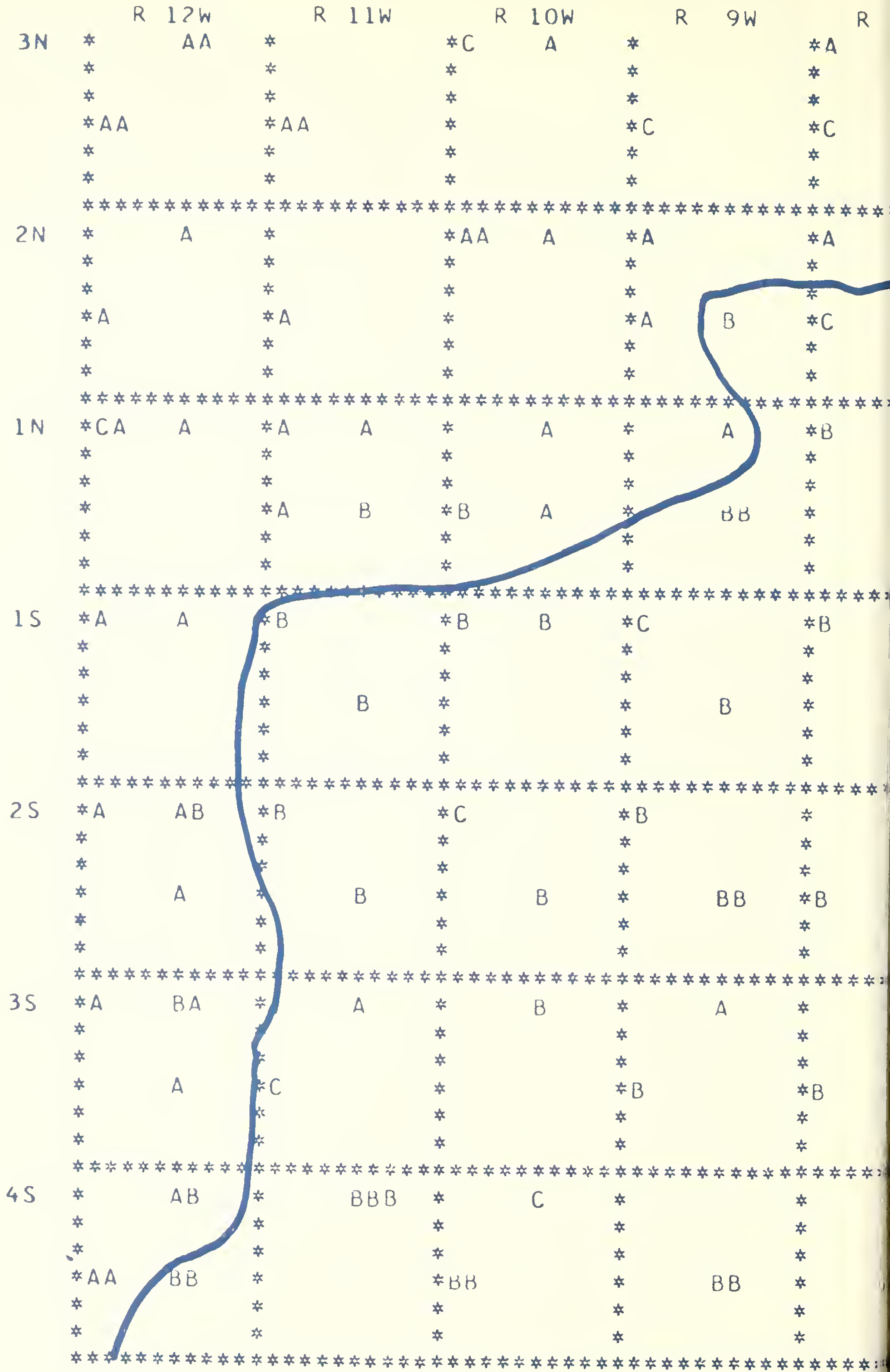
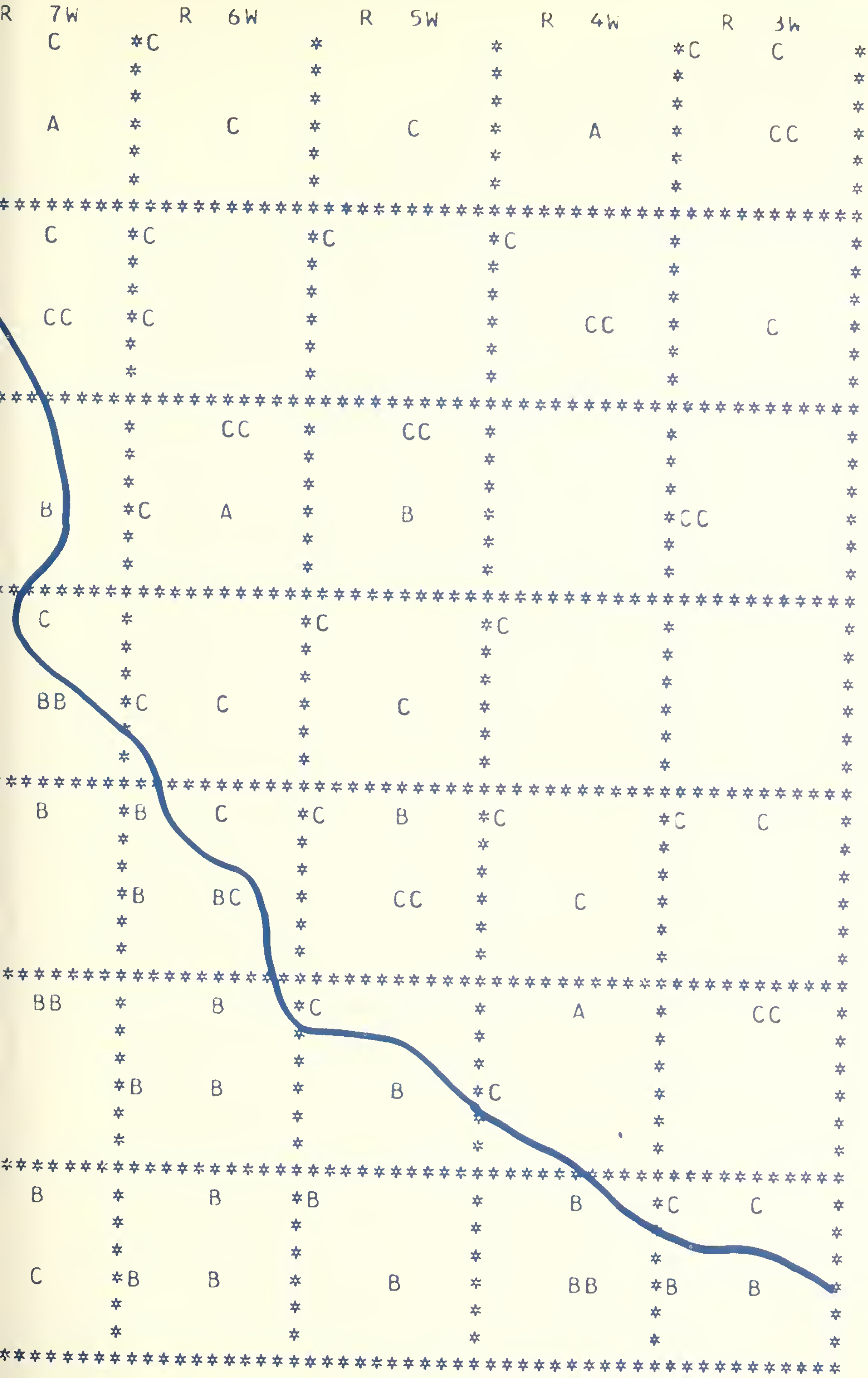


Figure 1.—Computer output showing the loca
and forest type of 175 plots. A table (not sh
here) of the internal numeric and external alp
betic coding schemes is printed at the beginnin



computer run. The codes shown here are:
ine type; *B*, spruce-fir type; and *C*, aspen-birch
The lines separating the three general types
hand-drawn.

the computer is on standard 80-column cards, and all output is printed on a line printer. No tape units or other peripheral devices are needed.

Example

An area extending from range 12W to 3W and from township 3N to 4S provides an example. A field crew has measured 175 sample plots. The necessary control cards are prepared,[3] and the plot cards prepared, sorted, and run. The forest type codes used are as follows:

Type	*Numeric and aphabetic codes*	
Pine		
White pine	03)	
Red pine	02)	A
Jack pine	01)	
Spruce-fir		
White spruce	16)	
Black spruce	12)	B
Balsam fir	11)	
Aspen-birch		
Aspen	91)	
Birch	92)	C

[3] *A source deck listing and instructions for setting up the control cards and for making the sort can be obtained from the Station.*

The sample output shown in figure 1 illustrates several important items. The townships are separated from each other by lines of asterisks to make the display more readable. Each township is divided into quarters, and seven lines of the computer output are allotted to each township. The forest type code of any plot or plots in the township appears on either the first or fourth line. For instance, township R3W - T4S has four plots in it, one in each quarter-township. The forest type lines are drawn in by hand on the computer output. This example, of course, is an extremely small-scale representation of reality. Normally the Forest Survey measures several thousand plots in each state. To display these plots by hand would be most time consuming.

Possible Applications

Throughout the development of AUTOMAP, the principal goal was to provide a method for displaying forest type data collected by field crews. However, AUTOMAP can be used for other purposes. For example, survey plots with a certain volume, basal area, cutting priority, or site quality can be displayed. In fact, any data can be displayed, so long as the rectangular coordinates of the different locations are known.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-46

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Use Hardwoods for Building Components

ABSTRACT.—Describes a system for prefabricating structural units from hardwoods for use in floors, roofs, and walls of A-frame or post-and-beam type construction. The interior face of the unit is decorative paneling; the exterior face is sheathing. Use of the system could reduce prefabricated house construction costs compared to conventional construction costs.

In recent years factory-built houses and house construction components have gained popularity because of on-site construction speed and lower costs. Most are made from softwood construction lumber and plywood, softwood laminated beams and decking, and softwood siding.

In the eastern hardwood regions of the United States the question has been asked: "Can local hardwood lumber be used for prefabricated building components?" To answer this question the North Central Forest Experiment Station at Carbondale, Illinois, and the Forest Products Technology Department at the Vocational Technical Institute of Southern Illinois University designed and built prefabricated red oak combination roof-floor-wall units for a 24- by 36-foot A-frame house.

Design

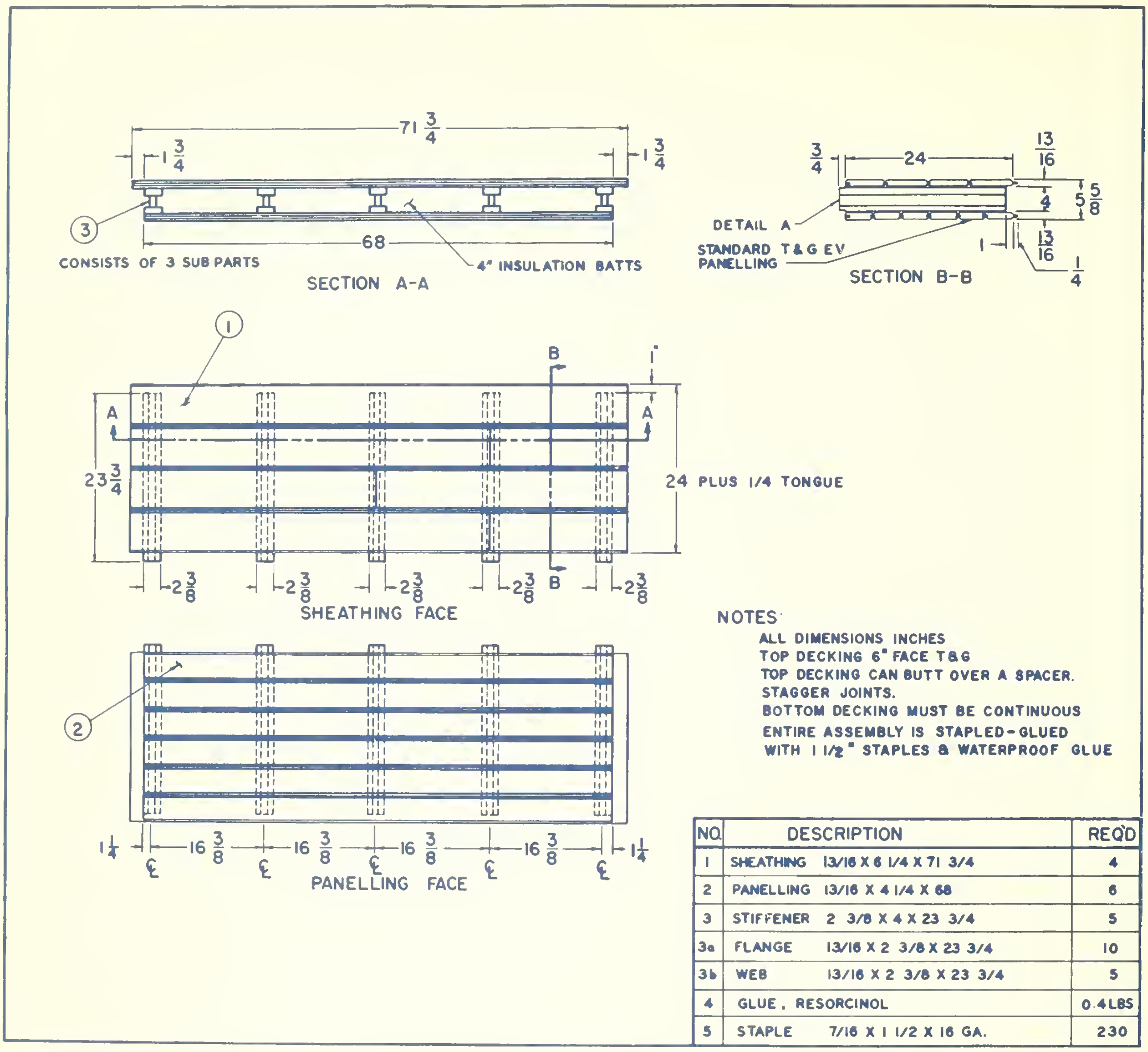
We chose red oak to utilize its strength for exterior sheathing and subflooring and its beauty for interior paneling. Several test units were made (1) to work out design details for a unit that would be interchangeable for walls, roofs, and floors in A-frame or post-and-beam construction, and (2) to establish that the units would safely span 6 feet with a 40-pound-per-square-foot live load. We decided on a 2-foot-wide unit with a 4-inch opening between faces to accept insulation and stiffeners. Because the interior faces of the units were to be exposed as finished paneling, and the sheathing or subflooring faces were not, we used six clear or sound 4-inch-wide boards on the paneling face and four 6-inch-wide lower quality boards on the sheathing faces (fig. 1). The use of two widths and two grades improved the utilization of random width No. 2 and No. 3 Common lumber.

Manufacture

We made 225 units (the number required for our A-frame) from No. 2 and No. 3 Common 4/4-inch red oak lumber kiln-dried to 10-percent moisture content. The paneling was first rough milled from random length, random width lumber to ⅞-inch-thick, 4⅜-inch-wide, and 70-inch-long cuttings, and the sheathing to ⅞-inch-thick, 6⅜-inch-wide, and 73-inch-long cuttings. Four-inch-wide cuttings for the paneling admitted sound character marks only, without holes. Six-inch-wide cuttings for subflooring or roof sheathing admitted sound defects and holes up to ½ inch in diameter. The rough cuttings were dressed, center-matched, and V-grooved on a molder to 13/16 inch thick. A ¼-inch tongue-and-groove pattern was machined on all cuttings. Sheathing was double-end-trimmed to 71¾ inches so it would overlap the A-frames set on 6-foot centers, and paneling was trimmed to 68 inches to fit between the A-frames.

Waste from rough milling the sheathing and paneling was used to make 4-inch-deep, 23¾-inch-long I-beam stiffeners for the units. Top and bottom flanges were tenoned (fig. 2) to form an interlocking tongue between adjacent units. Flange and web dimensions were made equal to simplify manufacture.

The units were assembled in a jig using 1½-inch staples driven by a pneumatic gun to provide gluing pressure for a cold-setting resorcinol resin adhesive. First, one flange of the I-beam was staple-glued to the web in an I-beam assembly jig; then the paneling was clamped in place in a unit assembly jig with the best faces down. Next, the preassembled I-beams (single flange and web) were staple-glued 16⅜ inches on center to the panel boards from the inner side of the unit so fasteners would not show on the



NO.	DESCRIPTION	REQ'D
1	SHEATHING 13/16 X 6 1/4 X 71 3/4	4
2	PANELLING 13/16 X 4 1/4 X 68	6
3	STIFFENER 2 3/8 X 4 X 23 3/4	5
3a	FLANGE 13/16 X 2 3/8 X 23 3/4	10
3b	WEB 13/16 X 2 3/8 X 23 3/4	5
4	GLUE, RESORCINOL	0.4 LBS
5	STAPLE 7/16 X 1 1/2 X 16 GA.	230

Figure 1.—Plan of combination roof-floor-wall unit, developed by Wood Products Pilot Plant, North Central Forest Experiment Station, U.S. Forest Service, in cooperation with Vocational Technical Institute of Southern Illinois University, design by William W. Rice, drawn by Charles Gaddis. For details of I-beam stiffener (flange and web), see figure 2.

paneled face. Then 4-inch insulation batts were placed between the I-beams, and the top I-beam flange was staple-glued in place. Finally, sheathing deckboards were staple-glued to the upper flange of the beams. Staple heads were exposed on the faces where roofing and finish flooring would cover the units.

The 225 units required 11,607 board feet of No. 2 Common and 351 board feet of No. 3 Common lumber (table 1). This lumber cost $968, and the yield was 64 percent. Labor, adhesive, staples, and insulation cost $672. Thus, total direct costs were $1,640, or $0.607 per square foot, to produce 2,700 square feet of combination roof-floor-wall units.

A-Frame Installation

To minimize weather damage to the interior of the A-frame, the roof units were installed first. Beginning at the first-floor level, units were installed with the tongued edge up. Successive courses of roof units were lifted into position and engaged with the tongues on the units already in place. Each unit weighed about 90 pounds, and they were easily set into place by two men with a rope and hooks. When

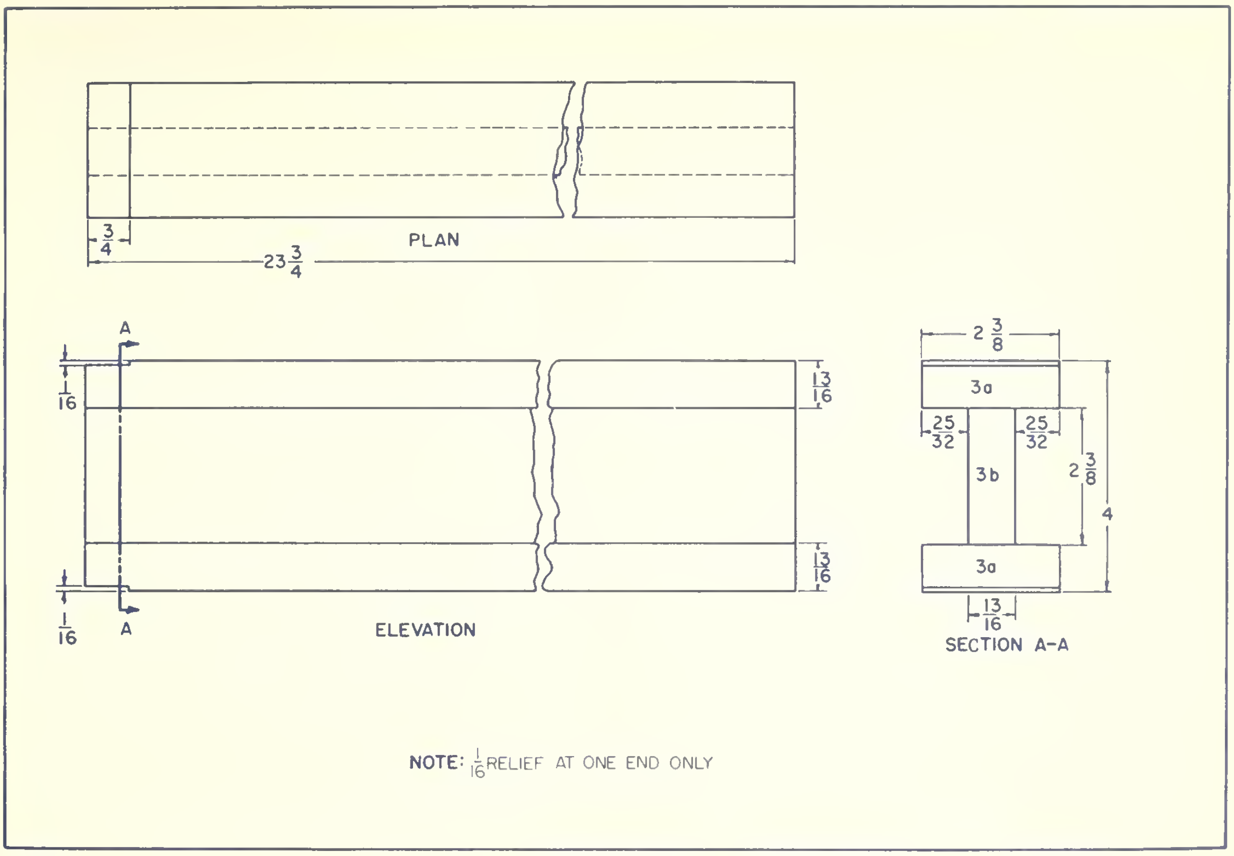


Figure 2.—Detail of I-beam stiffener.

Table 1.—*Prefabrication and installation costs for 225 combination units for an A-frame building, using 4/4 red oak lumber*

Item	Cost (dollars)
Lumber:	
No. 2 Common, 11,607 bd. ft.	940.67
No. 3 Common, 351 bd. ft.	27.13
Adhesive, 27 pounds	27.81
Staples, 2,500	6.00
Insulation, 2,000 sq. ft.	135.00
Labor for milling and assembly	1/ 503.19
Total direct production costs	1,639.80
Installation labor and equipment	1/ 250.80
Total cost	1,890.60
Cost per sq. ft. of unit:	
Before installation	0.607
After installation	0.700

1/ Costs are adjusted to industry wage scales and production levels, and include operation and depreciation of equipment.

a unit was firmly engaged with the one below, the sheathing board ends were nailed to the A-frame beams with a portable pneumatic nailer (fig. 3). Sixteen nails per unit (2 nails per board end) were driven by one man in about 20 seconds.

Floor units were installed in a similar manner (insulation batts were omitted from the second-floor units). At the ridge and where floors butted to the sloping roof, individual panel or sheathing boards (or both) and insulation batts were added to close gaps. Total installation cost for labor and materials was $251. Total installed cost of the panels was $1,891, or $0.70 per square foot of roof and floor area.

Post-and-Beam Installation

For post-and-beam construction, we estimate a wall, roof, or floor unit of the type used, covering 12 square feet, could be installed between wall posts, roof, or floor beams in about 3 man-minutes by two men. If units are installed on roof or floor beams, the sheathing faces of the units constitute the roof sheathing or subflooring, and the panel faces are the

Figure 3.—Installing roof units on A-frame beams with a portable pneumatic nailer.

Figure 4.—Combination units. Shows I-beam stiffeners and insulation in place. Visible face is solid red oak paneling.

ceiling paneling (fig. 4). The sheathing face of the units can be papered and shingled as in conventional construction. Strip flooring can be applied directly to the floor units; but parquetry, blocks, or linoleum should have an underlay of hardboard or plywood. The exterior face of wall units could be covered with siding as desired.

Besides the advantages of rapid construction with combination roof and floor units, labor and material is saved in framing. Beams are placed on 6-foot centers compared with the 16-inch centers required with joists or rafters. Walls and ceilings with solid hardwood paneling, if applied over conventional framing, would be prohibitively expensive for many homeowners. But combination units of this type manufactured from No. 2 Common hardwood lumber puts solid hardwood paneling within the reach of most homebuilders.

At $0.70 per square foot of wall or floor, we estimate a prefabricator-contractor team, using combination units, could make and install a conventional post-and-beam or A-frame house shell, including siding and roofing, for about $7 per square foot of floor space. We believe this is less than the usual cost for conventional prefabricated, installed shells with insulated walls and ceilings in a comparable state of completion.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-47

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

The Influence of Residual Stand Densities on Regeneration in Sugar Maple Stands

ABSTRACT.—Studies of regeneration 2, 5, and 10 years after cutting mature and overmature sugar maple stands to several residual densities show that (1) sugar maple is still the predominant species under all stand densities (2) nearly all regeneration reaching larger size classes became established before cutting (3) heavier cuttings (30, 50, and 70 square feet) are more rapidly making up deficits in sapling and pole sized classes than the lightest cutting (90 square feet).

Regeneration of sugar maple in northern hardwood stands in the Lake States is generally a simple matter (Eyre and Zillgitt 1953): Usually 15,000 to 30,000 seedling-size sugar maple per acre occupy the forest floor under mature uncut stands (U.S. Forest Serv. 1929), and many of them will develop after partial cutting. The number that develop and their rate of growth, however, can be influenced to meet the requirements of different forest management objectives by changing overstory densities. This Note describes seedling development under different degrees of overstory removal and briefly discusses the possible consequences for management.

In 1951 a stocking-level study was begun in Upper Michigan in mature northern stands that averaged about 80 percent sugar maple. Residual stand densities in trees 10 inches d.b.h. and over were 30, 50, 70, and 90 square feet of basal area per acre. Seedlings and saplings were measured under these overstories at 2-, 5-, and 10-year intervals on 1,000 quarter-milacre plots.

RESULTS

Five-year results reported by Church (1960) indicated that seedlings developed in about the same manner regardless of the overstory treatment. Ten years after cut, however, marked differences were apparent. Numbers of seedlings 6 to 35 inches tall decreased greatly under the lighter overstories, but increased slightly under 90 square feet. In contrast, the larger seedlings (36 inches tall to 0.5 inch d.b.h.) increased greatly in all densities except the 90-square-foot level (fig. 1).

About half of the smallest seedlings had appeared after cutting, but more than 99 percent of the larger seedlings were advance regeneration.[1] Trees up to 36 inches tall 10 years after cutting ranged from 5 to 35 years old and averaged about 12 years. Measurements of seedling internode lengths under overstories of 50 to 90 square feet showed that, on the average, seedlings grew more slowly under the denser overstory. However, under 90 square feet, removal of fewer trees resulted in fewer openings, less uniform overstories, and more variation in seedling growth than the heavier cuttings produced. Seedlings and saplings in openings in the 90-square-foot area apparently grew about as well as those in the less dense stands.

[1] *John H. Cooley; unpublished report on file at the North Central Forest Experiment Station, Marquette, Mich.*

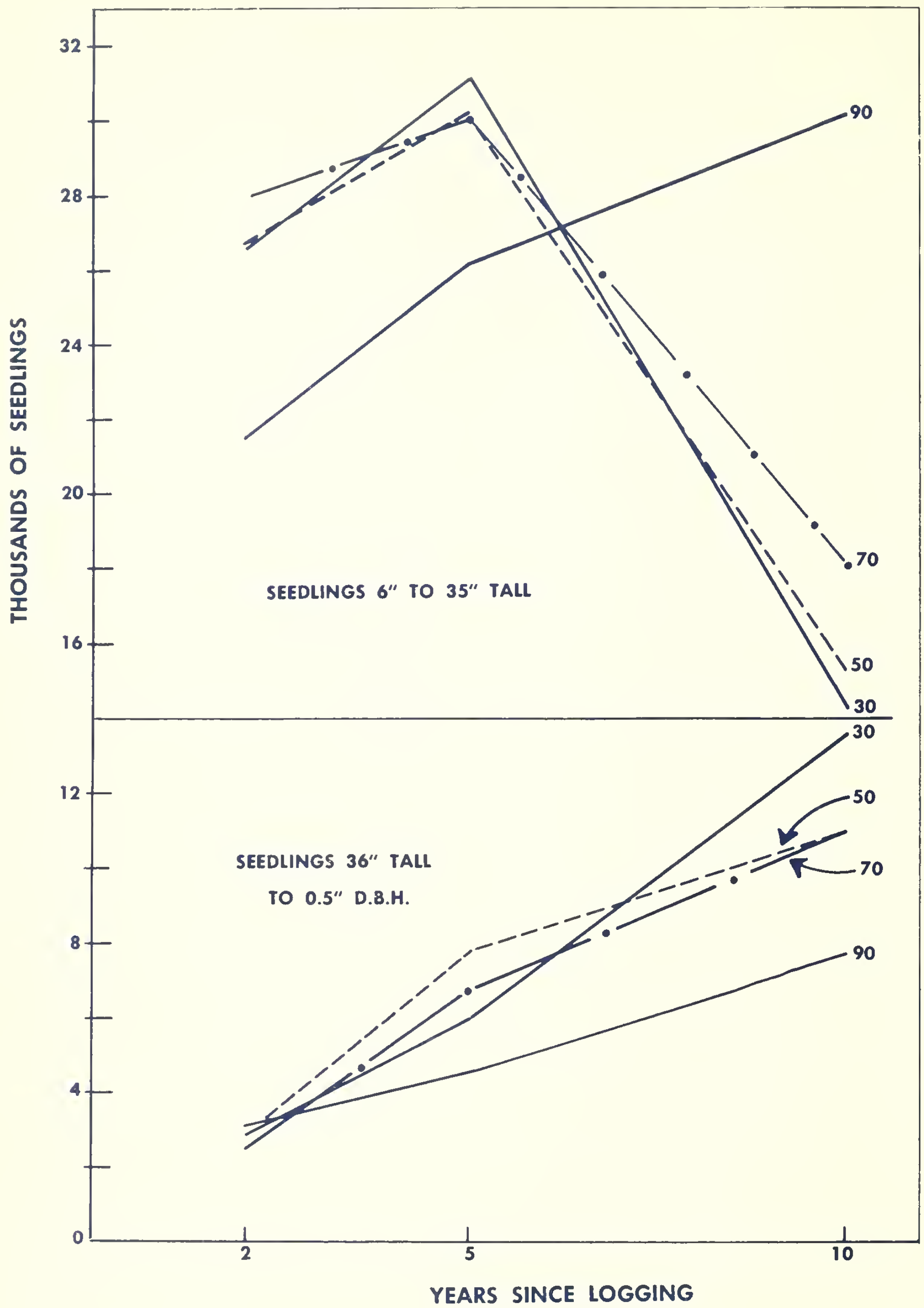

Figure 1.—Abundance of seedling reproduction under different levels of residual overstory (30, 50, 70, and 90 square feet of basal area)

Seedling development added to the next larger size class (table 1). In 10 years the number of 1-inch saplings per acre had increased from less than 100 in all stand densities to more than 1,000 in the 30- and 50-square-foot densities, more than 700 in the 70-square-foot density, and about 550 in the 90-square-foot density. The seedling growth stimulated by removal of the overstory had not greatly influenced other inch classes, but growth of the saplings added to the pole-size class (table 2).

Ten years after cutting, overstory density had only slightly influenced the number of quadrats stocked with species other than sugar maple. The lightest overstories (30 and 50 square feet) had 8 percent more quadrats stocked with yellow birch than the heaviest cutting had (90 square feet). Overstory density also had little effect on the total numbers of birch, and most of those are in the smallest size class. Sugar maple remains the predominant species, accounting for 90 percent of the seedlings and 75 percent of the saplings.

Table 1.—Summary of sapling-sized reproduction per acre 2, 5, and 10 years after logging, by tree size and residual stand density

DBH (inches)	Years since logging	Number of trees under a stand density (sq. ft. of basal area) of-- 30	50	70	90
1	2	90	52	81	101
	5	160	103	186	179
	10	1,052	1,071	717	545
2	2	35	34	47	31
	5	55	44	55	39
	10	104	103	89	77
3	2	20	16	21	27
	5	35	30	34	27
	10	36	36	51	27
4	2	20	10	16	13
	5	10	12	14	16
	10	12	1	21	20

Table 2.—*Change in number of poles per acre by residual basal area*

Residual basal area (sq. ft.)	Number of poles: At time of cut	Number of poles: 10 years later	Number of saplings that grew to pole size	Number of poles that grew to sawtimber size
30	36	50	27	11
50	32	50	28	10
70	34	49	24	9
90	31	42	19	7

DISCUSSION

Many mature sugar maple stands are deficient in both sapling and pole-sized material. The study indicates that the three heaviest cuttings will make up the deficit soonest. However, regeneration reacted in much the same fashion under 30, 50, and 70 square feet of overstory; there is little reason for reducing the overstory below 70 square feet to provide more stems for future timber products. Furthermore, if present trends continue, the future promises an overabundance of poles in the heavier cuttings, possibly requiring repeated thinning of a low-value product.

The abundance of sugar maple and small number of relatively intolerant species such as yellow birch point to the difficulty in significantly changing composition solely by manipulating the overstory on sites that initially support large numbers of sugar maple. The slight additions of other valuable species such as yellow birch on the heaviest cuttings probably would not outweigh the anticipated loss in quality of the overstory sugar maple (Eyre and Zillgitt 1953), which is also a valuable species. The advanced age of the seedlings and their ability to respond to release illustrates sugar maple's aggressiveness and high tolerance rating and explains why other species do not become established after cutting.

Because the three heavier cuttings should initially provide more fast-growing seedlings, more succulent material will be available for browse; but rapid growth would reduce the time this material is available.

Esthetically, the 90-square-foot stand appears more parklike than any of the heavier cuttings, which have dense understories of up to 14,000 seedlings over 3 feet tall and 1,000 or more saplings per acre. Stands of 90 square feet, however, support about 6,000 seedlings and saplings per acre in patches that are sometimes extensive enough to destroy the parklike vista. Higher residual overstory basal areas probably will be necessary in any stand to be maintained for recreation use.

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1968

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U. S. FOREST SERVICE

RESEARCH NOTE NC-48

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Deer Browse Production of Oak Stands in Central Lower Michigan[1]

ABSTRACT.—The extensive oak forests of Lower Michigan provide essential habitat for whitetailed deer and other wildlife. Clearcutting these stands results in high browse production (500-1000 lbs./acre) compared to uncut stands (200-500 lbs./acre). Most browse in uncut stands is under 18 inches tall, whereas much of that in open stands is above snowline and thus available in winter.

Forest communities in which oaks are the dominant trees occupy approximately 30 percent of the forest area and 60 percent of the sawtimber area in the Manistee National Forest and adjacent state and private forest lands in the western half of central Lower Michigan. A few oak stands are being converted to pine; others are managed for oak. But the only management practiced in the majority of the stands is fire protection. Because of the proximity of the forest to major centers of population and the increasing pressure for hunting and other recreational activities, wildlife relationships are important. This report describes deer-habitat components of a variety of oak stands ranging from closed old-growth to recently cut and open stands. Emphasis is placed on food production for white-tailed deer.

Historical records and tree age data indicate that the areas included in our study supported pine-oak mixtures which were cut and burned between 1880 and 1900. Since then the "closed" stands of this study developed and have not been cut. Those designated as "open" stands developed after more recent cutting and burning (fig. 1).

Methods

Seven areas, which ranged in size from 19 to 25 acres, were selected to represent a variety of ecological situations. Six of the areas were in or adjacent to the Udell Experimental Forest (Manistee County) or in the Pine River Experimental Forest (Wexford County); the seventh was in Newaygo County. Soils of the six sample areas on flat or undulating terrain can be classified in the Rubicon-Grayling Sand Plain Association; the seventh (Stand 1) on the slope of a moraine is in the Roselawn Sand Association. These soils have common characteristics: perviousness and low retention of moisture, high silicon content, acid reaction, and relatively low natural fertility.[2]

In each area the vegetation was sampled at points 30 to 40 feet apart. Plot layout was based on these points. Since a single plot size does not serve to measure all plant characteristics efficiently, especially when a variety of life forms is involved, plots of four different kinds were used as follows:

1. All woody stems greater than 1 inch d.b.h. were recorded by species and d.b.h. on plots 20 by 50 feet.
2. Leaf and stem cover (in two height categories: 18 inches to 10 feet and over 10 feet) was recorded along 50-foot line transects placed through the center of the 20x50-foot plots.
3. The number of stems from 18 inches in height to 1 inch d.b.h. were tallied in plots 3.3 feet square (¼ milacre). Within these same plots the annual growth (both stems and leaves) of all browse plants 18 inches to 6 feet in height was clipped and weighed.
4. The amount of browse from woody plants and forbs below 18 inches in height was determined by clipping and weighing material from a plot 3.3 by 1.6 feet nested in each larger 3.3-foot-square plot. Eighteen inches was chosen as the breaking point since snow depths greater than that preclude digging for low browse by deer and since a natural break in shrub height occurs at that level.

Browse was weighed in the field and results are presented as green weight. Samples of browse dried and weighed at intervals indicated that for most

1 *This study was a joint effort of the Lower Michigan National Forest, Michigan State University, and the North Central Forest Experiment Station. Field work was done by Larry Lehman and Paul Matthiae. The assistance and guidance provided by George W. Irvine are gratefully acknowledged.*

2 *Veatch, J. O. Soils and land of Michigan. Mich. State Coll. Press, 241 p. 1953.*

Figure 1.—(*Top*) Stand 1, a mixed oak stand 70 to 80 years of age in the Udell Hills near Wellston, Michigan. (*Bottom*) Stand 5, a residual mixed oak stand one year after a commercial clearcut in 1964; near Wellston, Michigan.

species dry weight was 50 percent of fresh weight. The intensity of browsing was tallied in four categories: none, light, moderate, and severe for stems within the 3.3-foot-square plots. Deer pellet groups and other animal sign were recorded when present in each 20x50-foot plot. Field work was completed during the summer of 1965; and tabulations were made, using a program for automatic data processing developed for browse production studies.[3]

Results and Discussion

Data are presented for two stand categories: stands with essentially closed canopies, and open stands with little crown cover. Details of history, structure, species composition, and browse production are provided in tables 1, 2, and 3. The common and scientific names of plants mentioned are listed in table 4.

Closed Stands

These three stands represent advanced stages of forest development in which oak species are the overstory dominants. Although similar in age, the stands differ considerably in structure and stocking. This may be due in part to site differences and in part to the history of the specific areas.

Well-stocked, essentially even-aged pole stands such as Stand 1 (fig. 1) are typical of those on the moraines that form the Udell Hills. These stands are dominated by white oak and red oak. Similar pole stands (Stand 2) on flat or undulating terrain with sandy, well-drained, and infertile soils differ in composition chiefly in that red maple is more abundant. The dense crown cover in these pole stands results in relatively low production of woody browse (table 3). Exceptions occur where stocking is reduced early in stand development, resulting in a partly open stand of larger trees (Stand 3). In such low-density stands with a relatively high canopy, browse production may be much greater than in the better stocked, older pole stands.

In these stands most of the browse is less than 18 inches in height and thus often below the snow line. Acorns, a supplemental food, are abundant on the ground in years of high production. Therefore, food for deer is available for consumption during the fall, late spring, or summer, but not so readily in winter. However, it is not logical to assume that woody browse above 18 inches tall is the only available winter food. If this were the case, these stands would provide meager fare indeed. In central Lower Michigan, snow depths vary greatly and in some winters low browse is extensively utilized by deer. The tree crowns provide ample summer cover. Since none of the closed stands included conifers, effective winter cover is lacking, a situation common throughout the oak type.

Open Stands

In the open stands large quantities of browse were produced, both above and below the 18-inch level, mainly by white and red oak, black cherry, red maple, sweetfern, and blueberry (table 3).

The open communities are representative of successional stages in the early development of oak stands, following disturbance. Where oak and red

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[3] *Manuscript on this automatic data processing program is in preparation at the Station.*

Table 1.—*Structure and history of the oak stands*

Stand number and history	Age	Basal area per acre	Height of codominants	Tree stems per acre with d.b.h. of-- 2"-8"	8"-18"	Crown cover above 10'	Browse per acre	Future stand type
	Years	Sq.ft.	Ft.	No.	No.	Percent 1/	Pounds 2/	
CLOSED STANDS (no recent disturbance)								
1. Well-stocked pole stand on moraine	70-80	94	56	391	70	127	351	Mixed oak
2. Pole stand, level sandy terrain	55-80	81	55	479	49	119	216	Oak - red maple
3. Open stand on good site	55-65	50	80	48	42	69	575	Mixed oak
OPEN STANDS								
4. Clearcut and burned 1935	24-30	30	18	301	5	34	857	Open - mixed oak
5. Clearcut 1964-65	1	26	1-2	299	4	36	535	Mixed oak
6. Clearcut 1962	3	24	3-8	188	0	20	976	Oak - red maple
7. Overstory cut 1955	10	29	4-10	256	7	37	863	Oak - red maple

1/ Percentage of line transect occupied. 2/ Green weight including stems and leaves of high and low browse.

Table 2.—*Crown cover expressed as a percentage of line transect occupied*

Species	High cover--over 10 feet: Closed stands 1	2	3	Open stands 4	5	6	7	Low cover--18 inches or less: Closed stands 1	2	3	Open stands 4	5	6	7
White oak	28	31	26	18	15	4	14	4	4	4	14	4	6	11
No. red oak	59	39	21	2	9	1	5	7	4	1	2	1	3	1
No. pin oak	19	7	16	3	4	1	-	-	(1/)	(1/)	2	(1/)	1	-
Red maple	17	36	2	2	7	12	15	4	10	1	1	7	3	8
Black cherry	-	1	-	8	-	(1/)	-	-	1	-	7	(1/)	(1/)	-
Bigtooth aspen	4	5	3	1	-	1	3	(1/)	(1/)	-	-	(1/)	8	(1/)
Juneberry	-	-	-	-	(1/)	1	-	-	2	-	-	1	(1/)	2
Sassafras	-	-	1	-	-	-	-	1	1	1	-	(1/)	(1/)	(1/)
Witchhazel	-	-	-	-	1	-	-	9	-	4	-	1	-	-
Total	127 4/	119 4/	69	34	36	20	37	26 2/	22	13 3/	26	14	21	22

1/ Trace. 2/ Includes 1% blueberry. 3/ Includes 2% huckleberry and traces of blueberry and sweetfern. 4/ Cover over 100 percent results when several layers are present.

Table 3.—*Browse production presented as green weight of stems and leaves (Pounds per acre)*

Species	Browse under 18 inches: Closed stands 1	2	3	Open stands 4	5	6	7	Browse 18 inches to 6 feet 1/: Closed stands 1	2	3	Open stands 4	5	6	7
White oak	1	14	1	4	175	22	83	-	2	-	102	49	257	147
No. red oak	9	6	-	-	12	17	41	-	17	21	-	33	233	3
No. pin oak	1	1	18	(2/)	1	-	-	2	-	-	79	-	-	-
Red maple	6	3	6	-	6	(2/)	14	13	20	-	5	40	9	97
Black cherry	(2/)	1	-	21	5	58	5	-	2	-	40	9	30	-
Bigtooth aspen	-	-	-	1	-	17	-	-	-	-	-	1	129	-
Juneberry	-	2	(2/)	-	8	3	9	-	1	-	-	13	-	-
Sassafras	44	55	8	-	55	3	14	13	10	1	-	-	-	3
Sweetfern	-	80	59	289	31	140	280	-	6	(2/)	-	-	-	2
Blueberry	184	14	322	316	65	52	160	22	-	-	-	-	-	-
Huckleberry	11	-	102	-	-	-	-	2	-	31	-	-	-	-
Wintergreen	14	2	3	(2/)	1	6	5	-	-	-	-	-	-	-
Witchhazel	-	-	3	-	-	-	-	29	-	-	-	32	-	-
Total	270	178	522	631	359	318	611	81	58	53	226	177	658	252

1/ Woody stem material alone averages 15 percent of the total and ranges from 10 to 20 percent.
2/ Trace.

Table 4.--Common and scientific names of trees, shrubs, and herbs mentioned in this report

Common name	Scientific name
TREES	
Bigtooth aspen	Populus grandidentata Michx.
Black cherry	Prunus serotina Ehrh.
Juneberry	Amelanchier spp.
Red maple	Acer rubrum L.
White oak	Quercus alba L.
Northern red oak	Q. rubra L.
Northern pin oak	Q. ellipsoidalis E. J. Hill
Sassafras	Sassafras albidum (Nutt.) Nees
SHRUBS AND HERBS	
Blueberry	Vaccinium angustifolium Ait.
Honeysuckle	Lonicera spp.
Huckleberry	Gaylussacia baccata (Wang.) K.Koch
Sweetfern	Myrica asplenifolia L.
Witchhazel	Hamamelis virginiana L.
Wintergreen	Gaultheria procumbens L.

maple stands have been cut or burned, most tree reproduction will develop as clumps of sprouts from the cut stumps and from severed saplings. Generally, in commercial cuts (Stands 5, 6, and 7) a few pole-size oak and red maple remain, but these trees do not interfere with rapid development of sprout clumps and browse (tables 2 and 3, fig. 1).

Browse production begins to increase the first growing season after cutting, and this increase continues for several years. The stump sprouts grow rapidly, and their contribution to browse production will decrease as the stems grow out of reach, perhaps by the end of the fifth or sixth year. Low-browse production will continue heavy as long as enough light is available for growth. In these oak stands a closed canopy appears to develop slowly (table 2) especially where logging was followed by fire (Stand 4); and hence a high level of browse production is maintained for as many as 20 or 30 years (table 3).

Amount of Browsing

In both open and closed stands the amount of browsing is influenced both by the quantity of material present and by the proximity of areas of coniferous cover in which deer might winter. In most stands oak species, blueberry, sweetfern, and sassafras were lightly or moderately browsed while red maple and aspen were heavily browsed. Browsing pressure in a few areas such as Stand 4 may be heavy enough to retard the development of tree regeneration, thus keeping the stand open.

Variability of Data

Browse production on individual plots varied widely. For tall-browse samples (including both stem and leaves) obtained on 1/4-milacre plots, the standard error of the mean averaged 44 percent of the mean for closed stands and 39 percent of the mean for open stands (range from 33 to 59 percent). In samples of low browse on 1/8-milacre plots the average standard error of the mean was 24 percent of the mean in closed stands and 26 percent in open stands (range 16 to 39 percent). Considering the clumped distribution of stump sprouts and of shrub stems in particular, this variability does not appear excessive.

Conclusion

The production of browse for deer is an important phase of multiple-use management in the oak stands of the Manistee National Forest and adjacent areas. Our data and observations suggest that clearcut areas often provide large quantities of food. Full utilization of this browse depends upon such factors as cover and snow depth. Blocks of conifers for winter cover could extend the period of use of the browse. At present most browsing amounts to a light thinning of the sprout clumps and has not greatly affected the growth of the oaks and red maple which will be the dominant species of the new stands.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-49

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Regeneration of Cutover Jack Pine Stands

ABSTRACT.—Jack pine can be regenerated on mineral soil seedbeds by scattering cone-bearing branches or repellent-treated seed. On some areas where competition develops, the seedlings may need to be released between the third and fifth years.

Past experiments to develop low cost techniques for regenerating jack pine have shown promising results when seeds or cone-bearing branches were scattered on mineral soil seedbeds (Eyre 1936, LeBarron and Eyre 1938, LeBarron 1944). One large-scale trial on the Chippewa National Forest was also successful (Zehngraff 1943).

The two tests reported here provide additional examples of satisfactory regeneration of jack pine obtained by these techniques. And since these studies were installed, the Superior National Forest has used the methods with good success on a number of areas. Similarly, in Manitoba, Canada, Cayford (1966) reports successful cone scattering and seeding trials on seedbeds prepared with mechanical equipment.

Planting usually gives more satisfactory results than scattering cones or seed, largely because planted seedlings have a head start on the other vegetation and their roots have a larger soil volume from which to draw moisture during the first few years. But planting is costly and this high investment may not be justified except on the better sites—sites that usually should be planted to a more valuable species such as red pine. Therefore, on sites where it is desirable to regenerate jack pine following the harvest of a mature stand, the techniques described in this Note are recommended.

Study Methods

In 1957 a pilot-scale regeneration study of scattering cone-bearing branches on mineral soil seedbeds was established in northeastern Minnesota. The study was replicated in three jack pine stands between the ages of 80 and 90 years. Stand densities ranged between 89 and 120 square feet of basal area per acre, and all three stands had light to medium shrub cover in the understory (fig. 1). The organic layer above the mineral soil averaged between 1.8 and 2.6 inches.

A heavy-duty disk was used to prepare seedbeds by exposing mineral soil on some plots prior to logging and on others following logging (fig. 2). Disking after logging exposed mineral soil on 48 percent of the area compared to 38 percent where the disking was done before logging. Plots that were logged but were not disked had mineral soil seedbeds on only 9 percent of the area.

Cone-bearing slash was scattered on the disked seedbeds. When this was done concurrently with disking, it required only 3.6 man-hours per acre; but when it was done as a separate task as was necessary on the areas disked before logging, it required 12.6 man-hours per acre. Most of this extra time was

F-517701

Figure 1.—Study areas in Minnesota prior to logging had 80- to 90-year-old stands of jack pine with a shrub understory of light to medium density.

F-517702

Figure 2.—Mineral soil seedbeds in the Minnesota study were prepared with this heavy-duty disk.

used to locate cone-bearing slash or mineral soil seedbeds. Cones distributed by logging only were found on 71 percent of the mil-acres, and scattering the cone - bearing branches increased this to over 90 percent.

In 1960 another version of this technique was tested in three areas in the Upper Peninsula of Michigan. Mineral soil seedbeds were prepared by scalping, and jack pine seed was scattered on the scalped seed spots. The areas had been clear cut earlier, removing pole-sized jack pine stands that were classed as medium stocking. The shrub cover was a very light stand of scattered blueberry; and the slash was 3 months, 1 year, and 3 years old on these areas at the time of site preparation.

The scalping was done with an "Imset scarifier" manufactured in Sweden. This machine prepared an average of 468 scalps per acre, each approximately 2 feet wide, 2 to 6 feet long, and 6 inches deep. The variation in length of scalps was caused by stumps or slash that tripped the scarifier blades before the preset 6-foot interval was reached. However, the average size of scalps was about the same on the three areas, indicating that the age of the slash was not important in the operation.

Jack pine seed was sown on each area at the rate of 8 to 10 seeds per scalp. The seed was treated with chemical repellents, arasan and endrin, to protect it from seed-eating birds, rodents, and insects.

Results

Regeneration surveys at the end of 1, 3, and 5 years showed the importance of seedbed preparation (table 1). Areas that were logged without any additional seedbed treatment were far below all other treatments in percent stocking. After 3 years the areas that were disked or scalped after logging were adequately stocked, and the areas disked before logging averaged only slightly below the arbitrarily established minimum of 60 percent stocking.

However, during the next 2 years the stocking declined on the disked areas of the Minnesota study. The light to medium shrub cover and some aspen reproduction were beginning to compete with the jack pine seedlings. In the Michigan areas, which had only a light to sparse shrub cover and also had scalped seedbeds, stocking continued to increase through the fifth year.

Table 1.—*Percent stocking*[1] *by kind of treatment*

Treatment	Years after treatment		
	1	3	5
Log only	6	9	11
Log, disk, scatter cones	53	60	45
Disk, log, scatter cones	53	56	42
Log, scalp, spot seed	51	66	74

1/ Based on milacre plots except for scalp treatment which is based on number of scalps.

Discussion

These studies illustrate several important requirements for regenerating jack pine: exposing a mineral soil seedbed, distributing cones or treated seed on the prepared seedbeds, and releasing the seedlings from other vegetation. Although each of these operations will not be equally important on all areas none of them should be overlooked.

Mineral soil seedbeds have been prepared with many kinds of mechanical equipment and undoubtedly many new kinds will be developed. At present, some of the more common equipment includes the shearing blade, rock rake, and Rapp cultivator. A heavy-duty disk, as was used in the Minnesota study, was perhaps the most popular a few years ago. The Imset scarifier used in the Michigan study was a forerunner of the Rapp cultivator. Whatever kind of equipment is used to prepare the seedbed, two major objectives should be: (1) to permit the tree seed to make contact with the mineral soil, where moisture conditions are considerably more stable than in the humus layers during the critical period of seed germination; and (2) to eliminate or sufficiently reduce the existing vegetation so that tree seedlings have a better chance to compete for moisture, nutrients, and light.

Scattering cone-bearing branches or repellent-treated seed on the prepared seedbeds provides a better opportunity for seedlings to become established. Whenever cone-bearing slash is readily available, it can be scattered on the seedbeds by one man directly behind the scarifying equipment. On areas where cones are scarce or difficult to utilize, sowing repellent-treated seed is recommended.

Although these studies did not test the benefits of releasing the seedlings, they indicate that competition may be important in some cases. The difference in the development of competing vegetation between these two studies is similar to the results from another study where disking and scalping were tested:[1] After 3 years the oven-dry weight of competing vegetation averaged 43 percent greater on seedbeds prepared by disking than on those prepared by scalping. But even on the seedbeds prepared by scalping, the seedlings would undoubtedly have benefited from release as they had nearly three-fourths as much competition as those on unprepared areas. Therefore, the most efficient equipment available should be used to prepare a mineral soil seedbed, and the seedlings should be released when necessary, usually between the third and fifth years.

[1] *Study NC-192 in files of the North Central Forest Experiment Station, Grand Rapids, Minnesota.*

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U. S. FOREST SERVICE

RESEARCH NOTE NC-50

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Michigan's Timber Volume

ABSTRACT.—Michigan's timber volumes increased about two-fifths since 1955 reaching 15.0 billion cubic feet of growing stock including 33.7 billion board feet of sawtimber-size material in 1966.

Michigan's timber volume increased 40 percent between 1955 and 1966 to 15.0 billion cubic feet of growing stock (table 1) and 33.7 billion board feet of sawtimber (table 2). While most stands are still young, they are approaching full stocking. Net annual growth in 1966 was 31 cubic feet per acre for growing stock and 105 board feet for sawtimber, up from 26 and 60, respectively.

During the 11 years between the two surveys, all species and species groups increased in growing stock (or total cubic foot) volume except the elms (fig. 1). Timber volume accumulated most rapidly in the northern Lower Peninsula. Only in the southern Lower Peninsula where the Dutch elm disease was serious and many heavily stocked stands were lost to urban development and highway construction, did timber volume decline. In 1966, the State's growing stock was about equally divided between the Upper and Lower Peninsulas. The largest growing stock volumes were found in the Upper Peninsula counties of Marquette, Ontonagon, Iron, Chippewa, Gogebic, and Baraga.

In terms of total volume, aspen is still the most abundant species in Michigan, comprising 15 percent of the growing stock. But its position is being challenged by sugar maple whose volume is increasing more rapidly. Sugar maple has already attained first place in the Upper Peninsula. The oaks make up 10 percent and red maple 8 percent of growing stock. Softwoods comprise slightly over one-fourth of the growing stock volume, having gained about 2 percent on the hardwoods since the last survey. Northern white cedar is the most abundant softwood, accounting for 6 percent of total volume.

Turning from growing stock to sawtimber volume, we find a slightly different situation. Sugar maple is by far the leading sawtimber species in Michigan, comprising 17 percent of the volume. The oaks account for 12 percent and hemlock 8 percent. The aspen-paper birch group showed the most rapid growth; aspen sawtimber volume more than doubled during the 11-year period.

Approximately half the growing stock and sawtimber volume of sugar maple, yellow birch, and hemlock in the State is found in the western Upper Peninsula. Aspen and the red and jack pine volume is heavily concentrated in the northern Lower Peninsula; beech is concentrated in the eastern Upper Peninsula.

Volume of all diameter classes has increased since 1955 but the largest rise has been in poletimber-size trees (fig. 2). Much improvement in quality of sawtimber trees may be expected as the wave of second growth (developed in closed stands) moves into the larger diameter classes.

Statistics presented here are from the second and third forest surveys of Michigan authorized by Congress and conducted by the U.S. Forest Service in cooperation with the Michigan Department of Conservation and others. The statistical accuracy is ± 1.2 percent (2 times out of 3) for growing stock volume and ± 2.4 percent (same basis) for sawtimber volume.

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Table 1.—*Volume of growing stock[1] on commercial forest land, by counties and species groups,[2] Michigan, 1966*

(Million cubic feet)

County	All species	SOFTWOODS						HARDWOODS					
		White pine	Other pine	Spruce	Balsam fir	Hem-lock	Other soft-woods	Aspen	Paper birch	Oak	Sugar maple-Yellow birch	Other soft Hard-woods	Other hard Hard-woods
EASTERN UPPER PENINSULA													
Alger	491.2	11.7	28.5	18.3	30.6	30.5	35.8	40.3	21.6	3.3	124.5	103.4	42.7
Chippewa	565.2	22.8	33.1	37.4	48.0	25.7	59.4	63.8	31.2	2.3	106.3	100.8	34.4
Delta	457.2	14.9	38.5	24.9	35.7	17.6	50.4	61.4	25.7	2.8	75.8	86.4	23.1
Luce	435.1	18.9	37.3	28.7	29.6	22.4	54.2	31.1	22.4	2.1	87.2	72.4	28.8
Mackinac	442.7	13.8	16.9	22.3	34.8	18.9	52.0	58.4	30.6	2.7	82.9	83.3	26.1
Menominee	409.4	13.5	13.3	23.7	32.4	17.7	59.4	44.9	25.1	4.2	73.4	79.8	22.0
Schoolcraft	494.0	23.4	42.3	28.3	35.2	25.3	45.2	43.7	25.0	2.5	95.1	96.8	31.2
Total	3,294.8	119.0	209.9	183.6	246.3	158.1	356.4	343.6	181.6	19.9	645.2	622.9	208.3
WESTERN UPPER PENINSULA													
Baraga	527.0	14.5	10.9	35.5	36.4	41.6	25.0	61.0	16.0	10.1	187.4	88.6	-
Dickinson	371.7	17.5	10.3	28.4	38.0	16.1	31.9	83.7	16.6	8.6	71.8	48.8	-
Gogebic	538.4	8.8	9.6	22.9	40.0	39.6	30.9	73.4	10.9	7.6	194.0	100.6	.1
Houghton	498.2	9.7	8.7	17.6	27.7	47.5	19.8	65.3	13.2	9.2	192.0	87.4	.1
Iron	591.3	22.5	7.6	43.2	47.0	39.1	30.1	100.1	21.6	10.3	180.4	89.4	-
Keweenaw	211.8	7.7	2.2	10.8	14.0	18.4	11.0	21.9	6.1	6.0	80.7	33.0	-
Marquette	939.9	43.2	35.8	79.8	67.7	64.3	70.0	119.8	31.9	24.7	268.0	134.6	.1
Ontonagon	614.1	12.8	6.9	22.5	39.0	41.6	24.2	115.8	17.9	10.8	208.0	114.5	.1
Total	4,292.4	136.7	92.0	260.7	309.8	308.2	242.9	641.0	134.2	87.3	1,382.3	696.9	.4
NORTHERN LOWER PENINSULA													
Alcona	269.8	4.4	10.9	5.7	12.6	3.7	23.8	64.0	16.6	47.1	15.1	50.5	15.4
Alpena	178.7	3.2	3.1	6.1	13.1	4.0	23.6	39.2	12.5	14.3	11.0	36.9	11.7
Antrim	145.2	1.9	6.5	1.4	3.1	2.7	8.3	26.8	6.9	20.1	19.9	34.7	12.9
Arenac	82.1	1.2	3.6	1.2	2.4	1.1	5.8	19.0	4.1	9.1	5.5	22.4	6.7
Bay	35.1	.6	.6	.3	1.1	.6	2.7	8.2	1.9	2.4	3.4	10.3	3.0
Benzie	117.6	1.3	2.5	.8	2.8	2.4	7.4	20.7	5.6	11.4	16.1	33.8	12.8
Charlevoix	165.0	2.1	2.3	1.8	4.5	4.0	12.6	30.8	7.9	14.5	26.1	41.8	16.6
Cheboygan	262.8	5.0	14.4	5.9	12.5	4.6	22.3	54.6	15.0	31.0	21.5	58.1	17.9
Clare	195.8	2.8	3.5	1.9	5.6	3.4	12.5	43.9	10.1	21.8	22.1	51.6	16.6
Crawford	197.3	3.5	27.0	1.6	4.8	1.9	10.4	32.2	8.7	53.4	12.6	31.4	9.8
Emmet	183.8	2.3	3.1	2.2	5.0	4.4	15.2	31.7	8.9	15.8	28.2	48.0	19.0
Gladwin	134.5	2.0	3.0	1.5	4.0	1.9	8.1	37.8	8.4	12.0	10.5	35.4	9.9
Grand Traverse	130.3	3.4	7.4	.8	2.1	2.5	6.7	17.2	5.7	25.9	16.2	30.7	11.7
Iosco	186.2	3.2	21.7	2.2	6.6	2.5	13.7	40.3	11.6	28.0	11.2	34.6	10.6
Isabella	80.1	1.2	1.4	.9	2.1	1.5	4.8	18.2	4.2	8.7	8.0	22.1	7.0
Kalkaska	205.8	4.3	19.3	3.3	8.1	3.9	16.9	32.8	11.9	26.7	21.7	41.9	15.0
Lake	202.4	3.9	15.5	.4	2.0	1.2	4.8	35.2	6.6	84.8	8.9	29.0	10.1
Leelanau	100.1	1.5	3.2	.7	2.4	2.2	4.9	19.3	6.9	8.6	16.2	24.7	9.5
Manistee	175.3	3.5	7.3	1.0	2.8	2.4	7.0	34.1	7.3	42.4	17.1	36.8	13.6
Mason	117.1	2.5	7.4	.4	1.2	1.9	3.4	19.5	4.5	30.0	12.9	24.3	9.1
Mecosta	110.6	1.9	3.3	.6	2.1	1.8	5.1	23.5	6.2	19.4	13.1	24.7	8.9
Midland	121.0	1.8	2.3	1.3	3.8	1.6	7.9	35.0	7.9	10.9	8.7	31.0	8.8
Missaukee	203.8	4.3	3.3	3.9	7.8	4.2	19.1	46.6	11.6	15.3	24.5	46.6	16.6
Montmorency	239.0	3.8	16.1	4.4	9.8	3.9	19.8	49.6	13.6	26.5	24.6	50.2	16.7
Newaygo	248.2	4.7	10.8	1.6	5.0	3.3	12.3	48.5	10.6	59.1	19.9	54.1	18.3
Oceana	117.0	1.7	4.7	.4	1.3	2.2	4.0	19.2	4.4	25.3	15.5	27.1	11.2
Ogemaw	180.0	2.7	14.1	1.5	4.2	2.7	8.4	35.3	8.5	38.9	15.6	36.1	12.0
Osceola	138.8	1.9	2.8	1.0	3.0	2.6	7.5	31.4	7.4	14.1	17.9	36.5	12.7
Oscoda	226.5	3.8	38.2	2.9	7.6	2.5	15.1	45.9	10.4	42.2	10.9	35.8	11.2
Otsego	205.0	3.5	6.9	3.1	8.4	3.8	18.9	48.2	12.6	17.4	23.4	44.2	14.6
Presque Isle	238.3	3.8	9.2	6.1	12.4	4.3	28.4	47.3	14.1	24.2	19.0	52.7	16.8
Roscommon	203.9	3.8	14.1	4.8	9.4	2.8	20.6	37.9	11.0	42.7	11.3	34.5	11.0
Wexford	175.7	2.5	10.9	1.1	3.8	3.3	9.3	35.1	8.2	20.6	23.8	42.2	14.9
Total	5,572.8	94.0	300.4	72.8	177.4	91.8	391.3	1,129.0	291.8	864.6	532.4	1,214.7	412.6
SOUTHERN LOWER PENINSULA													
Allegan	85.8	2.4	1.3	-	-	.8	1.0	5.7	1.1	23.3	6.4	30.0	13.8
Barry	64.2	1.3	.5	-	-	.2	.7	2.9	.3	23.4	3.6	19.8	11.5
Berrien	48.2	.9	.3	-	-	.2	.5	2.3	.4	16.3	3.3	15.7	8.3
Branch	38.4	.9	.1	-	-	.1	.4	2.3	.3	13.7	2.5	11.7	6.4
Calhoun	66.6	1.0	.3	-	-	.2	1.0	4.8	.6	21.9	3.1	22.3	11.4
Cass	53.4	1.0	.5	-	-	.2	.6	3.6	.4	18.5	3.9	15.4	9.3
Clinton	33.9	.8	.1	-	-	.3	.1	1.7	.1	9.4	2.8	12.6	6.0
Eaton	36.0	1.1	.2	-	-	.4	.3	2.1	.5	7.7	3.6	13.8	6.3
Genesee	41.2	.5	.2	-	-	.1	.6	3.2	.3	13.8	2.3	13.1	7.1
Gratiot	33.6	.7	.1	-	-	.2	.4	6.4	.6	7.0	2.0	11.6	4.6
Hillsdale	48.5	.8	.3	-	-	.2	.2	2.2	.4	16.7	3.2	16.1	8.4
Huron	45.6	.3	-	-	-	.1	.5	8.0	.8	7.9	2.0	19.6	6.4
Ingham	41.7	.7	.1	-	-	.2	.2	1.6	.1	12.5	3.7	14.6	8.0
Ionia	41.1	1.7	.4	-	-	.5	.4	2.6	.5	9.6	4.1	14.4	6.9
Jackson	61.7	1.0	1.0	-	-	.1	.5	3.2	.3	24.7	3.5	17.3	10.1
Kalamazoo	45.4	.7	.6	-	-	.1	.6	3.2	.4	15.7	2.4	14.2	7.5
Kent	82.1	2.0	.9	-	-	.6	.8	5.7	.8	24.1	7.0	26.3	13.9
Lapeer	51.4	1.2	.3	-	-	.3	.8	4.0	.7	15.1	3.2	17.1	8.7
Lenawee	41.3	.9	.2	-	-	.1	.3	1.8	.2	16.4	2.2	12.1	7.1
Livingston	58.7	1.0	.9	-	-	.2	.5	3.0	.5	24.0	3.4	15.9	9.3
Macomb	35.1	.7	.3	-	-	-	.4	1.7	.2	14.2	2.0	9.5	6.1
Monroe	23.1	.2	.2	-	-	-	.2	1.4	.1	5.5	1.3	10.2	4.0
Montcalm	92.7	2.0	1.2	-	-	.4	1.5	6.9	1.3	29.2	6.5	29.6	14.1
Muskegon	124.0	2.7	2.4	-	-	.4	1.6	8.1	.9	47.3	7.2	33.4	20.0
Oakland	83.7	1.4	.8	-	-	.2	1.3	6.4	.8	30.1	4.2	25.5	13.0
Ottawa	46.5	1.6	3.2	-	-	.3	.7	2.4	.2	16.3	2.9	11.7	7.2
Saginaw	70.2	1.4	.3	-	-	.3	.8	9.3	.8	16.9	4.2	25.9	10.3
St. Clair	52.9	1.3	.3	-	-	.4	.8	4.3	.6	15.3	4.4	16.9	8.6
St. Joseph	39.7	.6	.2	-	-	-	.4	2.4	.3	15.1	1.5	12.6	6.6
Sanilac	39.6	.8	.2	-	-	.2	.7	8.2	.6	6.4	2.4	14.5	5.6
Shiawassee	30.3	.9	.1	-	-	.3	.1	1.5	.3	7.4	3.2	11.0	5.5
Tuscola	66.5	1.2	.4	-	-	.2	.8	13.0	1.1	14.7	4.0	21.9	9.2
Van Buren	58.5	1.2	.8	-	-	.3	.7	3.6	.5	14.5	4.1	22.4	10.4
Washtenaw	57.2	1.0	.3	-	-	.3	.4	1.8	.2	22.2	4.3	16.3	10.4
Wayne	26.2	.6	.1	-	-	.2	.1	2.2	.2	8.2	2.0	8.6	4.0
Total	1,865.0	38.5	19.1	-	-	8.6	20.9	143.5	17.4	585.0	122.4	603.6	306.0
State Total	15,025.0	388.2	621.4	517.1	733.5	566.7	1,011.5	2,257.1	625.0	1,556.8	2,682.3	3,138.1	927.3

SEE FOOTNOTES ON PAGE 4.

Table 2.—*Volume of sawtimber*[1] *on commercial forest land, by counties and species groups,*[2] *Michigan 1966*
(Million board feet)[3]

County	All species	SOFTWOODS: White and red pine	SOFTWOODS: Hemlock	SOFTWOODS: Other softwoods	HARDWOODS: Sugar maple	HARDWOODS: Yellow birch	HARDWOODS: Select oak	HARDWOODS: Beech	HARDWOODS: Red maple	HARDWOODS: Basswood	HARDWOODS: Elm	HARDWOODS: Aspen and Paper birch	HARDWOODS: Other hardwoods
EASTERN UPPER PENINSULA													
Alger	1,295.6	112.5	156.8	161.3	315.3	93.7	9.0	166.9	96.8	22.7	38.5	79.6	42.5
Chippewa	1,283.6	182.9	132.3	210.1	255.3	77.1	5.0	133.2	73.6	21.2	35.5	102.6	54.8
Delta	973.9	145.7	90.7	181.3	162.0	56.4	4.6	84.8	55.9	17.4	26.9	93.4	54.8
Luce	1,100.8	172.7	115.3	199.5	218.8	70.2	5.4	113.2	68.8	14.5	25.0	61.9	35.5
Mackinac	974.8	118.3	96.0	169.5	185.5	59.1	5.1	98.3	57.1	17.6	25.7	95.6	47.0
Menominee	930.8	119.1	89.7	189.8	160.1	57.0	8.5	82.3	57.1	15.5	28.8	79.5	43.4
Schoolcraft	1,190.1	184.3	129.4	182.2	228.1	74.6	6.8	120.1	81.3	16.2	36.8	83.4	46.9
Total	7,749.6	1,035.5	810.2	1,293.7	1,525.1	488.1	44.4	798.8	490.6	125.1	217.2	596.0	324.9
WESTERN UPPER PENINSULA													
Baraga	1,434.0	104.4	213.4	225.9	439.7	133.1	26.5	-	69.2	29.3	49.3	111.6	31.6
Dickinson	873.1	123.1	83.8	251.0	152.6	48.4	15.7	-	30.4	10.4	21.5	113.4	22.8
Gogebic	1,132.6	59.4	168.0	167.4	371.2	114.4	17.4	-	52.0	28.2	44.3	77.0	33.3
Houghton	1,211.4	63.6	206.7	144.3	414.0	122.2	21.9	-	59.2	28.4	31.4	93.1	26.6
Iron	1,329.3	129.9	176.8	227.0	373.3	114.8	21.6	-	57.4	22.8	36.3	143.4	26.0
Keweenaw	615.0	50.9	97.9	87.4	198.2	60.5	12.8	-	30.6	10.1	15.4	41.2	10.0
Marquette	2,525.5	302.7	342.7	540.5	631.6	194.5	52.2	-	107.1	37.6	73.2	197.3	46.1
Ontonagon	1,298.4	78.6	184.5	182.5	410.8	116.2	21.1	-	60.9	28.9	45.8	131.0	38.1
Total	10,419.3	912.6	1,473.8	1,826.0	2,991.4	904.1	189.2	-	466.8	195.7	317.2	908.0	234.5
NORTHERN LOWER PENINSULA													
Alcona	454.0	36.7	16.0	47.1	21.4	2.3	74.8	14.5	27.3	15.8	38.6	88.8	70.7
Alpena	299.9	23.4	17.7	47.4	16.3	2.0	25.0	9.4	20.6	11.3	27.9	60.4	38.5
Antrim	284.8	14.4	13.2	15.9	34.9	1.4	37.3	22.3	16.7	18.4	29.9	43.0	37.4
Arenac	156.6	10.1	5.4	9.7	11.0	.9	14.6	6.3	17.8	8.7	21.6	27.2	23.3
Bay	69.3	3.9	3.1	4.6	6.1	.4	4.9	3.7	7.6	3.4	10.2	12.2	9.2
Benzie	258.2	10.9	12.7	11.7	31.5	1.4	24.4	23.0	24.2	18.8	34.9	33.4	31.3
Charlevoix	330.5	15.2	19.7	21.1	45.5	1.9	32.6	32.4	18.1	24.7	34.5	47.0	37.8
Cheboygan	468.1	38.4	20.2	50.5	31.7	3.0	52.7	19.4	35.0	21.0	50.4	81.9	63.9
Clare	380.1	21.8	15.6	22.3	36.8	2.2	41.7	23.5	32.1	24.6	44.8	65.1	49.6
Crawford	319.5	25.0	7.8	31.7	16.5	1.4	77.3	11.1	14.3	12.2	21.0	43.0	58.2
Emmet	381.5	16.9	22.2	25.5	51.6	2.3	34.9	36.3	21.1	27.4	43.8	52.3	47.2
Gladwin	251.0	17.0	8.7	15.0	18.0	1.2	22.4	10.6	24.4	12.9	32.2	53.6	35.0
Grand Traverse	276.8	21.2	12.5	13.8	31.1	1.1	40.0	22.6	20.6	18.6	30.5	28.8	36.0
Iosco	325.4	32.5	10.9	37.0	17.6	1.8	46.4	11.0	21.4	12.2	29.5	61.5	43.6
Isabella	165.2	9.0	7.4	8.4	16.0	.9	15.7	9.3	16.7	9.2	21.8	27.2	23.6
Kalkaska	371.5	33.7	18.0	40.7	34.6	2.2	44.6	21.4	21.4	20.0	34.9	54.7	45.3
Lake	359.8	26.4	5.3	12.7	15.0	.9	120.6	12.3	18.6	12.1	20.7	42.6	72.6
Leelanau	200.8	13.2	10.9	10.8	27.1	1.2	19.2	17.7	10.9	14.8	20.8	33.6	20.6
Manistee	350.7	24.8	12.1	13.6	32.5	1.3	65.9	25.0	20.0	20.5	34.3	48.6	52.1
Mason	237.0	17.4	10.0	8.5	25.0	1.0	45.5	18.3	11.8	13.6	23.6	26.6	35.7
Mecosta	225.3	14.7	9.2	9.6	23.1	1.0	37.0	16.0	12.4	12.2	22.9	35.0	32.2
Midland	217.8	16.2	7.0	14.0	12.2	1.1	19.9	7.6	20.8	10.2	26.9	50.4	31.5
Missaukee	381.7	31.3	20.0	31.6	42.6	2.0	32.4	24.7	20.4	23.4	33.0	76.2	44.1
Montmorency	412.2	30.0	16.6	46.2	37.3	2.7	45.8	22.1	23.0	23.2	38.8	75.7	50.8
Newaygo	476.4	33.7	15.7	22.1	36.7	2.3	89.2	26.0	35.4	25.2	48.2	66.6	75.3
Oceana	255.9	12.0	11.3	8.1	32.4	1.1	43.8	23.7	14.2	16.2	29.7	28.0	35.4
Ogemaw	318.5	20.1	13.2	22.2	25.4	1.6	59.4	15.6	18.4	15.7	27.3	48.4	51.2
Osceola	278.5	14.9	13.1	13.3	31.7	1.6	28.7	21.9	19.4	19.0	33.0	46.3	35.6
Oscoda	365.4	32.0	10.4	45.4	15.5	2.0	65.2	10.6	20.5	11.5	29.0	64.1	59.2
Otsego	352.2	27.7	17.6	34.0	33.4	2.1	34.2	21.3	17.7	20.5	29.6	72.0	42.1
Presque Isle	415.4	28.3	18.8	52.0	29.6	2.8	42.8	18.3	28.1	18.4	43.2	73.2	59.9
Roscommon	342.8	26.4	12.2	43.8	17.4	1.5	63.4	11.0	17.7	12.0	25.1	56.0	56.3
Wexford	326.5	19.4	16.6	17.1	38.7	2.0	41.1	25.3	18.6	21.4	32.9	49.7	43.7
Total	10,309.3	718.6	431.1	807.4	896.2	54.6	1,443.4	594.2	667.2	549.1	1,025.5	1,673.1	1,448.9
SOUTHERN LOWER PENINSULA													
Allegan	245.7	16.2	5.8	1.5	20.2	.5	60.3	9.2	31.9	10.6	16.9	5.3	67.3
Barry	187.7	8.5	1.0	1.5	11.6	.4	58.4	6.3	27.4	5.2	12.3	1.6	53.5
Berrien	144.6	6.0	1.7	.6	10.2	.3	42.7	5.1	21.6	5.2	9.8	2.0	39.4
Branch	113.3	4.9	.9	.5	7.2	.2	36.1	3.4	16.0	3.5	7.7	1.8	31.1
Calhoun	178.8	6.5	1.1	1.7	9.2	.5	51.2	4.7	28.0	4.9	14.6	4.8	51.6
Cass	150.5	7.4	1.7	1.5	10.8	.4	45.6	5.8	19.7	4.7	8.8	2.7	41.4
Clinton	108.0	4.7	1.9	.2	8.8	.3	26.6	4.6	18.7	4.4	8.2	2.2	27.4
Eaton	104.2	7.4	2.4	.3	11.1	.3	21.2	5.2	14.9	5.4	8.1	1.9	26.0
Genesee	118.0	3.1	1.3	..9	7.3	.2	35.3	3.4	17.9	3.9	8.5	3.0	33.2
Gratiot	82.6	4.7	1.3	.4	6.3	.2	16.6	3.1	12.9	3.4	7.2	2.5	24.0
Hillsdale	148.2	5.4	1.4	.5	9.7	.6	45.1	5.2	23.6	4.2	10.4	2.7	39.4
Huron	109.2	1.7	.4	.8	4.8	.1	20.7	1.4	23.8	3.5	15.3	6.8	29.9
Ingham	134.8	4.5	1.7	.2	12.2	.6	35.7	6.7	22.7	5.2	10.1	1.1	34.1
Ionia	123.8	11.1	3.3	.6	13.0	.4	25.4	6.5	14.4	5.9	7.8	2.4	33.0
Jackson	180.0	7.2	.8	1.0	11.0	.6	62.6	5.4	23.8	4.6	10.2	2.3	50.5
Kalamazoo	127.0	5.8	.5	1.0	7.3	.4	37.9	3.8	18.4	3.6	8.7	2.6	37.0
Kent	229.7	13.8	4.0	1.0	21.5	.4	56.8	10.1	30.8	9.8	15.7	4.6	61.2
Lapeer	143.6	7.7	2.0	1.0	9.5	.3	39.2	4.6	20.0	4.8	9.7	3.0	41.8
Lenawee	123.1	5.8	.4	.3	6.8	.3	43.9	3.7	16.1	2.8	7.6	1.8	33.6
Livingston	170.8	7.7	1.1	.9	10.6	.5	58.8	5.4	20.9	4.4	9.5	2.6	48.4
Macomb	103.8	4.4	.2	.9	6.2	.3	35.2	3.6	13.6	2.1	6.3	1.3	29.7
Monroe	67.6	1.0	.4	.3	3.8	.1	15.6	1.5	15.1	2.4	7.5	1.7	18.2
Montcalm	245.1	13.0	2.7	2.3	18.1	.3	67.6	8.1	32.0	8.3	18.6	6.2	67.9
Muskegon	339.4	18.4	2.8	3.1	22.9	.5	106.8	11.0	40.7	9.4	19.5	5.2	99.1
Oakland	234.3	9.7	1.3	1.9	12.6	.3	75.2	5.5	31.5	5.9	16.5	5.7	68.2
Ottawa	123.4	9.6	2.1	.8	8.8	.2	37.5	4.2	14.0	3.8	5.7	1.1	35.6
Saginaw	190.2	9.2	2.0	1.5	12.0	.3	46.0	4.8	33.5	5.9	18.2	6.0	50.8
St. Clair	147.2	9.0	2.6	1.1	12.5	.3	38.8	5.9	18.9	6.3	10.0	3.0	38.8
St. Joseph	114.1	3.7	.2	.8	4.5	.1	36.6	2.1	18.8	2.4	8.2	2.1	34.6
Sanilac	92.4	5.4	1.5	1.0	6.9	.3	17.1	2.9	13.4	4.2	9.1	4.3	26.3
Shiawassee	95.4	5.6	2.3	.2	10.5	.2	20.5	5.0	14.3	4.6	7.2	1.2	23.8
Tuscola	153.0	8.3	1.7	1.2	11.3	.3	32.9	4.7	20.9	5.9	13.1	5.5	47.2
Van Buren	167.4	8.5	2.7	1.0	13.0	.4	38.3	6.3	28.0	6.6	14.9	3.8	43.9
Washtenaw	178.7	7.0	2.1	.6	14.3	.6	57.1	7.0	24.2	6.6	9.6	1.4	48.2
Wayne	79.9	3.8	1.4	.3	6.2	.2	22.2	2.5	11.0	2.7	5.6	2.3	21.7
Total	5,255.5	256.7	60.7	33.4	372.7	11.9	1,467.5	178.7	753.4	177.1	377.1	108.5	1,457.8
State Total	33,733.7	2,923.4	2,775.8	3,960.5	5,785.4	1,458.7	3,144.5	1,571.7	2,378.0	1,047.0	1,937.0	3,285.6	3,466.1

SEE FOOTNOTES ON PAGE 4.

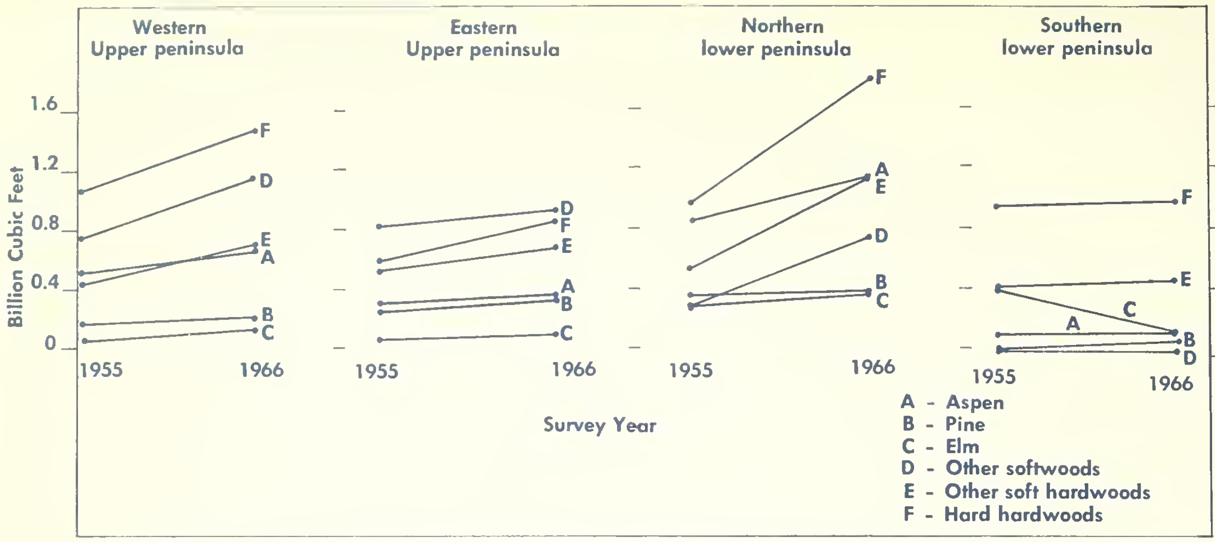

Figure 1.—Change in growing stock volume between surveys by survey unit and species group.

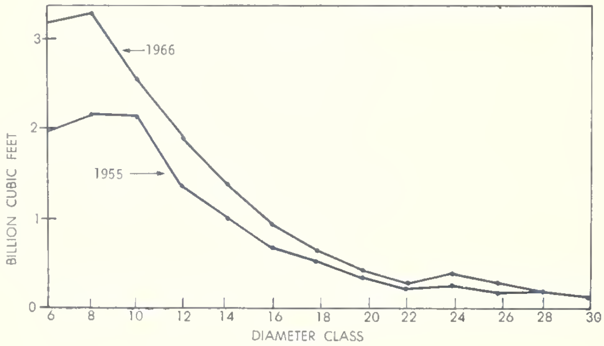

Figure 2.—Distribution of growing stock volume by diameter class, Michigan, 1955 and 1966.

FOOTNOTES: Table 1.

1 *Net volume of live poletimber and sawtimber trees from the stump to a variable 4-inch top diameter outside bark of the central stem. Does not include limbs or cull tree volume.*

2 *Species groups: Spruce—Black and white spruces.*
Other softwoods—Tamarack and northern white cedar.
Aspen—Bigtooth and quaking aspen.
Other soft hardwoods—Primarily red maple, black ash, balsam poplar, cottonwood, yellow poplar, basswood, black cherry, the elms, hackberry and sycamore.
Other hard hardwoods—Primarily hickory, beech, white ash and black walnut.

FOOTNOTES: Table 2.

1 *Net volume of live merchantable sawtimber trees (softwoods 9.0 inches d.b.h. or larger and hardwoods 11.0 inches d.b.h. and larger) from the stump to a point in the central stem at which utilization for sawn products is limited by large branches, forks or other defects, or by a diameter outside bark of 8.0 inches.*

2 *Species groups: Select oak—All white oaks and northern red oak. Aspen-paper birch—Bigtooth aspen, quaking aspen and paper birch.*

3 *International ¼-inch rule.*

U. S. FOREST SERVICE

RESEARCH NOTE NC-51

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Size of Aspen Crop Trees Little Affected by Initial Sucker Density

ABSTRACT. — Size of aspen crop trees at age 15 years is essentially the same for a wide range of initial sucker densities. High densities are not necessary to produce adequately stocked stands.

Complete clearcutting of quaking aspen (*Populus tremuloides* Michx.) usually results in dense stands of suckers, but partial cutting, which includes many commercial clearcuts, results in much lower densities. Since initial densities vary from a few hundred to several thousand stems per acre, questions arise as to what constitutes adequate stocking and how sucker density affects growth and stand development.

In 1952 an experiment was installed in a 1-year-old stand of aspen suckers that had developed after a commercial clearcut of a well-stocked stand of mature aspen (site index 70-75 feet at 50 years).[1] After the logging and before the installation of any treatments, all residual aspen and other hardwoods were cut. Five levels of stocking were replicated three times on 1/20-acre plots with the following number of stems per acre: 260, 500, 1,000, 1,500, and 10,060 (check). Additional suckers that developed on the thinned plots were removed annually.

[1] *The first 5-year results of this study were published as Lake States Forest Exp. Sta. Tech. Note 490.*

Results show that natural mortality in dense aspen stands reduces the number of stems rapidly during the early years of growth. The stands with 10,000 one-year-old stems per acre had less than 2,000 stems after 15 years (fig. 1). This amounts to approximately 85-percent mortality for this period compared with 50 percent for the lightest thinning and about 23 percent for the heavier thinnings.

As expected, thinning resulted in differences in overall average diameter. Except for the 500-stems-per-acre treatment, the average diameter of all trees was inversely related to stand density. But the average diameter of crop trees only, again excepting the 500-stems-per acre treatment, showed no significant difference by treatment (table 1 and fig. 2).

The reason for the comparatively small average diameter in the treatment thinned to 500 stems per acre is not known. Since total tree heights within this treatment are also shorter by 8 to 10 feet, possibly site quality is lower than in the other treatments (table 1). Another plausible explanation for the low rate of growth is the high incidence of dieback, *Pollaccia radiosa* (frequently called *Napicladium tremulae*) which was noted in all three replications of this treatment at the 15-year remeasurement.

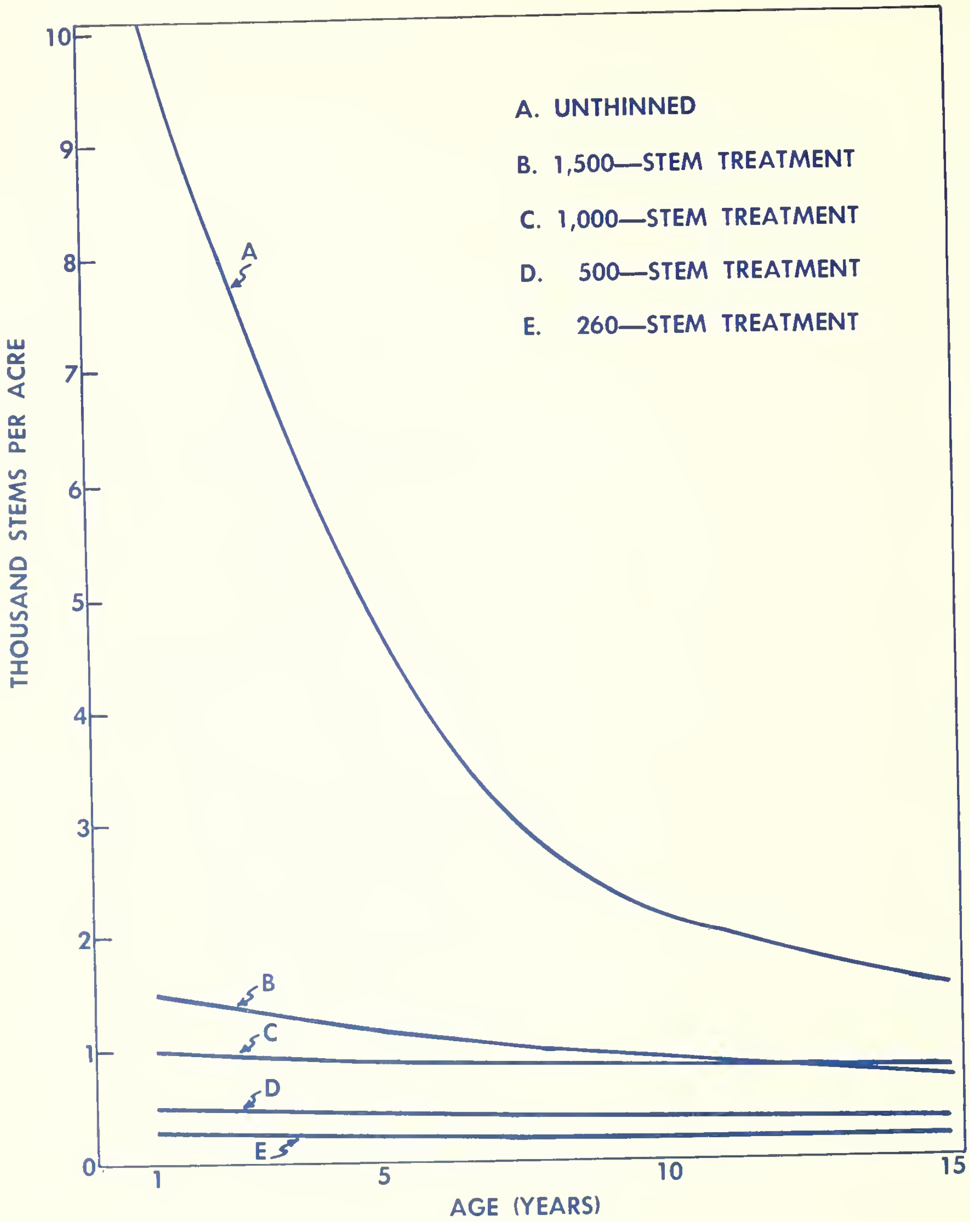

Figure 1. — Relation between age and number of stems per acre in thinned and unthinned young aspen stands.

Table 1. — Average diameter and total height of aspen suckers 15 years after thinning

Stems per acre after thinning	Average diameter (inches)			Average total height (feet)
	All trees	200 largest trees	400 largest trees	
10,060 (check)	2.5	4.2	3.9	32
1,500	3.1	4.5	4.0	31
1,000	3.5	4.6	4.3	30
500	2.9	3.8	1/ 2.9	22
260	4.3	2/ 4.3	2/ 4.3	31

1/ Based on 390 trees. 2/ Based on 190 trees.

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FIGURE 2. — The crop trees in this unthinned plot are nearly as large at age 15 years as those on the thinned plots.

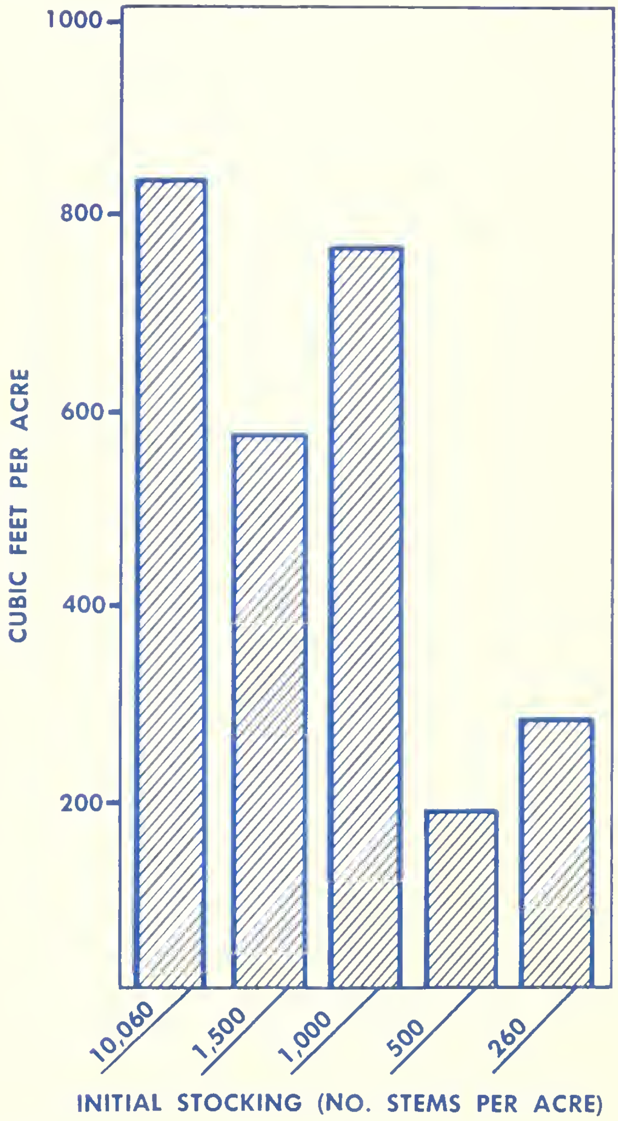

FIGURE 3. — Relation between initial stocking density and cubic feet per acre after 15 years of growth.

A comparison of total cubic-foot volumes for the five treatments after 15 years of growth shows that the unthinned check area, with 830 cubic feet per acre has the greatest volume. In contrast, the two most heavily thinned treatments have only about one-fourth this volume (fig. 3). Differences between means of the unthinned plots and the two lighter thinnings are not significant.

The results of this study show that if the forest manager obtains an aspen sucker stand ranging from 1,000 to 10,000 one-year-old stems per acre on a good site after complete removal of the overstory, he will have an adequate number of potential crop trees 15 years later without thinning; and lack of thinning will not affect their diameter.

1968

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U. S. FOREST SERVICE

RESEARCH NOTE NC-52

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Antibiotics Do Not Control Blister Rust in Eastern White Pine Seedlings

ABSTRACT. — To prevent blister rust infections in Eastern white pine seedlings, the antibiotics, cycloheximide (Acti-dione) and Phytoactin, were tested in root dips, root slurries, and foliar drenches before planting and after planting the trees. None of the methods and materials tested was effective.

The antibiotics, cycloheximide (Acti-dione) and Phytoactin, have been extensively tested as a control measure for white pine blister rust (*Cronartium ribicola* Fischer) in sapling, pole, and mature stands of Eastern white pine (*Pinus strobus* L.), Western white pine (*P. monticola* Dougl.), and sugar pine (*P. lambertiana* Dougl.). These antibiotics were reported to have controlled branch and trunk cankers on Western white pine (*3*, *4*), but not on Eastern white pine (*5*, *6*, *7*), or sugar pine (*2*). More recent findings, however, have indicated that the antibiotics are not an effective control method on Western white pine (*1*).

Moss (*4*) reported that Phytoactin (0.25- and 4-percent concentrations) soil drenches and slurry root dips were most promising as a protectant against blister rust infections in 1-, 2-, and 3-year-old Western white pine seedlings. Cycloheximide and its derivatives also reduced infection, but were too toxic to seedlings to be used as a practical nursery soil drench treatment. Van Arsdel (*8*), using 4-year-old potted Eastern white pine with patch-grafted cankers, reported that foliar sprays of cycloheximide (100 ppm) and Phytoactin (100 ppm) on new shoot and needle growth killed the cankers.

In the Lake States the highest mortality to seedlings due to blister rust infection usually occurs during the first 5 years after outplanting. If systemic antibiotic treatments could protect seedlings during these years, chances for fatal infection and subsequent tree death would be greatly reduced.

The experiment reported here tested the effectiveness of preplanting and postplanting applications of antibiotic root dips, root slurries, and foliar drenches in preventing blister rust infections on Eastern white pine seedlings.

Treatments

On May 6, 1963, a sunny cool day, bundles of twenty-five 3-0 seedlings were completely dipped or root-slurred in Phytoactin or cycloheximide solutions at the nursery and then machine-planted in a 3x5-foot spacing in an open field. The experimental design was a randomized complete block consisting of 12 treatments (table 1) of 100 seedlings each replicated 5 times. Triton X-100 (0.1 percent) was used as a surfactant in the cycloheximide treatments. Untreated trees were used as controls.

The post-planting treatments differed from the pre-planting treatments in several ways: (a) They were applied as foliar drenches from 3-gallon backpack sprayers in July 1963 to trees planted in 1962 as 2-0 stock; the same trees were treated again in 1964. (b) There were only 9 treatments (table 2), replicated 4 times. And (c) they were applied on cloudy humid days.

Table 1. — Amount of blister rust infection occurring on Eastern white pine seedlings treated with antibiotics before planting[1]

Treatment and concentration	Method of application	Percentage of seedlings infected by 1967
Phytoactin L-456 + water (1200 ppm)	Complete dip	2/ 12.3
Phytoactin L-414 + water (500 ppm)	Root slurry	15.4
Phytoactin L-413 + water (250 ppm)	Root slurry	16.3
Phytoactin L-380 + water (300 ppm)	Complete dip	16.8
Control (no treatment)		17.2
Phytoactin L-381 + water (600 ppm)	Complete dip	17.4
Phytoactin L-415 + water (1000 ppm)	Root slurry	19.7

1/ The following complete dip treatments caused such severe tree mortality that no data were taken:

Semicarbazone 1% WP (wettable powder) + water + Triton X-100 (50 ppm)
Semicarbazone 3% suspension + water + Triton X-100 (50 ppm)
Acti-dione ferrated 5% WP + water + Triton X-100 (50 ppm)
Actispray + water + Triton X-100 (50 ppm)
Actispray + water + Triton X-100 (25 ppm)

2/ Light to moderate phytotoxicity which resulted in considerable foliage loss.

Table 2. — Amount of blister rust infection occurring on Eastern white pine seedlings treated with antibiotics after planting

Treatment and concentration	Percentage of trees infected by 1967
Actispray + water + Triton X-100 (50 ppm)	1/ 9.6
Acti-dione ferrated 5% WP + water + Triton X-100 (25 ppm)	1/ 10.2
Actispray + water + Triton X-100 (25 ppm)	1/ 10.5
Semicarbazone 1% WP + water + Triton X-100 (50 ppm)	1/ 13.2
Phytoactin L-380 + water (300 ppm)	20.3
Phytoactin L-456 + water (1200 ppm)	23.0
Control (no treatment)	23.3
Phytoactin L-381 + water (600 ppm)	23.7
Semicarbazone 3% suspension + water + Triton X-100 (50 ppm)	(2/)

1/ Moderate to severe phytotoxicity caused considerable mortality or reduced the amount of foliage on surviving trees by at least 50 percent.

2/ Trees killed or severely injured by the treatment.

Data on the amount of blister rust infection were taken annually beginning in summer 1965. Plentiful ribes (*Ribes cynosbati* and *hirtellum*) in the area were responsible for the high levels of infection obtained.

Results

By 1967, from 12 to 20 percent of the seedlings treated with Phytoactin before planting were infected (table 1). (The slight differences in percentages by treatment do not have practical value.) The cycloheximide treatments had caused such severe tree mortality that no data were taken. For the post-planting treatments, 10 to 24 percent of the trees were infected by 1967. In addition, the cycloheximide treatments had caused moderate to severe phytotoxicity on most of the surviving trees.

The tests show that Phytoactin does not protect Eastern white pine seedlings against blister rust infection; and cycloheximide is too toxic to be used for that purpose.

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1968

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U. S. FOREST SERVICE

RESEARCH NOTE NC-53

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

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The Impact of Insects on Second-Year Cone Crops in Red Pine Seed-Production Areas

ABSTRACT. — Second-year cone crops in red pine seed-production areas have been severely damaged by five species of insects. Control of the two most destructive pests could increase present seed yields in most areas by at least 50 percent. Some seed-production areas may not produce harvestable seed crops until cone-insect populations are suppressed.

The National Forest System has established red pine (*Pinus resinosa* Ait.) seed-production areas (SPA's) in most National Forests of the north central United States. These areas were developed from the best natural stands of red pine and are managed solely for the production of seed.

Because insects were apparently reducing seed yields, sampling was begun in 1962 to quantify the impact of insects on the cone crops. Only cones in the second (final) year of development were sampled. This Note summarizes the results of these surveys.

Survey Methods

All cones on one whorl of midcrown branches were collected from a number of trees in half or more of all SPA's. Sample trees were arbitrarily selected in 1962 and 1963 but since then have been randomly selected. The sample size was 5 trees in an SPA in 1962 and 1963, 10 in 1964, and 15 since then. The cones from each tree were bagged and sent to the laboratory where they were dissected and classified according to type of damage. Keys by Lyons (1957b) and Hard (1964) were helpful in identifying the damage.

The Overall Losses

From 34 to 83 percent of the annual cone samples were damaged by insects (table 1). The amount of damage in individual SPA's and the local importance of individual pests may be well above or below the annual averages.

Over the 6-year period five insects have been responsible for most of the cone damage. The two most destructive insects were the red pine cone beetle, *Conophthorus resinosae* Hopkins, and the red pine coneworm, *Dioryctria disclusa* Heinrich. Another coneworm, *Eucosma monitorana* Heinrich, and a pine seedworm, *Laspeyresia toreuta* Grote, ranked next in importance. The cone midge, *Rubsaamenia* sp., infested fewer cones than any of the other insects.

The cone beetle and the two coneworms usually destroy the entire cone so that few or no seeds survive. *Laspeyresia*, on the other hand, feeds only on the individual seeds and rarely destroys all seeds in a cone. Usually there are 1 or 2 *Laspeyresia* larvae per cone, and each consumes 4 to 10 seeds (there are about 40 seeds in a cone) (Lyons 1956, 1957a).

Rubsaamenia feeds primarily on cone scale tissue but may also feed on seeds. Typically, its feeding causes excessive resin flow which usually makes the cone scales stick together, thus hindering seed release.

These are the losses occurring during the second year of cone development. The impact of insects on the first-year conelets is as yet unknown, but the odds are high that their damage is significant.

Losses in Individual Seed-Production Areas

Insect damage to annual cone crops was highly variable both within and among SPA's (table 2). The total range was from 0 to 100 percent. Some consistencies are evident, though, in the midst of this great variability. Some seed-production areas such as Birch Hill and Bearsdale Springs have had consistently greater cone damage than others like Black Creek, Cary Dam, and Ogontz River. The average level of cone damage in the former areas was more than 60 percent but was less than 17 percent in the latter areas. The factors underlying differences in the level of cone damage both among and within SPA's will be explored in another paper.

Table 1. Percentage of sample cones infested by different insects in red pine seed-production areas

Year	Total number cones examined	Number seed-production areas sampled	Percentage cones damaged by: *Conophthorus resinosae*	*Dioryctria disclusa*	*Eucosma monitorana*	*Laspeyresia toreuta*	*Rubsaamenia* sp.	Other	Total
1962	262	9	18	15	5	< 1	6	5	49
1963	304	9	25	31	2	5	1	2	66
1964	1,881	7	20	8	2	4	1	< 1	35
1965	1,648	10	28	23	4	8	3	17	83
1966	3,211	14	12	9	2	6	5	< 1	34
1967	2,242	17	18	7	10	8	2	< 1	45

Table 2. Variations in insect-caused damage within and among eight seed-production areas[1]

Seed-production area	Percentage sample cones damaged by insects: 1964	1965	1966	1967	1964-67
Birch Hill	29	86	76	84	60
Black Creek	4	0	15	90	14
Bearsdale Springs	42	99	99	100	88
Cary Dam	22	33	12	15	16
Farr Lake	63	79	100	46	74
Norway Lake	--	84	12	42	31
Ogontz River	--	40	6	57	17
Portage Lake	--	99	100	20	98

1/ Data are presented only for those areas in which collections were made for at least 3 consecutive years.

Conclusions

1. Control of the two most important pests — the red pine cone beetle and the red pine coneworm — during the second year of cone development would increase present seed yields from most SPA's by at least 50 percent.

2. Insect control during the first year of cone development might increase seed yields even further if insects are at all destructive to the first-year conelets.

3. SPA's with consistently high insect damage may not produce harvestable cone crops unless cone insect populations are suppressed.

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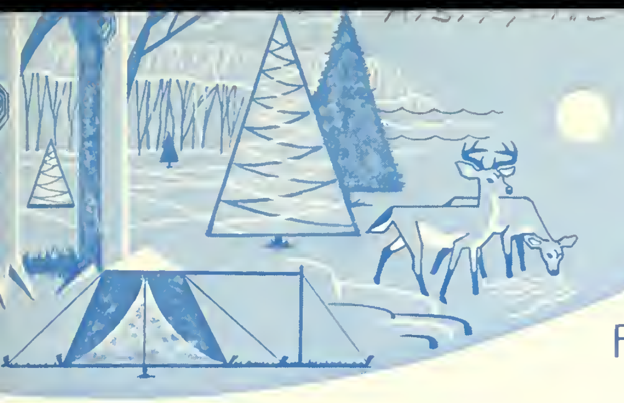
1968



U.S. FOREST SERVICE

RESEARCH NOTE NC-54

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Bark Separation During Chipping With a Parallel Knife Chipper

ABSTRACT. — Five winter-cut northern species were chipped in a frozen and unfrozen condition with a parallel knife chipper. The degree of bark separation during chipping and a relative gradation of chip size are reported.

Bark is normally removed from pulpwood in the roundwood stage. This means that crooked tops and limbs are not used because barking, handling, and transporting such material is not feasible with present harvesting machines and systems. But a method of chipping in the woods and removing and segregating the bark during or after chipping would allow utilization of large tops and limbs which are presently left in the forest to rot.

The primary objective of the study reported here was to determine the degree of bark separation while chipping frozen and unfrozen winter-cut wood. (We chose winter-cut wood because we believed it had maximum adhesion of bark to wood.) If an adequate degree of separation occurs during chipping, then segregation of bark from wood after chipping becomes the primary target of research. Two processes, the Hosmer[1] and Vac-sink,[2] have been developed for segregating bark after chipping but have had only limited success. The results from this study provide additional basic information to help in the solution of the bark segregation problem.

Tests

A parallel knife chipper[3] was chosen for this study since it is the lightest construction of all the types of pulpwood chippers and appears suitable for *portable* remote chipping. The particular machine for this study was installed at a Lake States pulpmill.

The five test species selected were hard maple (*Acer saccharum*), soft maple (*Acer saccharinum*), eastern hemlock (*Tsuga canadensis*), quaking aspen (*Populus tremuloides*), and spruce (*Picea glauca*). For each species five frozen and five unfrozen logs were chipped. The tests on unfrozen logs were run in December; those on frozen logs in February. The mean maximum ambient temperature for several days preceding the December test was 34.4° F. whereas the mean maximum temperature in February was 19.8°. The day prior to chipping in February the temperature was down to −22°.

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[1] *Blackford, J. M. Bark extraction techniques bring bush chipper closer, Canad. Forest Ind. 86(1): 50-53, 1966; Harvesting wood via felchip, Pulp and Paper 39(19): 83-85, 1965; and Separating bark from wood chips, Forest Prod. J. 11(11): 515-519, 1961.*

[2] *Anonymous. Vac-sink or debarking by vacuum, Pulp and Paper 35(10): 55, 1961. Wesner, Adam L., Method of separating wood chips from bark chips, U.S. Patent 3032188, 1962; and Vac-sink for recovery of pulpwood chips from wood-bark waste, Pulp and Paper 37(17): 61-65, 1962.*

[3] *A chipper where primary cutting action is parallel to the wood grain.*

As each log was chipped, 40 to 50 pounds of chips were removed from the discharge system of the chipper and stored in polyethylene bags in an unheated building to retain maximum moisture until analyzed. (Two months was the maximum storage time before analysis.)

Analysis of Data

For the bark separation analysis, the total sample for each log was dumped in a pile from the polyethylene storage bag, the pile was quartered, each quarter was halved, and three of these halved portions were chosen at random for analysis. The free wood, free bark, tight bark (chips with adhered bark), and fines (bark and wood) were sorted by hand, and each class of material was weighed on a beam balance. In addition, the bark from the fraction of chips containing tight bark was removed to obtain a measure of the total percent of bark in the sample.

A secondary objective of the study was to screen a sample of chips from each log to obtain a relative gradation of chip sizes. For this analysis a volume of chips equivalent to a quartered section (approximately 10 pounds) was chosen at random from each log and placed in a Gilson square-mesh testing screen with the following screen elements: 1-inch, .75-inch, .50-inch, .25-inch, and pan. Each sample was agitated in the Gilson screening machine for 4 minutes. The fractions remaining on each screen were weighed on a conventional beam-type scale.

Results

Chipped frozen wood had a higher percentage of free wood, bark, and fines, and a lower percentage of bark bonded to wood (tight wood) than chipped unfrozen wood (table 1). Chips produced from frozen wood also showed a significant increase in fines and small chips compared to chips produced from unfrozen wood (table 2). Although chip length was quite constant at 1-¼ inch, the greatest concentration of chips occurred on the .50-inch mesh screen since the chip width was random. The only exception was hemlock where over 50 percent of the chips produced from both frozen and unfrozen hemlock remained on the .25-inch mesh screen or pan.

Table 1. — Percentages of free wood chips, bark, fines, and chips with bark

Item	Hard maple		Soft maple		Spruce		Aspen		Hemlock	
	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
Free wood	82.32	85.22	81.35	85.70	73.81	79.84	77.77	82.13	76.27	77.89
Bark	6.26	9.00	5.47	6.84	2.04	7.65	7.12	7.56	5.60	7.90
Fines	1.72	1.70	1.04	1.92	1.24	3.43	2.35	3.29	3.50	7.99
Tight bark	9.70	4.08	12.14	5.54	22.91	9.08	12.76	7.02	14.63	6.22
All bark as a percent of total material[2]	9.7	11.0	10.7	9.6	11.9	12.5	14.2	13.7	14.0	14.2
Unloosened bark as a percent of total material[3]	2.6	1.2	4.7	1.8	9.2	3.1	5.9	4.5	6.7	2.3

[1] Each tabulated value is the mean percentage from three samples from each of five logs. The percentages are based on green weight. The first four figures in each column add to 100 percent.

[2] The bark was removed from those chips that still had the bark on and was weighed. This weight of bark was added to the weight of free bark and one-half the weight of fines.

[3] Bark adhering to wood chips.

Table 2. — Percentage of chips retained on each screen[1]

Sieve size, (inches)	Hard maple Unfrozen	Hard maple Frozen	Soft maple Unfrozen	Soft maple Frozen	Spruce Unfrozen	Spruce Frozen	Aspen Unfrozen	Aspen Frozen	Hemlock Unfrozen	Hemlock Frozen
1.0	14.2	3.7	6.2	1.5	9.7	2.9	1.6	1.3	1.3	0.6
.75	19.7	13.4	15.5	9.3	12.5	10.5	8.9	8.5	5.7	3.4
.50	44.2	49.4	49.9	51.2	40.2	43.0	48.7	45.9	38.0	28.8
.25	16.3	25.1	21.8	29.3	28.7	32.4	30.0	32.1	39.1	46.7
Pan	4.1	6.1	5.2	6.3	7.2	8.8	9.0	9.5	14.4	18.5
Total	98.5	97.7	98.6	97.6	98.3	97.6	98.2	97.3	98.5	98.0

1/ The percentage of each fraction was determined from the total initial sample size. A small part of each sample was lost during screening and weighing, as indicated by final percentages.

Discussion

Specifications as to the amount of bark allowed in wood chips vary with the pulping process and individual mill using a given pulping process. Sulfite mills, which have nearly 28 percent of the pulping capacity in the Lake States, have the strictest requirements on bark removal. Often no bark is allowed. The remaining mill capacity could probably accept higher bark contents in varying degrees.

This study has shown that, except for unfrozen spruce, 51 to 89 percent (varies with species and whether frozen or not) of bark is separated from the wood during chipping. Thus, economical "after-chipping" bark removal methods might be realistically devised to allow some bark impurities and still be suitable for a significant portion of the pulpwood market. Under these conditions remote chipping could then be considered as a reliable means of supplying increasingly larger portions of the market.

1968

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U. S. FOREST SERVICE

RESEARCH NOTE NC-55

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Marketing Practices of Northern Minnesota Sawmills

ABSTRACT. — Most of the lumber produced in northern Minnesota is marketed in Minnesota, and the marketing area increases as mill size increases. Aspen is a dominant species. About 45 percent of the lumber is graded; concentration and grading would improve marketing. Less than one-third of the by-products are marketed.

In 1965, 92 percent of the sawmills in 23 northern Minnesota counties (fig. 1) marketed their entire output within the state. This was disclosed by a sawmill survey made in 1966 by the Department of Iron Range Resources and Rehabilitation in cooperation with the North Central Forest Experiment Station.[1]

Average distance to market increased directly with the production size class of the mills (fig. 2). Markets for mills cutting less than 100,000 board feet per year averaged 23 miles from the mill compared with 228 miles for the largest mills. Apparently very little lumber produced by the smaller mills is reaching markets in the Twin Cities.

[1] *Data were obtained by personal interviews at sample mills selected from the "Directory of Northern Minnesota Sawmills and Other Wood-Using Industries" published in 1965. The survey included all mills producing 1 million board feet or more annually, 88.9 percent of mills producing 500,000 to 999,000 board feet, 41.9 percent of mills producing 250,000 to 499,000 board feet, 24.4 percent of mills producing 100,000 to 249,000 board feet, 13.6 percent of mills producing up to 100,000 board feet, and 14.0 percent of the mills that were idle in 1965.*

The mills in the 23 counties produced 102.4 million board feet of lumber during 1965. Approximately 45 percent was produced by mills that grade their output; these mills were only 15 percent of the operating mills but included most of the mills cutting over 1 million board feet per year. The rest of the mills marketed their lumber ungraded or mill run. Some of this volume was sold to the larger mills that grade it for the market, but nearly half the total production arrived on the market as ungraded lumber.

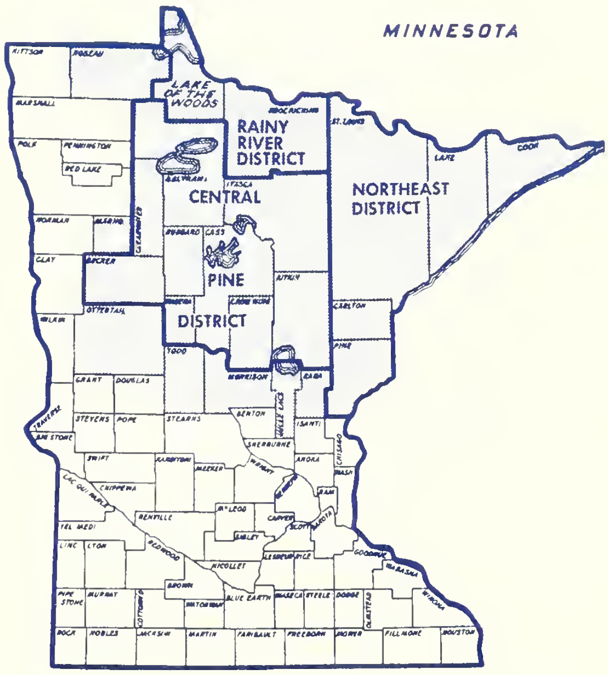
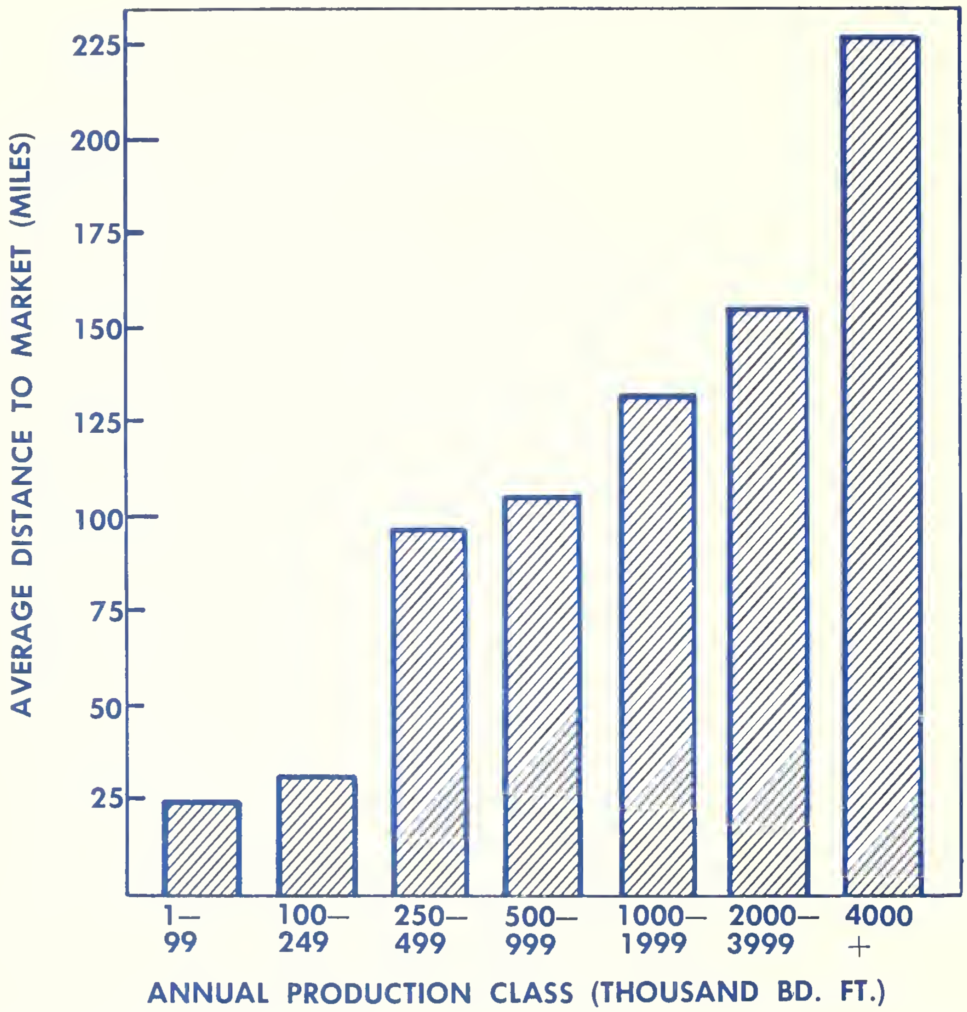


FIGURE 1. — Study counties are shaded. Forestry Survey districts are outlined with heavy lines.

FIGURE 2. — Mill size as related to market area.



Lumber produced by the mills in this area was nearly equally divided between softwoods (54 percent) and hardwoods (46 percent). About one-third of the mills sawed primarily softwoods. Another third were primarily hardwood mills, and the remaining third sawed a mixture of the two. Aspen comprised at least 50 percent of the production of about one-third of the mills; production of over half of these mills (one-sixth of all mills) was over 75 percent aspen. The importance of this species to the area is indicated by the 25.4 million board feet produced.[2]

[2] *Rowie, Carl D., and James E. Blyth. Northern Minnesota lumber production declines from 1960 to 1965. U. S. Forest Serv. Res. Note NC-30, 4 p., 1967. N. Cent. Forest Exp. Sta., St. Paul, Minn.*

The number of mills cutting mainly for their own use decreased nearly 50 percent since 1960 and represented about 13 percent of the active mills in 1965. Most of the production from these mills entered commercial markets in the form of wood products manufactured by them.

About one-third of all mills did some custom sawing. How much of their production was marketed commercially is unknown, but since three-fourths of these mills cut less than 100,000 board feet per year, their influence on the commercial market was minor.

The quality of lumber produced by sawmills depends directly on the quality of logs sawn. If logs are not graded or purchased on grade by the sawmills, timber harvesters have little or no incentive to produce high-quality logs and will generally buck trees to obtain the most scale rather than the highest quality logs. Apparently this is the predominant practice in northern Minnesota since only 7 percent of the mills graded their logs in 1965.

Only about 32 percent of the total production of slabs and edgings was marketed; one-fourth of the mills participated in these sales. Roughly half of this volume was sold as chips to pulpmills, less than 1 percent was sold for the production of charcoal, and the balance was sold as fuelwood. About 72 percent was sold by weight. Twelve percent of the sawmills, whose lumber output represented 11 percent of total production, sold sawdust; about two-thirds was sold for agricultural use and the remainder for industrial fuel.

Several market surveys have revealed that one of the reasons manufacturers do not use more locally produced lumber is their inability to obtain adequate supplies of the grades they require.[3] Since only the largest producers usually can afford certified graders, some means should be developed to concentrate or grade the production of smaller producers. Possibly a joint effort of the industry in cooperation with public agencies could solve this problem and thereby induce Minnesota manufacturers to use more lumber produced in northern Minnesota.

1968

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[3] *Warner, John W., and Carl H. Tubbs. Wood use by manufacturing firms in Minneapolis and St. Paul. U. S. Forest Serv., Lake States Forest Exp. Sta., Sta. Pap. 75, 30 p. 1958.* Also *Blyth, James E., and Edward N. Therrien. Primary wood use by manufacturing firms in Duluth-Superior. U. S. Forest Serv. Res. Note LS-52, 4 p., 1964. Lake States Forest Exp. Sta., St. Paul, Minn.*

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U. S. FOREST SERVICE

RESEARCH NOTE NC-56

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Using Black Light to Find Jack-Pine Budworm Egg Masses

ABSTRACT. — Jack pine foliage infested with jack-pine budworm egg masses was examined under two kinds of light — black light and a combination of natural and fluorescent light. Black light significantly increased the accuracy of count but not the efficiency of examination.

Examining branches for egg masses of the jack-pine budworm (*Choristoneura pinus pinus* Freeman) is a tedious, time consuming job. Most egg masses are deposited on the concave surfaces of needles, and are often hidden from view, especially when the needles are compact and appressed. Even experienced examiners may miss some. With the spruce budworm the proportion missed is related to population level, the nature of the foliage, and the experience of the workers.[1]

Our preliminary investigations showed that egg masses fluoresce under black light when the needles are sprayed with a 0.05-percent solution of Fluorescein in 95-percent ethanol. Subsequently, we found that egg masses fluoresce naturally under black light without treatment.

This Note evaluates the aid black light gives examiners searching for egg masses.

[1] *See two articles by R. F. Morris: One source of error in budworm population work. Can. Dep. Agr. Div. Forest Biol. Bi-Mon. Progr. Rep. 7(6): 1-2; 1951.* Also *The development of sampling techniques for forest insect defoliators, with particular reference to the spruce budworm. Can. J. Zool. 33(4): 225-294; 1955.*

Methods and Materials

Eighty branch samples, 2 branches from each of 40 trees, were collected after larval eclosion in August 1967 from the upper crowns of heavily infested jack pine. Branches were placed in cloth bags, transported to the laboratory, and stored in a freezer. Later they were examined under black light and under a combination of fluorescent and natural light.

A standard black-light lamp (F40BLB) with a built-in filter was used for the black-light examinations. The filter absorbs most of the visible light and transmits a high percentage of near-ultraviolet energy. In a windowless room, the lamp was suspended about one foot above a table and shielded so that the examiner's eyes were not in direct line with the emitted light. A 6-volt battery spotlight was provided for checking doubtful egg masses[2] *after* they had been found under black light. Examiners were never permitted to use the spotlight for locating egg masses. Black construction paper covering the working area of the table prevented light reflection.

The other (normal) examinations were conducted in a well-lighted laboratory with a large window, fluorescent ceiling lights, and two standard fluorescent lamps (F15T8·CW) mounted in desk-type receptacles. White paper covering the working area of the table provided contrast.

[2] *Pitch droplets also fluoresce under black light, and occasionally they will resemble an egg mass. A completely parasitized egg mass also may have to be examined under a spotlight.*

The student examiners, three women and one man, had a range of experience examining foliage for egg masses: Examiner 1 had the most experience, examiner 2 (male) had limited experience, while examiners 3 and 4 had none.

Each worker examined 20 branches. Branches were clipped into small workable segments of about 6 inches or less. Branch surfaces without needles were discarded. The small segments were examined by rotating and bending the twigs so that all needle surfaces would be exposed to view. Egg masses found were left in place so that they could be examined under the other light source. Loose needles were also examined. The time required to examine each branch and the number of egg masses found were recorded. The foliage examined one day was reexamined by the same worker 1 or 2 days later under a different light source. The extra time was provided between examinations to reduce any remembrance factors. Examiners 1 and 2 examined foliage first under fluorescent light and then under black light; this order was reversed for examiners 3 and 4.

Efficiency

The total examination time for all examiners was longer under black light (table 1). Examiner 4 took significantly more time under black light than fluorescent light; the reason is not known. Although this examiner's branches were on the average slightly larger than those of other examiners, egg-mass densities found under black light were not significantly different among examiners.

A comparison was made of the percentage of branches where less, the same, or more time was spent under black light than fluorescent light. From 55 to 70 percent of the branches examined by the first three workers required less or the same time using black light, while 80 percent of the branches examined by the fourth worker took more time using black light. When total branches (80) of all examiners are considered, 52 percent were examined in less or the same time using black light.

Table 1. — A comparison of examination time and numbers of jack-pine budworm egg masses found under black light (BL) and under fluorescent light (FL) by each examiner

Examiner	Mean foliated branch length[1/]	Examination time			Egg masses found		
		FL	BL	FL-BL	FL	BL	BL-FL
	Inches	Min.	Min.	Min.	No.	No.	No.
1	24.7	259	220	+39	109	114	+5
2	24.1	214	191	+23	83	95	[2/]+12
3	23.4	163	151	+12	80	73	-7
4	30.5	137	230	[2/]-93	64	100	[2/]+36
Total		773	792	-19	336	382	[2/]+46

[1/] Measured from the first green needles near the base of the branch to the apical bud.

[2/] Differences between BL and FL significant at $t_{.05}$ level.

Accuracy

The number of egg masses found under black light significantly exceeded the number found under fluorescent light for two of the four workers (table 1). Examiner 4 found 36 more egg masses and took 93 minutes longer using black light.

On 80 to 90 percent of the branches, examiners 1, 2, and 4 found more egg masses or the same number under black light as they had found under fluorescent light; examiner 3 found the same or more masses on only 60 percent of her branches (table 2). All examiners combined found more or the same number of egg masses under black light on 80 percent of all branches as they found under fluorescent light.

Table 2. — A comparison of numbers of egg masses found under black light (BL) and under fluorescent light (FL) by each examiner

Examiner	Percentage of 20 branches where number of egg masses found was--		
	Greater under BL than FL	Same under BL as FL	Less under BL than FL
1	30	60	10
2	50	30	20
3	25	35	40
4	60	30	10
Average	41	39	20

To determine the characteristics of egg masses missed under black light, examiner 1 reexamined 30 branches under black light and removed all egg masses found. Then under fluorescent light she removed each needle and carefully searched it for any egg masses missed under black light. All egg masses were examined with a stereomicroscope and classified as normal or parasitized. Each class was further subdivided into new and old masses. Of 196 egg masses, 21 were missed under black light. Of these 21 masses, 3 were normal-new, 6 were normal-old, 11 were parasitized-new, and 1 was parasitized-old. Thus nearly all of the masses overlooked under black light were either parasitized or old.

Additional Equipment Needed for Blacklight Technique

The black-light technique requires little additional equipment. Most laboratory rooms can be darkened by mounting photographer's black cloth or sheets of plywood painted dull black over windows. Light entering around door jambs and window casings is not critical so long as the rays do not strike the examiner's working area. Although a 48-inch F40BLB black-light lamp was used in this study, two 18-inch F15T8BLB black-light lamps can be mounted in standard desk-type receptacles for concentrating emitted rays within a limited area. Penlights may be substituted for 6-volt battery spotlights.

Possible Use With Other Insects

Tests showed that spruce budworm egg masses also fluoresce under black light so the technique may be useful for locating eggs of other species of insects.

1968

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U. S. FOREST SERVICE

RESEARCH NOTE NC-57

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Forest Land In Indiana Counties, 1967

ABSTRACT.—Commercial forest land has declined slightly from 4.1 million acres in 1950 to 3.9 million acres in 1967. The more heavily forested counties are in the southern half of the State where forest land has been increasing.

Since 1950 commercial forest land in Indiana has declined from 4.1 million to close to 3.9 million acres. The decline occurred in the lightly forested northern counties while the southern counties gained slightly in commercial forest land.

The proportion of land in forest increases from north to south, with a noticeable change midway in the State. Glaciers smoothed off the northern half of the State making it more suitable for agriculture. Here the forests occupy about 7 percent of the land area. The southern part of the State, with its rolling landscape, supports most of the commercial forests.

With more than three-fourths of the commercial forest land in the south it is not surprising that 70 percent of the primary wood-using plants (mainly sawmills) are located in the southern counties, or that the increase in the number of these plants has been greater than in the north. The more heavily forested counties — such as Brown, Crawford, Monroe, and Perry — are found here. These counties are more than half covered with commercial forests. Although forest land has increased slightly in the south, the net change throughout the State had been downward.

Forest Survey Unit	*Commercial Forest Land* (Thousand Acres)		*Change Since 1950* (Percent)
	1950	*1967*	
Lower Wabash	793.0	836.2	+ 5.4
Knobs	1,684.0	1,769.2	+ 5.1
Upland Flats	434.0	353.7	—18.5
Northern	1,171.0	936.7	—20.0
Total	4,082.0	3,895.8	— 4.6

Between 1950 and 1967, commercial forest land in the north dropped from 1,171,000 to 937,000 acres, a decline of 20 percent. This land use change was probably caused primarily by urbanization, farm consolidation, and highway construction.

Only 2 percent of the forest land in Indiana is considered noncommercial. More than half, 38,500 acres, is in state parks that are reserved from timber cutting. The remaining 30,000 acres have unproductive soils.

The forest area information in this report is part of the results of the Second Indiana Forest Survey made during the summer of 1966 and the winter of 1967. The survey was conducted by the North Central Forest Experiment Station in cooperation with the Forestry Division of the Indiana Department of Natural Resources. The sampling error of this survey is ± 2 percent for the 3.9 million acres of commercial forest land.

1968

BURTON L. ESSEX
Resource Analyst

Table 1. *Area of land and forest land, by counties, Indiana, 1967*

Survey Unit & county	All land[1/]	All forest	Forest Land[2/]: Non-commercial[3/]	Forest Land[2/]: Commercial[4/]	Commercial forest as a percent of land area
	Thousand acres	Thousand acres	Thousand acres	Thousand acres	Percent
NORTHERN UNIT					
Adams	220.8	14.3	0.3	14.0	6.3
Allen	429.3	35.6	.3	35.3	8.2
Bartholomew	257.3	35.5	.3	35.2	13.7
Benton	261.8	3.2	.2	3.0	1.1
Blackford	106.9	7.0	.1	6.9	6.4
Boone	273.3	11.5	.4	11.1	4.1
Carroll	239.4	16.2	.2	16.0	6.7
Cass	265.5	20.4	.2	20.2	7.6
Clinton	260.5	9.9	.4	9.5	3.6
Decatur	236.7	23.4	.4	23.0	9.7
DeKalb	234.0	22.0	.3	21.7	9.3
Delaware	254.6	11.6	.4	11.2	4.4
Elkhart	299.5	25.7	.3	25.4	8.5
Fountain	254.1	27.1	.6	26.5	10.4
Fulton	235.4	16.0	.2	15.8	6.7
Grant	269.4	14.3	.3	14.0	5.2
Hamilton	256.6	13.8	.2	13.6	5.3
Hancock	195.2	9.1	.2	8.9	4.6
Hendricks	266.9	15.6	.3	15.3	5.7
Henry	256.0	14.4	.2	14.2	5.5
Howard	187.5	6.8	.2	6.6	3.5
Huntington	249.6	20.5	.2	20.3	8.1
Jasper	359.7	25.1	.7	24.4	6.8
Jay	247.0	18.9	.3	18.6	7.5
Johnson	201.6	12.5	.3	12.2	6.0
Kosciusko	345.7	27.8	.3	27.5	8.0
LaGrange	243.8	19.3	.3	19.0	7.8
Lake	328.0	9.7	.2	9.5	2.9
LaPorte	388.6	28.3	.3	28.0	7.2
Madison	289.9	12.3	.6	11.7	4.0
Marion	256.1	13.7	.3	13.4	5.2
Marshall	283.8	25.4	.3	25.1	8.8
Miami	243.2	20.4	.2	20.2	8.3
Montgomery	324.5	23.8	2.0	21.8	6.7
Newton	264.3	18.6	.2	18.4	7.0
Noble	263.9	24.3	1.1	23.2	8.8
Porter	271.7	27.9	2.3	25.6	9.4
Pulaski	277.1	27.0	2.8	24.2	8.7
Randolph	292.5	14.7	.6	14.1	4.8
Rush	261.8	12.5	.2	12.3	4.7
St. Joseph	298.4	21.8	.2	21.6	7.2
Shelby	261.8	13.5	.5	13.0	5.0
Starke	198.7	24.7	.3	24.4	12.3
Steuben	198.0	23.6	1.0	22.6	11.4
Tippecanoe	319.7	19.2	.4	18.8	5.9
Tipton	167.0	6.4	.1	6.3	3.8
Wabash	269.3	21.3	.2	21.1	7.8
Warren	235.5	20.3	.2	20.1	8.5
Wayne	259.1	23.3	.2	23.1	8.9
Wells	235.5	17.3	.9	16.4	7.0
White	317.9	12.7	.3	12.4	3.9
Whitley	215.5	20.2	.2	20.0	9.3
Total	13,629.9	960.4	23.7	936.7	6.9

1/ 1960 Bureau of the Census.
2/ Land at least 10 percent stocked by forest trees of any size, or formerly having such tree cover; excludes land currently developed for nonforest use such as urban or thickly settled residential or resort areas, city parks, orchards, improved roads, or improved pasture land. The minimum area classified as forest land was 1 acre. Roadside, streamside, and shelterbelt strips of timber with crown width of at least 120 feet and all unimproved roads and trails, streams, and clearings in forest areas were classified as forest.

Table 1, continued.

Survey Unit & county	All Land[1/]	All forest	Forest Land[2/] Non-commercial[3/]	Commercial[4/]	Commercial forest as a percent of land area
	Thousand acres	Thousand acres	Thousand acres	Thousand acres	Percent
LOWER WABASH UNIT					
Clay	233.0	53.3	0.3	53.0	22.7
Daviess	275.0	41.9	-	41.9	15.2
Gibson	318.9	48.9	-	48.9	15.3
Greene	351.4	99.8	.3	99.5	28.3
Knox	330.5	39.4	-	39.4	11.9
Martin	220.8	111.1	-	111.1	50.3
Parke	288.6	92.4	2.4	90.0	31.2
Pike	214.4	79.8	-	79.8	37.2
Posey	263.6	42.1	-	42.1	16.0
Putnam	313.6	72.2	.7	71.5	22.8
Sullivan	292.5	54.1	.3	53.8	18.4
Vanderburgh	154.3	20.0	-	20.0	13.0
Vermillion	168.3	35.0	-	35.0	20.8
Vigo	265.5	50.2	-	50.2	18.9
Total	3,690.4	840.2	4.0	836.2	22.7
KNOBS UNIT					
Brown	207.3	148.8	15.5	133.3	64.3
Clark	245.8	92.3	.2	92.1	37.5
Crawford	199.7	113.4	.6	112.8	56.5
DuBois	277.0	96.8	.1	96.7	34.9
Floyd	95.4	36.8	.2	36.6	38.4
Harrison	306.6	131.6	.7	130.9	42.7
Jackson	332.8	122.2	.3	121.9	36.6
Lawrence	293.8	127.6	2.1	125.5	42.7
Monroe	262.5	134.5	.7	133.8	51.0
Morgan	259.8	92.0	.1	91.9	35.4
Orange	259.2	119.2	.8	118.4	45.7
Owen	249.2	115.7	1.9	113.8	45.7
Perry	245.8	143.6	.8	142.8	58.1
Scott	123.5	45.2	.1	45.1	36.5
Spencer	253.4	69.6	1.8	67.8	26.8
Warrick	250.2	76.2	.7	75.5	30.2
Washington	330.2	130.6	.3	130.3	39.5
Total	4,192.2	1,796.1	26.9	1,769.2	42.2
UPLAND FLATS UNIT					
Dearborn	195.8	41.7	2.7	39.0	19.9
Fayette	137.6	16.3	.5	15.8	11.5
Franklin	252.2	58.2	1.6	56.6	22.4
Jefferson	234.2	62.3	1.6	60.7	25.9
Jennings	241.3	68.5	1.0	67.5	28.0
Ohio	55.7	13.5	.3	13.2	23.7
Ripley	282.9	54.6	4.8	49.8	17.6
Switzerland	141.4	39.3	.5	38.8	27.4
Union	107.5	13.2	.9	12.3	11.4
Total	1,648.6	367.6	13.9	353.7	21.4
State Total	23,161.1	3,964.3	68.5	3,895.8	16.8

3/ Unproductive forest land incapable of yielding crops of industrial wood because of adverse site conditions and productive public forest land withdrawn from commercial timber use through statute or administrative regulation.
4/ Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization.

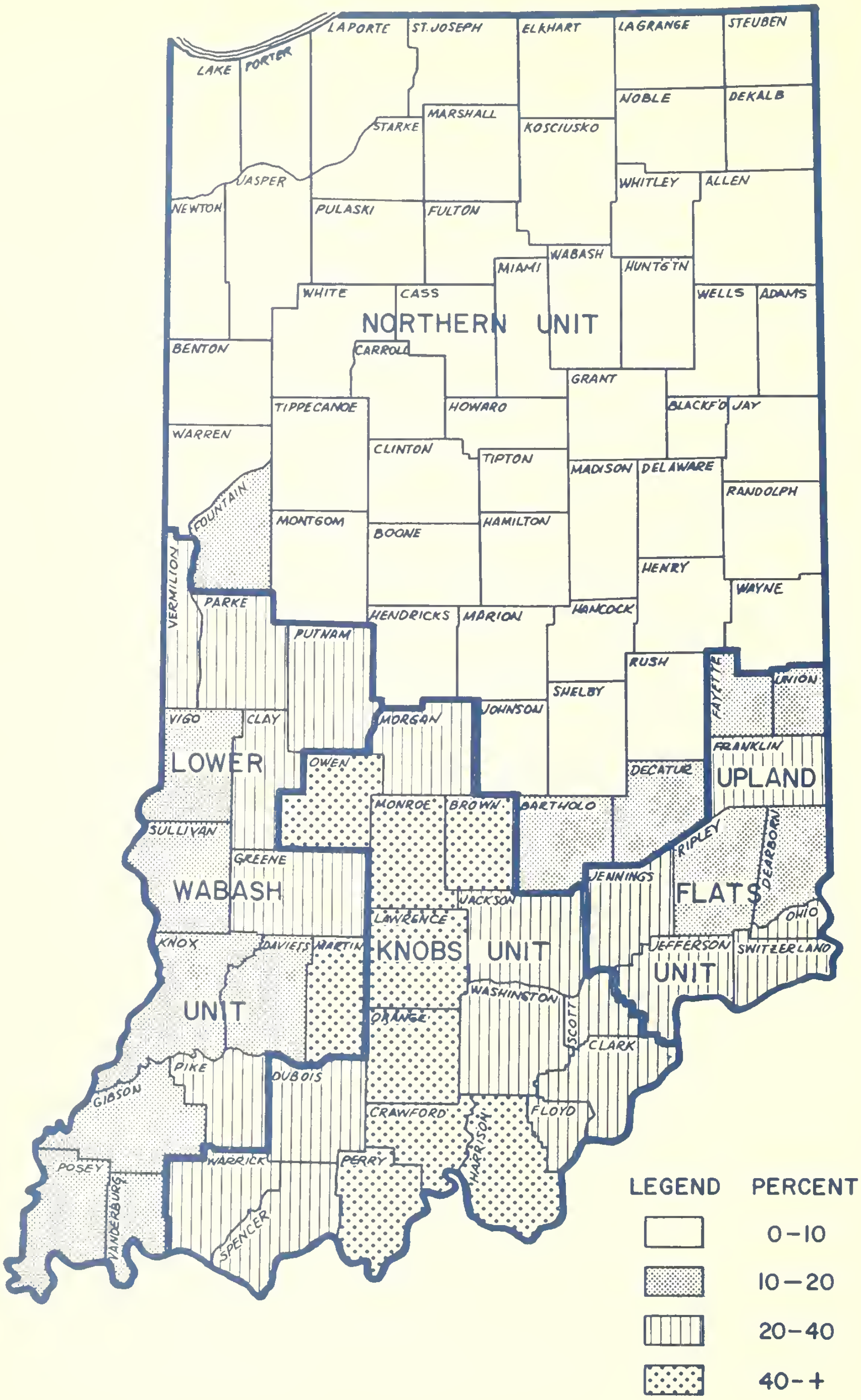

Figure 1. — Commercial forest as a percent of land area, by county, Indiana, 1967.

U. S. FOREST SERVICE

RESEARCH NOTE NC-58

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Timber Volume in Indiana, 1967

ABSTRACT.—The recently completed Second Forest Survey of Indiana shows that the State's timber volume has increased by one-fourth in the 17 years since the previous survey. Timber volume by county is presented.

The majority of Indiana's 3.5 billion cubic feet of growing stock[1] and 10.9 billion board feet of sawlog[2] material is in the south-central counties. A 17-county block here, (Knobs Forest Survey Unit) contains half of the growing stock and sawtimber volume in the State (Fig. 1). Timber is economically important in this rugged upland area, which is largely unsuited for agriculture. It provided nearly one-third of the sawlogs cut in Indiana in 1966. The oaks — chiefly white, black, and northern red — make up 46 percent of the growing stock and 52 percent of the sawtimber volume here (Tables 1 and 2).

A 14-county block (Lower Wabash Unit) in southwestern Indiana accounts for one-fifth of the State total timber volume with the oaks again the most prominent. This is a flat-to-rolling area that contains the wide riverbottoms of the Wabash and White Rivers. The poorly-drained upland area in the southeast (Upland Flats Unit) contain 7 percent of the State's timber volume. The remainder of the State (Northern Survey Unit) contains mostly small, scattered tracts occurring as farm woodlots. Despite having less than one-fourth of the State's total timber volume, this unit contributed almost 40 percent of the sawlogs cut in Indiana in 1966.

Indiana's growing stock volume increased about one-fourth between 1950 and 1967. However, this increase was not distributed proportionately across the State. Volume in the southern section increased by 50 percent to 2.7 billion cubic feet. Accumulating timber growth in the younger trees increased the volume in existing stands. In the three southern units the average volume rose from about 600 to 925 cubic feet per acre. An opposite trend was found in the Northern Unit where cubic-foot volume decreased by almost 25 percent to 0.8 billion cubic feet since 1950. Most of the reduction can be attributed to a 20-percent loss in commercial forest land in this area (see Research Note NC-57, "Forest Land in Indiana Counties, 1967").

Growing stock trends are shown in the following tabulation:

Growing Stock	*1950*	*1967*
	Million Cubic Feet	
Three Southern Units	1,783.1	2,733.7
Northern Unit	1,004.6	769.3
Total	2,787.7	3,503.0

The State's sawtimber volume has not kept pace with the increase in younger growing stock. Heavier cutting of sawtimber-size trees, a loss of commercial forest land in the north, and a rise in mortality of sawtimber trees (especially elm), have decreased board-foot volumes slightly (1 percent) since 1950. Volume in the south rose by almost one-third to 8.4 billion board feet while volume in the north was reduced by nearly one-half to 2.5 billion board feet. Sawtimber trends are shown in the following tabulation:

Sawtimber	*1950*	*1967*
	Million Board Feet	
Three Southern Units	6,382	8,394
Northern Unit	4,628	2,491
Total	11,010	10,885

White oak, hickory, black oak, hard maple, and northern red oak are the most abundant species; they make up 52 percent of Indiana's growing-stock volume. Almost all species have increased in growing-stock volume since 1950. The largest percentage increases, were in two bottom-land species — cottonwood and sycamore — which increased by 118 and 97 percent respectively. In total volume, hickory, a species with limited markets, increased the most, from 262 million to 442 million cubic feet. Elm, hit hard by Dutch Elm disease, was reduced from 265 to 96 million cubic feet.

[1] *Net volume in cubic feet, of sawtimber and poletimber trees of commercial species from stump to a minimum 4-inch top.*

[2] *Net volume in board feet, International ¼-inch rule, of merchantable sawlogs in sawtimber trees.*

Table 1. — *Volume of growing stock*[1] *on commercial forest land by county and species groups,*[2] *Indiana, 1967*
(Million cubic feet)

County	All species	Softwoods	White oak group	Red oak group	Hickory	Hard maple	Soft maple	Beech	Ash	Cottonwood	Yellow poplar	Sycamore	Other Hardwoods
						LOWER WABASH UNIT							
Clay	47.5	0.6	5.9	9.0	7.2	2.5	2.9	0.4	2.8	0.5	3.6	2.8	9.3
Daviess	39.0	-	5.0	6.9	6 3	1.8	3.2	0.5	2.4	0.7	2.5	2.1	7.6
Gibson	48.6	0.9	6.0	7.1	6.4	2.8	5.0	0.5	3.2	1.0	3.0	3.1	8.6
Knox	34.2	0.9	4.0	5.5	4.4	1.7	4.5	0.3	2.1	0.9	2.3	1.9	5.7
Martin	113.0	1.0	16.5	23.5	18.0	6.6	5.3	1.3	5.9	0.6	9.4	5.3	19.6
Parke	81.4	0.9	10.9	15.4	12.2	4.1	5.5	0.7	4.8	0.9	8.6	4.0	15.4
Pike	52.3	1.0	6.0	8.2	7.3	2.3	4.1	0.4	3.4	0.9	3.2	3.4	12.1
Posey	43.0	1.7	5.3	6.7	5.9	2.2	2.9	0.5	2.5	1.0	2.8	3.5	8.0
Putnam	69.7	1.8	9.9	13.1	11.2	3.9	4.0	0.8	3.9	0.6	5.5	3.2	11.8
Sullivan	49.8	0.9	5.8	7.6	7.5	2.5	4.3	0.6	3.3	1.0	3.0	2.5	10.8
Vanderburgh	19.5	0.4	2.4	3.3	2.8	1.2	1.5	0.2	1.2	0.4	1.4	1.2	3.5
Vermillion	37.2	2.1	4.4	5.9	5.1	2.0	3.1	0.3	1.8	0.4	2.3	2 4	7.4
Vigo	42.9	1.0	5.0	7.0	6.4	2.2	3.1	0.4	2.8	1.0	2.7	2.6	8.7
Greene	88.1	0.3	12.3	17.7	13.5	4.5	5.5	0.9	5.0	0.7	7.0	3.9	16.8
Total	766.2	13.5	99.4	136.9	114.2	40.3	54.9	7.8	45.1	10.6	55.3	41.9	146.3
						KNOBS UNIT							
Brown	144.1	2.3	38.1	33.1	19.4	11.5	1.8	6.8	5.1	0.2	7.9	3.9	14.0
Clark	93.9	4.9	23.8	19.9	12.1	7.4	1.1	3.7	3.6	0.4	4.5	2.9	9.6
Crawford	103.7	2.9	26.7	22.9	14.3	7.5	1.0	4.5	3.6	0.4	5.8	3.8	10.3
DuBois	100.8	2.1	23.3	20.9	13.4	8.5	1.5	4.5	4.1	0.9	5.1	4.4	12.1
Floyd	38.8	1.5	9.8	8.6	5.2	3.1	0.4	1.8	1.3	0.1	2.1	0.9	4.0
Harrison	122.0	4.8	29.3	26.0	16.6	9.3	1.3	5.4	4.4	0.6	6.7	5.0	12.6
Jackson	118.7	2.3	28.3	24.8	14.9	10.4	1.7	5.6	4.6	0.9	6.0	5.4	13.7
Lawrence	111.0	1.3	25.3	22.6	15.2	9.0	1.3	5.7	4.1	1.1	6.7	6.2	12.5
Monroe	132.5	3.1	33.6	29.5	17.6	10.6	1.3	5.3	4.9	0.6	7.5	4.8	13.7
Morgan	88.3	1.5	22.5	18.8	11.5	7.4	1.1	3.1	3.5	0.4	4.7	3.8	10.0
Orange	105.5	3.4	23.5	20.2	13.6	9.4	1.0	5.0	3.7	1.4	5.9	6.9	11.5
Owen	113.0	1.7	29.9	25.2	15.2	8.8	1.3	4.6	4.1	0.4	5.9	4.1	11.8
Perry	146.3	6.3	37.0	31.9	19.4	11.4	1.5	6.3	5.3	0.6	7.7	4.8	14.1
Scott	47.7	0.4	11.7	10.0	6.0	4.2	0.6	2.0	1.8	0.7	2.6	2.9	4.8
Spencer	62.3	0.8	11.9	11.0	8.7	6.4	0.8	3.6	2.6	0.8	3.3	4.0	8.4
Warrick	53.7	0.7	11.1	9.7	7.8	4.6	0.9	2.1	2.2	0.5	2.9	3.3	7.9
Washington	142.5	2.1	35.9	30.6	19.8	12.9	1.7	7.3	5.2	0.5	7.2	4.1	15.2
Total	1.724.8	42.1	421.7	365.8	230.7	142.4	20.3	77.3	64.1	10.5	92.5	71.2	186.2
						UPLAND FLATS UNIT							
Dearborn	23.0	-	4.4	3.7	2.2	3.5	1.5	2.2	1.2	-	1.3	0.1	2.9
Fayette	12.7	-	2.3	2.2	1.1	1.9	0.7	1.1	0.7	0.1	0.8	0.1	1.7
Franklin	42.5	0.1	8.3	7.7	4.7	7.1	2.0	3.1	2.4	0.3	2.0	0.4	4.4
Jefferson	42.5	0.1	8.2	8.1	5.5	5.8	2.0	2.6	2.7	-	2.1	0.5	4.9
Jennings	56.6	-	10.8	10.1	7.1	9.2	2.7	4.6	2.7	0.2	2.9	0.5	5.8
Ohio	8.3	-	1.5	1.4	1.0	1.7	0.3	0.6	0.4	-	0.5	0.1	0.8
Ripley	32.4	0.1	5.9	5.8	3.6	4.4	1.7	2.4	2.1	0.2	1.8	0.6	3.8
Switzerland	15.9	0.1	3.0	3.4	1.6	1.4	0.7	1.1	1.0	-	0.9	0.3	2.4
Union	8.8	-	1.5	1.6	0.8	1.1	0.5	0.8	0.5	0.2	0.3	0.2	1.3
Total	242.7	0.4	45.9	44.0	27.6	36.1	12.1	18.5	13.7	1.0	12.6	2.8	28.0
						NORTHERN UNIT							
Adams	13.6	-	1.6	2.4	1.1	0.8	0.8	0.2	1.1	1.5	0.4	1.3	2.4
Allen	30.2	0.2	3.6	4.8	2.5	2.0	1.7	0.9	2.6	3.2	0.8	2.3	5.6
Bartholomew	33.4	-	4.2	5.6	2.8	4.0	1.7	1.9	3.3	1.5	0.8	1.6	6.0
Benton	0.8	-	0.1	0.2	-	-	0.1	-	0.1	-	-	0.1	0.2
Blackford	6.3	0.1	0.8	1.1	0.5	0.7	0.3	0.2	0.5	0.7	0.1	0.2	1.1
Boone	6.1	0.3	1.0	1.3	0.7	0.5	0.3	0.1	0.6	-	0.2	0.2	0.9
Carroll	11.8	0.1	1.9	2.2	1.4	0.7	0.5	0.2	1.2	0.2	0.4	0.5	2.5
Cass	17.1	0.1	2.1	3.2	1.5	2.0	0.7	0.8	1.7	0.8	0.4	0.4	3.4
Clinton	6.9	0.1	0.6	1.0	0.5	0.7	0.5	0.2	0.9	0.1	0.2	0.4	1.7
Decatur	21.8	0.2	2.6	3.8	1.6	2.4	1.1	1.3	2.1	1.0	0.5	1.2	4.0
DeKalb	18.7	0.1	1.8	3.1	1.4	1.3	1.1	0.5	1.7	2.4	0.5	1.4	3.4
Delaware	10.4	-	1.1	1.8	0.7	1.5	0.5	0.7	0.8	0.3	0.3	0.4	2.3
Elkhart	18.4	0.1	2.3	3.5	1.5	1.3	1.3	0.6	1.8	1.2	0.4	0.7	3.7
Fountain	25.7	0.3	2.9	4.5	2.4	3.3	1.2	1.2	2.2	1.3	0.6	1.3	4.5
Fulton	14.3	0.1	2.0	2.9	1.3	1.3	0.8	0.6	1.0	1.0	0.4	0.3	2.6
Grant	10.8	-	1.3	2.0	0.9	1.5	0.5	0.8	0.8	0.6	0.4	0.2	1.8
Hamilton	11.2	-	1.7	2.1	1.0	0.8	0.5	0.3	1.0	1.6	0.3	0.3	1.6
Hancock	6.0	-	0.5	0.9	0.5	0.9	0.2	0.2	0.8	0.1	0.2	0.2	1.5
Hendricks	12.3	-	1.5	2.1	1.2	0.7	0.7	0.4	1.3	0.6	0.5	1.1	2.2
Henry	12.1	-	1.6	2.2	1.1	1.5	0.4	0.6	1.0	0.2	0.5	0.3	2.7
Howard	5.9	0.1	0.7	1.0	0.5	0.4	0.3	0.1	0.5	0.7	0.1	0.6	0.9
Huntington	15.9	0.3	2.3	3.0	1.4	1.3	1.0	0.4	1.3	1.1	0.5	0.6	2.7
Jasper	18.3	0.2	2.6	4.1	1.9	1.2	0.7	0.6	1.6	1.0	0.6	0.6	3.2
Jay	18.2	-	1.8	3.3	1.4	2.4	0.9	0.9	1.6	1.5	0.4	0.6	3.4
Johnson	10.5	-	1.3	2.3	0.9	0.9	0.8	0.4	0.8	0.5	0.3	0.4	1.9
Kosciusko	22.4	0.1	2.9	4.0	1.9	2.4	0.8	0.8	2.1	1.1	0.7	1.3	4.3
LaGrange	13.9	0.2	2.2	2.8	1.4	0.9	0.6	0.3	1.2	0.5	0.4	1.1	2.3
Lake	8.5	-	1.5	1.7	0.7	0.3	0.4	0.2	0.7	1.4	0.1	0.3	1.2
LaPorte	21.5	0.1	3.3	4.9	2.1	1.3	0.9	0.5	1.7	1.6	0.8	0.6	3.7
Madison	8.2	0.1	0.5	1.0	0.5	1.6	0.4	0.7	0.8	0.2	0.2	0.4	1.8
Marion	11.1	-	1.3	2.0	0.9	1.3	0.5	0.7	1.2	0.3	0.3	0.4	2.2
Marshall	21.2	0.3	3.2	4.5	2.1	1.7	0.8	0.7	1.8	0.5	0.6	1.3	3.7
Miami	15.3	-	2.2	2.9	1.6	1.6	0.8	0.6	1.3	0.5	0.5	0.7	2.8
Montgomery	18.0	0.3	2.7	4.0	2.0	1.0	0.8	0.5	1.4	0.7	0.9	0.6	3.1
Newton	12.0	-	1.6	2.6	1.2	0.6	0.8	0.2	1.3	0.3	0.3	0.5	2.6
Noble	18.7	0.1	2.7	4.2	1.9	1.4	0.8	0.6	1.4	1.3	0.5	0.4	3.4
Porter	20.9	0.1	2.8	4.0	2.1	1.5	1.2	0.7	2.2	0.6	0.8	0.8	4.1
Pulaski	19.1	-	2.8	3.6	2.0	1.9	0.8	0.6	1.6	0.8	0.7	0.6	3.7
Randolph	12.6	-	1.6	2.6	0.9	1.3	0.7	0.5	1.2	0.8	0.4	0.3	2.3
Rush	10.5	-	1.1	1.4	0.8	1.3	0.6	0.5	1.1	0.8	0.3	0.5	2.1
St. Joseph	18.3	0.1	2.7	3.8	1.6	1.2	1.1	0.6	1.6	1.1	0.5	0.6	3.4
Shelby	8.6	0.1	0.4	1.1	0.7	1.1	0.4	0.4	1.0	0.7	0.2	0.4	2.1
Starke	21.8	0.1	2.8	4.6	1.9	1.8	0.8	0.5	1.6	2.8	0.8	0.6	3.7
Steuben	17.0	0.4	2.0	3.6	1.6	1.4	0.7	0.7	1.2	1.7	0.5	0.4	2.8
Tippecanoe	13.4	0.1	1.8	2.5	1.3	1.4	0.7	0.6	1.1	0.2	0.5	0.4	2.8
Tipton	5.1	-	0.5	1.0	0.4	0.5	0.4	0.2	0.5	0.7	0.1	0.2	0.6
Wabash	17.2	0.2	2.1	3.1	1.6	1.1	1.3	0.5	1.5	1.4	0.6	0.7	3.1
Warren	19.1	-	2.5	3.4	1.9	1.5	1.0	0.7	1.5	1.3	0.7	1.2	3.4
Wayne	16.8	0.1	2.0	3.1	1.4	1.4	0.8	0.6	1.6	0.6	0.6	0.8	3.8
Wells	16.1	-	2.1	2.8	1.5	1.3	1.1	0.6	1.4	1.2	0.4	1.0	2.7
White	9.6	-	2.0	2.4	1.1	0.7	0.4	0.2	0.7	0.1	0.4	0.3	1.3
Whitley	15.7	0.1	2.2	2.9	1.5	1.4	0.8	0.6	1.4	1.0	0.5	0.3	3.0
Total	769.3	4.8	99.4	144.9	69.3	68.8	39.0	28.4	68.4	47.3	23.1	33.9	142.0
STATE TOTAL	3,503.0	60.8	666.4	691.6	441.8	287.6	126.3	132.0	191.3	69.4	183.5	149.8	502.5

See footnotes on page 4.

Table 2. — *Volume of sawtimber*[1] *on commercial forest land by county and species groups,*[2] *Indiana, 1967*
(Million board feet)[3]

County	All species	Softwoods	White oak group	Red oak group	Hickory	Hard maple	Soft maple	Beech	Ash	Cottonwood	Yellow poplar	Sycamore	Other Hardwoods
						LOWER WABASH UNIT							
Clay	141.0	3.0	19.5	33.8	21.2	5.7	7.2	1.1	6.0	1.8	12.3	9.7	19.6
Daviess	112.4	-	17.5	26.3	18.7	3.8	6.4	1.2	5.1	2.5	8.4	6.7	15.8
Gibson	151.6	5.6	21.8	27.4	18.8	6.7	12.5	1.7	7.2	3.7	10.2	10.1	25.9
Knox	102.1	5.9	13.8	19.7	13.0	4.1	10.1	0.9	3.8	3.4	7.6	6.1	13.8
Martin	335.8	5.8	53.5	88.4	49.2	14.6	14.3	3.7	14.0	2.5	32.0	17.1	40.7
Parke	235.5	5.7	36.0	57.0	32.4	8.7	12.6	2.2	11.3	3.7	23.1	11.9	30.9
Pike	144.0	3.1	19.5	29.6	20.5	5.3	9.5	1.0	7.5	3.3	10.4	11.0	23.3
Posey	137.0	11.3	18.5	26.5	17.2	4.4	7.2	1.4	6.3	3.7	9.6	11.7	19.2
Putnam	212.2	11.4	32.6	48.8	31.5	9.4	10.9	2.1	9.3	2.2	18.6	10.5	24.8
Sullivan	147.0	5.7	20.1	28.6	22.9	5.2	11.9	1.8	6.4	3.6	10.1	8.0	22.8
Vanderburgh	60.0	2.8	8.0	12.2	7.9	3.3	3.8	0.6	2.9	1.6	5.2	3.6	8.1
Vermillion	118.7	14.1	14.9	21.6	14.7	5.0	8.1	1.1	5.0	1.5	7.5	8.6	16.6
Vigo	128.9	5.7	17.1	27.1	19.1	4.6	7.8	1.3	5.9	3.4	9.3	8.3	19.3
Greene	245.3	0.2	39.8	65.1	35.6	9.1	11.9	2.4	11.2	2.9	23.3	11.7	32.0
Total	2,271.5	80.0	332.7	512.2	322.6	89.8	134.2	22.5	102.0	39.9	187.6	135.0	312.9
						KNOBS UNIT							
Brown	462.6	3.8	125.8	132.1	51.7	26.8	4.1	25.4	14.1	0.6	27.6	13.9	36.6
Clark	285.3	11.8	73.6	76.8	32.1	16.8	2.6	14.0	8.5	1.1	15.9	8.6	23.5
Crawford	307.1	5.6	81.4	85.8	35.2	16.7	2.4	15.6	8.6	1.8	19.8	10.7	23.5
DuBois	330.2	4.2	76.7	85.4	40.1	20.9	4.0	19.0	11.5	3.7	18.7	14.8	32.2
Floyd	122.8	4.4	31.7	33.8	13.7	7.5	1.0	6.9	3.6	0.4	7.3	3.2	9.4
Harrison	380.8	8.1	95.9	103.0	44.7	21.4	3.1	20.7	12.0	2.6	23.4	15.1	30.8
Jackson	372.1	4.2	91.2	96.0	40.6	24.6	3.9	21.7	12.4	3.6	22.3	17.1	34.5
Lawrence	350.9	2.2	83.2	88.7	41.7	20.9	3.2	20.9	11.1	4.5	23.7	18.8	30.9
Monroe	402.4	4.3	104.9	110.4	45.5	24.1	3.1	19.3	12.5	2.4	27.5	16.3	32.1
Morgan	269.5	3.1	70.2	72.2	29.9	17.5	2.4	11.9	8.4	1.5	16.4	12.8	23.2
Orange	316.4	4.7	73.3	77.1	35.5	21.2	2.4	18.2	9.4	5.8	20.0	21.2	27.6
Owen	347.2	3.6	93.6	96.6	39.2	20.7	2.9	17.1	10.1	1.4	21.0	13.2	27.8
Perry	450.1	11.3	117.6	123.6	50.7	26.7	3.8	23.7	14.0	2.4	26.9	15.0	34.4
Scott	154.2	0.9	38.4	39.8	16.6	9.6	1.2	7.9	4.8	3.0	9.5	10.0	12.5
Spencer	203.2	3.0	39.1	43.8	27.3	15.6	1.9	14.0	7.7	3.2	12.1	13.2	22.3
Warrick	163.0	1.0	34.7	36.5	22.8	11.1	1.7	8.4	4.7	2.3	10.6	11.1	18.1
Washington	465.2	4.6	119.4	123.5	56.1	31.2	4.4	28.0	14.7	1.9	26.2	15.0	40.2
Total	5,383.1	80.9	1,350.7	1,425.1	623.4	333.3	48.1	291.7	168.1	42.2	328.9	231.1	459.6
						UPLAND FLATS UNIT							
Dearborn	73.4	-	16.4	13.9	6.6	8.5	5.4	7.5	2.9	-	5.6	0.2	6.4
Fayette	40.1	-	8.5	8.3	3.4	4.6	2.5	3.8	1.3	0.5	3.4	0.3	3.5
Franklin	131.8	-	29.2	27.2	13.3	19.0	6.4	10.6	5.9	0.9	9.5	1.1	10.7
Jefferson	126.2	0.1	27.7	27.5	16.2	13.8	5.5	9.0	6.5	0.1	8.5	0.9	10.6
Jennings	175.5	-	37.2	36.2	21.8	22.5	8.5	15.5	6.8	0.5	11.6	0.9	14.0
Ohio	24.6	-	4.9	5.1	2.7	4.2	1.0	2.3	0.9	-	1.8	-	1.7
Ripley	98.2	-	20.6	20.2	10.3	10.6	5.0	8.0	4.8	0.8	7.4	1.4	9.1
Switzerland	42.9	-	9.8	11.1	3.7	2.6	1.9	4.0	1.6	-	3.9	0.6	3.7
Union	27.4	-	5.5	5.4	2.7	2.8	1.6	2.5	1.2	0.7	1.6	0.6	2.8
Total	740.1	0.1	159.8	154.9	80.7	87.4	37.8	63.2	31.9	3.5	52.3	6.0	62.5
						NORTHERN UNIT							
Adams	45.0	-	5.9	9.0	3.0	2.7	1.8	.9	3.2	8.3	1.4	5.7	5.1
Allen	97.4	0.5	12.5	17.7	6.3	6.9	4.7	3.7	6.9	13.1	3.0	9.5	12.6
Bartholomew	114.3	-	16.2	21.5	7.0	14.6	5.0	7.6	8.9	7.2	2.9	6.9	16.5
Benton	1.7	-	0.2	0.7	0.1	0.1	0.3	-	0.1	-	0.1	0.1	-
Blackford	21.5	0.2	2.9	4.5	1.5	2.2	0.7	0.9	1.5	2.9	0.4	0.5	3.3
Boone	18.7	-	3.7	4.9	1.6	1.8	0.8	0.5	1.5	0.1	0.6	0.6	2.6
Carroll	35.4	0.3	7.1	8.3	3.2	2.1	1.5	1.0	2.3	0.2	1.5	1.9	6.0
Cass	56.1	0.3	7.9	12.4	3.7	7.1	2.2	3.2	4.6	2.7	1.5	1.3	9.2
Clinton	22.6	0.2	2.1	3.8	1.2	2.7	1.5	0.8	2.6	0.5	0.6	1.5	5.1
Decatur	71.7	0.3	9.7	14.1	4.1	8.7	3.3	5.1	5.6	4.3	1.8	4.8	9.9
DeKalb	60.8	0.2	5.8	11.3	3.6	4.8	3.0	2.0	4.5	9.7	1.9	5.9	8.1
Delaware	34.0	-	4.3	6.4	1.8	5.7	1.1	3.0	2.5	0.8	1.1	1.6	5.7
Elkhart	60.6	0.2	8.4	13.0	3.6	4.4	3.7	2.6	5.3	5.5	1.6	2.6	9.7
Fountain	84.4	0.5	10.3	15.6	5.8	13.0	3.6	5.1	6.3	5.6	2.1	5.2	11.3
Fulton	47.4	0.3	7.6	11.2	3.5	3.9	2.3	2.3	2.8	4.5	1.6	1.2	6.2
Grant	36.3	-	4.7	7.5	2.3	5.5	1.3	2.8	2.6	2.7	1.1	0.8	4.9
Hamilton	38.4	-	6.4	8.1	2.9	2.9	1.6	1.3	2.7	6.6	0.9	1.2	3.8
Hancock	20.4	0.2	1.8	3.4	1.4	3.5	0.5	0.6	2.4	0.6	0.6	1.0	4.4
Hendricks	38.2	-	5.6	7.6	2.8	1.7	2.2	1.7	2.8	2.3	1.8	4.3	5.4
Henry	38.6	0.2	6.0	8.4	3.1	4.9	1.1	2.3	2.7	0.2	1.6	1.1	7.0
Howard	18.6	-	2.1	3.6	1.0	1.3	1.1	0.4	1.5	2.7	0.4	2.6	1.9
Huntington	50.1	0.2	8.7	10.7	3.4	4.4	2.5	1.7	3.6	4.5	1.9	2.3	6.3
Jasper	55.7	0.2	9.5	14.8	4.3	3.5	2.3	2.3	3.6	4.1	2.2	1.9	7.0
Jay	63.0	-	6.6	12.4	3.8	9.3	2.5	3.6	5.2	6.6	1.4	2.6	9.0
Johnson	35.4	-	4.9	8.5	2.5	3.1	2.1	1.7	2.5	2.2	1.2	1.5	5.2
Kosciusko	74.0	0.2	10.7	14.8	4.6	8.6	2.5	3.2	5.8	4.4	2.5	5.3	11.4
LaGrange	45.2	0.2	8.0	10.2	3.6	3.2	1.8	1.4	3.0	1.9	1.5	4.5	5.8
Lake	29.4	-	5.9	7.0	2.3	1.0	0.9	0.7	1.4	6.0	0.5	1.1	2.6
LaPorte	67.8	-	12.2	18.9	5.0	4.1	2.5	2.0	3.7	6.5	2.7	1.9	8.3
Madison	27.8	0.4	1.5	3.9	1.2	6.5	1.0	2.8	2.8	1.0	0.7	1.4	4.6
Marion	36.8	0.1	4.8	7.8	2.4	4.1	1.7	2.6	3.3	1.5	1.1	1.4	6.0
Marshall	71.0	0.2	11.5	17.0	5.7	6.1	2.8	3.0	5.0	2.4	2.1	5.2	10.0
Miami	49.5	-	7.9	10.8	3.8	5.6	2.3	2.5	3.8	2.2	1.7	3.1	5.8
Montgomery	52.6	-	9.6	14.0	4.6	3.2	2.2	1.8	3.3	2.1	2.9	1.8	7.1
Newton	36.1	-	6.0	9.2	2.7	2.0	1.8	0.7	3.3	1.1	1.3	2.1	5.9
Noble	58.9	0.1	10.2	14.9	4.8	5.0	2.3	2.7	3.8	5.3	1.9	1.1	6.8
Porter	64.0	-	10.6	14.8	5.4	4.5	3.4	2.7	4.9	2.1	2.7	2.4	10.5
Pulaski	59.3	-	10.3	12.6	4.6	7.1	2.2	2.2	4.5	2.6	2.4	2.6	8.2
Randolph	42.2	-	6.1	10.3	2.7	5.0	2.0	2.2	3.1	3.3	1.3	1.3	4.9
Rush	35.7	-	4.4	5.3	2.2	4.9	1.7	1.8	3.0	3.4	1.0	1.9	6.1
St. Joseph	58.0	0.2	9.9	13.7	4.1	3.6	3.1	2.2	4.6	4.2	1.9	2.5	8.0
Shelby	29.5	0.5	1.5	4.0	1.7	4.0	1.2	1.5	3.1	3.0	0.6	1.3	6.1
Starke	69.4	0.1	9.5	16.1	4.8	5.7	2.3	2.2	3.8	11.3	2.7	1.6	8.2
Steuben	54.1	0.4	6.9	13.2	4.2	4.8	2.1	2.8	3.5	7.3	1.7	1.1	6.1
Tippecanoe	40.4	0.2	6.8	8.7	3.1	4.6	2.0	2.2	2.8	0.4	1.7	1.3	6.6
Tipton	17.3	-	1.9	3.6	1.2	1.9	1.3	0.7	1.1	2.7	0.3	0.9	1.7
Wabash	56.0	0.2	7.6	11.3	3.9	3.8	3.1	2.0	4.4	6.1	2.1	3.2	8.3
Warren	62.0	0.1	8.9	12.7	4.7	5.2	2.7	2.8	3.8	5.4	2.7	5.4	7.6
Wayne	53.0	0.2	7.6	11.9	3.6	4.6	1.8	2.3	4.3	2.3	2.1	2.9	9.4
Wells	54.4	-	7.6	10.7	3.9	4.3	3.5	2.4	3.9	5.0	1.7	4.8	6.6
White	31.2	-	7.4	9.3	3.0	2.3	0.9	0.6	1.7	0.2	1.4	0.9	3.5
Whitley	50.8	-	8.2	11.3	3.6	4.4	2.6	2.3	3.9	4.0	1.7	1.2	7.6
Total	2,490.7	6.9	394.4	537.4	174.9	240.9	110.4	113.5	183.9	193.6	82.0	132.8	350.0
STATE TOTAL	10,885.4	167.9	2,207.6	2,629.6	1,201.6	751.5	330.5	490.9	485.9	279.2	650.8	504.9	1,185.0

See footnotes on page 4.

White oak, black oak, hickory, northern red oak, and hard maple are the most abundant sawtimber-size trees in Indiana, comprising over half the total board-foot volume. All these species except hard maple increased in volume since the last survey in 1950. Other species have not fared as well: elm, black walnut, soft maple, ash, and beech all have decreased in volume since 1950.

The sampling error for the State's growing-stock volume of 3.5 billion cubic feet is ± 3.1 percent at one standard error (the 67-percent confidence limit). Sampling error increases as volume decreases; for 20 million cubic feet the probable error would be within ± 40.8 percent (± 8 million cubic feet).

These volume statistics are from the Second Forest Survey of Indiana made between September 1966 and June 1967 by the North Central Forest Experiment Station and the Indiana Department of Natural Resources, Division of Forestry.

1968

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Figure 1. — Growing stock volume in Indiana counties, 1967.

FOOTNOTES: Table 1.

1 *Net volume of live merchantable sawtimber and poletimber trees from the stump to a variable 4-inch top diameter outside bark of the central stem. Does not include limbs or cull tree volume.*

2 *Species: Softwoods — Primarily eastern redcedar, tamarack, jack pine, shortleaf pine, red pine, white pine, Scotch pine, Virginia pine, and baldcypress. White oak group — white oak, swamp white oak, bur oak, swamp chestnut oak, chinkapin oak, chestnut oak, and post oak. Red oak group — northern red oak, cherrybark oak, Shumard oak, black oak, scarlet oak, southern red oak, shingle oak, and pin oak. Other hardwoods — primarily sweetgum, blackgum, aspen, basswood, black walnut, black cherry, and elm.*

FOOTNOTES: Table 2.

1 *Net volume of live merchantable sawtimber trees (softwoods 9.0 inches d.b.h. or larger and hardwoods 11.0 inches d.b.h. and larger) from the stump to a point in the central stem at which utilization for sawn products is limited by large branches, forks, or other defects, or by a diameter outside bark of 7.0 inches for softwoods and 9.0 inches for hardwoods.*

2 *See footnote 2 for table 1.*

3 *International ¼-inch rule.*

U. S. FOREST SERVICE

RESEARCH NOTE NC-58
REVISED

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Timber Volume in Indiana, 1967

ABSTRACT.—The recently completed Second Forest Survey of Indiana shows that the State's timber volume has increased by one-fourth in the 17 years since the previous survey. Timber volume by county is presented.

The majority of Indiana's 3.5 billion cubic feet of growing stock[1] and 10.9 billion board feet of sawlog[2] material is in the south-central counties. A 17-county block here, (Knobs Forest Survey Unit) contains half of the growing stock and sawtimber volume in the State (Fig. 1). Timber is economically important in this rugged upland area, which is largely unsuited for agriculture. It provided nearly one-third of the sawlogs cut in Indiana in 1966. The oaks — chiefly white, black, and northern red — make up 46 percent of the growing stock and 52 percent of the sawtimber volume here (Tables 1 and 2).

A 14-county block (Lower Wabash Unit) in southwestern Indiana accounts for one-fifth of the State total timber volume with the oaks again the most prominent. This is a flat-to-rolling area that contains the wide riverbottoms of the Wabash and White Rivers. The poorly-drained upland area in the southeast (Upland Flats Unit) contain 7 percent of the State's timber volume. The remainder of the State (Northern Survey Unit) contains mostly small, scattered tracts occurring as farm woodlots. Despite having less than one-fourth of the State's total timber volume, this unit contributed almost 40 percent of the sawlogs cut in Indiana in 1966.

Indiana's growing stock volume increased about one-fourth between 1950 and 1967. However, this increase was not distributed proportionately across the State. Volume in the southern section increased by 50 percent to 2.7 billion cubic feet. Accumulating timber growth in the younger trees increased the volume in existing stands. In the three southern units the average volume rose from about 600 to 925 cubic feet per acre. An opposite trend was found in the Northern Unit where cubic-foot volume decreased by almost 25 percent to 0.8 billion cubic feet since 1950. Most of the reduction can be attributed to a 20-percent loss in commercial forest land in this area (see Research Note NC-57, "Forest Land in Indiana Counties, 1967").

Growing stock trends are shown in the following tabulation:

Growing Stock	*1950*	*1967*
	Million Cubic Feet	
Three Southern Units	1,783.1	2,733.7
Northern Unit	1,004.6	769.3
Total	2,787.7	3,503.0

The State's sawtimber volume has nearly kept pace with the increase in younger growing stock.[3] Volume in the south rose by almost two-thirds to 8.4 billion board feet while volume in the north was reduced by nearly one-third to 2.5 billion board feet. Sawtimber trends are shown in the following tabulation:

Sawtimber	*1950*	*1967*
	Million Board Feet	
Three Southern Units	5,064	8,394
Northern Unit	3,672	2,491
Total	8,736	10,885

White oak, hickory, black oak, hard maple, and northern red oak are the most abundant species; they make up 52 percent of Indiana's growing-stock volume. Almost all species have increased in growing-stock volume since 1950. The largest percentage increases, were in two bottom-land species — cottonwood and sycamore — which increased by 118 and 97 percent respectively. In total volume, hickory, a species with limited markets, increased the most. from 262 million to 442 million cubic feet. Elm, hit hard by Dutch Elm disease and to a lesser extent phloem necrosis, was reduced from 265 to 96 million cubic feet.

[1] *Net volume in cubic feet of sawtimber and pole-timber trees of commercial species from stump to a minimum 4-inch top.*

[2] *Net volume in board feet, International ¼-inch rule, of merchantable sawlogs in sawtimber trees.*

[3] *The 1950 board-foot volumes have been adjusted to 1967 standards so as to make comparisons between the two years possible.*

Table 1. — *Volume of growing stock*[1] *on commercial forest land by county and species groups,*[2] *Indiana, 1967*

(Million cubic feet)

County	All species	Softwoods	White oak group	Red oak group	Hickory	Hard maple	Soft maple	Beech	Ash	Cottonwood	Yellow poplar	Sycamore	Other Hardwoods
						LOWER WABASH UNIT							
Clay	47.5	0.6	5.9	9.0	7.2	2.5	2.9	0.4	2.8	0.5	3.6	2.8	9.3
Daviess	39.0	-	5.0	6.9	6.3	1.8	3.2	0.5	2.4	0.7	2.5	2.1	7.6
Gibson	48.6	0.9	6.0	7.1	6.4	2.8	5.0	0.5	3.2	1.0	3.0	3.1	8.6
Knox	34.2	0.9	4.0	5.5	4.4	1.7	4.5	0.3	2.1	0.9	2.3	1.8	5.7
Martin	113.0	1.0	16.5	23.5	18.0	6.6	5.3	1.3	5.9	0.6	9.4	5.3	19.6
Parke	81.4	0.9	10.9	15.4	12.2	4.1	5.5	0.7	4.8	0.9	8.6	4.0	15.4
Pike	52.3	1.0	6.0	8.2	7.3	2.3	4.1	0.4	3.4	0.9	3.2	3.4	12.1
Posey	43.0	1.7	5.3	6.7	5.9	2.2	2.9	0.5	2.5	1.0	2.8	3.5	8.0
Putnam	69.7	1.8	9.9	13.1	11.2	3.9	4.0	0.8	3.9	0.6	5.5	3.2	11.8
Sullivan	49.8	0.9	5.8	7.6	7.5	2.5	4.3	0.6	3.3	1.0	3.0	2.5	10.8
Vanderburgh	19.5	0.4	2.4	3.3	2.8	1.2	1.5	0.2	1.2	0.4	1.4	1.2	3.5
Vermillion	37.2	2.1	4.4	5.9	5.1	2.0	3.1	0.3	1.8	0.4	2.3	2.4	7.4
Vigo	42.9	1.0	5.0	7.0	6.4	2.2	3.1	0.4	2.8	1.0	2.7	2.6	8.7
Greene	88.1	0.3	12.3	17.7	13.5	4.5	5.5	0.9	5.0	0.7	7.0	3.9	16.8
Total	766.2	13.5	99.4	136.9	114.2	40.3	54.9	7.8	45.1	10.6	55.3	41.9	146.3
						KNOBS UNIT							
Brown	144.1	2.3	38.1	33.1	19.4	11.5	1.8	6.8	5.1	0.2	7.9	3.9	14.0
Clark	93.9	4.9	23.8	19.9	12.1	7.4	1.1	3.7	3.6	0.4	4.5	2.9	9.6
Crawford	103.7	2.9	26.7	22.9	14.3	7.5	1.0	4.5	3.6	0.4	5.8	3.8	10.3
DuBois	100.8	2.1	23.3	20.9	13.4	8.5	1.5	4.5	4.1	0.9	5.1	4.4	12.1
Floyd	38.8	1.5	9.8	8.6	5.2	3.1	0.4	1.8	1.3	0.1	2.1	0.9	4.0
Harrison	122.0	4.8	28.3	26.0	16.6	9.3	1.3	5.4	4.4	0.6	6.7	5.0	12.6
Jackson	118.7	2.3	28.3	24.9	14.9	10.4	1.7	5.6	4.6	0.9	6.0	5.4	13.7
Lawrence	111.0	1.3	25.3	22.6	15.2	9.0	1.3	5.7	4.1	1.1	6.7	8.2	12.5
Monroe	132.5	3.1	33.6	29.5	17.6	10.6	1.3	5.3	4.9	0.6	7.5	4.8	13.7
Morgan	88.3	1.5	22.5	18.8	11.5	7.4	1.1	3.1	3.5	0.4	4.7	3.8	10.0
Orange	105.5	3.4	23.5	20.2	13.6	9.4	1.0	5.0	3.7	1.4	5.9	6.9	11.5
Owen	113.0	1.7	29.9	25.2	15.2	8.8	1.3	4.6	4.1	0.4	5.9	4.1	11.8
Perry	146.3	6.3	37.0	31.9	19.4	11.4	1.5	6.3	5.3	0.6	7.7	4.8	14.1
Scott	47.7	0.4	11.7	10.0	6.0	4.2	0.6	2.0	1.8	0.7	2.6	2.9	4.8
Spencer	62.3	0.8	11.9	11.0	8.7	6.4	0.8	3.6	2.6	0.8	3.3	4.0	8.4
Warrick	53.7	0.7	11.1	9.7	7.8	4.6	0.9	2.1	2.2	0.5	2.9	3.3	7.9
Washington	142.5	2.1	35.9	30.6	19.8	12.9	1.7	7.3	5.2	0.5	7.2	4.1	15.2
Total	1,724.8	42.1	421.7	365.8	230.7	142.4	20.3	77.3	64.1	10.5	92.5	71.2	186.2
						UPLAND FLATS UNIT							
Dearborn	23.0	-	4.4	3.7	2.2	3.5	1.5	2.2	1.2	-	1.3	0.1	2.9
Fayette	12.7	-	2.3	2.2	1.1	1.9	0.7	1.1	0.7	0.1	0.8	0.1	1.7
Franklin	42.5	0.1	8.3	7.7	4.7	7.1	2.0	3.1	2.4	0.3	2.0	0.4	4.4
Jefferson	42.5	0.1	8.2	8.1	5.5	5.8	2.0	2.6	2.7	-	2.1	0.5	4.9
Jennings	56.6	-	10.8	10.1	7.1	9.2	2.7	4.6	2.7	0.2	2.9	0.5	5.8
Ohio	8.3	-	1.5	1.4	1.0	1.7	0.3	0.6	0.4	-	0.5	0.1	0.8
Ripley	32.4	0.1	5.9	5.8	3.6	4.4	1.7	2.4	2.1	0.2	1.8	0.6	3.8
Switzerland	15.9	0.1	3.0	3.4	1.6	1.4	0.7	1.1	1.0	-	0.9	0.3	2.4
Union	8.8	-	1.5	1.6	0.8	1.1	0.5	0.8	0.5	0.2	0.3	0.2	1.3
Total	242.7	0.4	45.9	44.0	27.6	36.1	12.1	18.5	13.7	1.0	12.6	2.8	28.0
						NORTHERN UNIT							
Adams	13.6	-	1.6	2.4	1.1	0.8	0.8	0.2	1.1	1.5	0.4	1.3	2.4
Allen	30.2	0.2	3.6	4.8	2.5	2.0	1.7	0.9	2.6	3.2	0.8	2.3	5.6
Bartholomew	33.4	-	4.2	5.6	2.8	4.0	1.7	1.9	3.3	1.5	0.8	1.6	6.0
Benton	0.8	-	0.1	0.2	-	-	0.1	-	0.1	-	-	0.1	0.2
Blackford	6.3	0.1	0.8	1.1	0.5	0.7	0.3	0.2	0.5	0.7	0.1	0.2	1.1
Boone	6.1	0.3	1.0	1.3	0.7	0.5	0.3	0.1	0.6	-	0.2	0.2	0.9
Carroll	11.8	0.1	1.9	2.2	1.4	0.7	0.5	0.2	1.2	0.2	0.4	0.5	2.5
Cass	17.1	0.1	2.1	3.2	1.5	2.0	0.7	0.8	1.7	0.8	0.4	0.4	3.4
Clinton	6.9	0.1	0.6	1.0	0.5	0.7	0.5	0.2	0.9	0.1	0.2	0.4	1.7
Decatur	21.8	0.2	2.6	3.8	1.6	2.4	1.1	1.3	2.1	1.0	0.5	1.2	4.0
DeKalb	18.7	0.1	1.8	3.1	1.4	1.3	1.1	0.5	1.7	2.4	0.5	1.4	3.4
Delaware	10.4	-	1.1	1.8	0.7	1.5	0.5	0.7	0.8	0.3	0.3	0.4	2.3
Elkhart	18.4	0.1	2.3	3.5	1.5	1.3	1.3	0.6	1.8	1.2	0.4	0.7	3.7
Fountain	25.7	0.3	2.9	4.5	2.4	3.3	1.2	1.2	2.2	1.3	0.6	1.3	4.5
Fulton	14.3	0.1	2.0	2.9	1.3	1.3	0.8	0.6	1.0	1.0	0.4	0.3	2.6
Grant	10.8	-	1.3	2.0	0.9	1.5	0.5	0.8	0.8	0.6	0.4	0.2	1.8
Hamilton	11.2	-	1.7	2.1	1.0	0.8	0.5	0.3	1.0	1.6	0.3	0.3	1.6
Hancock	6.0	-	0.5	0.9	0.5	0.9	0.2	0.2	0.8	0.1	0.2	0.2	1.5
Hendricks	12.3	-	1.5	2.1	1.2	0.7	0.7	0.4	1.3	0.6	0.5	1.1	2.2
Henry	12.1	-	1.6	2.2	1.1	1.5	0.4	0.6	1.0	0.2	0.5	0.3	2.7
Howard	5.9	0.1	0.7	1.0	0.5	0.4	0.3	0.1	0.5	0.7	0.1	0.6	0.9
Huntington	15.9	0.3	2.3	3.0	1.4	1.3	1.0	0.4	1.3	1.1	0.5	0.6	2.7
Jasper	18.3	0.2	2.6	4.1	1.9	1.2	0.7	0.6	1.6	1.0	0.6	0.6	3.2
Jay	18.2	-	1.8	3.3	1.4	2.4	0.9	0.9	1.6	1.5	0.4	0.6	3.4
Johnson	10.5	-	1.3	2.3	0.9	0.9	0.8	0.4	0.8	0.5	0.3	0.4	1.9
Kosciusko	22.4	0.1	2.9	4.0	1.9	2.4	0.8	0.8	2.1	1.1	0.7	1.3	4.3
LaGrange	13.9	0.2	2.2	2.8	1.4	0.9	0.6	0.3	1.2	0.5	0.4	1.1	2.3
Lake	8.5	-	1.5	1.7	0.7	0.3	0.4	0.2	0.7	1.4	0.1	0.3	1.2
LaPorte	21.5	0.1	3.3	4.9	2.1	1.3	0.9	0.5	1.7	1.6	0.8	0.6	3.7
Madison	8.2	0.1	0.5	1.0	0.5	1.6	0.4	0.7	0.8	0.2	0.2	0.4	1.8
Marion	11.1	-	1.3	2.0	0.9	1.3	0.5	0.7	1.2	0.3	0.3	0.4	2.2
Marshall	21.2	0.3	3.2	4.5	2.1	1.7	0.8	0.7	1.8	0.5	0.6	1.3	3.7
Miami	15.3	-	2.2	2.9	1.6	1.6	0.8	0.6	1.3	0.5	0.5	0.7	2.6
Montgomery	18.0	0.3	2.7	4.0	2.0	1.0	0.8	0.5	1.4	0.7	0.9	0.6	3.1
Newton	12.0	-	1.6	2.6	1.2	0.6	0.8	0.2	1.3	0.3	0.3	0.5	2.6
Noble	18.7	0.1	2.7	4.2	1.9	1.4	0.8	0.6	1.4	1.3	0.5	0.4	3.4
Porter	20.9	0.1	2.8	4.0	2.1	1.5	1.2	0.7	2.2	0.6	0.8	0.8	4.1
Pulaski	19.1	-	2.8	3.6	2.0	1.9	0.8	0.6	1.6	0.8	0.7	0.6	3.7
Randolph	12.6	-	1.6	2.6	0.9	1.3	0.7	0.5	1.2	0.8	0.4	0.3	2.3
Rush	10.5	-	1.1	1.4	0.8	1.3	0.6	0.5	1.1	0.8	0.3	0.5	2.1
St. Joseph	18.3	0.1	2.7	3.8	1.6	1.2	1.1	0.6	1.6	1.1	0.5	0.6	3.4
Shelby	8.6	0.1	0.4	1.1	0.7	1.1	0.4	0.4	1.0	0.7	0.2	0.4	2.1
Starke	21.8	0.1	2.8	4.6	1.9	1.6	0.8	0.5	1.6	2.8	0.8	0.6	3.7
Steuben	17.0	0.4	2.0	3.6	1.6	1.4	0.7	0.7	1.2	1.7	0.5	0.4	2.8
Tippecanoe	13.4	0.1	1.8	2.5	1.3	1.4	0.7	0.6	1.1	0.2	0.5	0.4	2.8
Tipton	5.1	-	0.5	1.0	0.4	0.5	0.4	0.2	0.5	0.7	0.1	0.2	0.6
Wabash	17.2	0.2	2.1	3.1	1.6	1.1	1.3	0.5	1.5	1.4	0.6	0.7	3.1
Warren	19.1	-	2.5	3.4	1.9	1.5	1.0	0.7	1.5	1.3	0.7	1.2	3.4
Wayne	16.8	0.1	2.0	3.1	1.4	1.4	0.8	0.6	1.6	0.6	0.6	0.8	3.8
Wells	16.1	-	2.1	2.8	1.5	1.3	1.1	0.6	1.4	1.2	0.4	1.0	2.7
White	9.6	-	2.0	2.4	1.1	0.7	0.4	0.2	0.7	0.1	0.4	0.3	1.3
Whitley	15.7	0.1	2.2	2.9	1.5	1.4	0.8	0.6	1.4	1.0	0.5	0.3	3.0
Total	769.3	4.8	99.4	144.9	69.3	68.8	39.0	28.4	68.4	47.3	23.1	33.9	142.0
STATE TOTAL	3,503.0	60.8	666.4	691.6	441.8	287.6	126.3	132.0	191.3	69.4	183.5	149.8	502.5

See footnotes on page 4.

Table 2. — *Volume of sawtimber*[1] *on commercial forest land by county and species groups,*[2] *Indiana, 1967*
(Million board feet)[3]

County	All species	Softwoods	White oak group	Red oak group	Hickory	Hard maple	Soft maple	Beech	Ash	Cottonwood	Yellow poplar	Sycamore	Other Hardwoods
						LOWER WABASH UNIT							
Clay	141.0	3.0	19.5	33.8	21.2	5.7	7.2	1.1	6.0	1.9	12.3	9.7	19.6
Daviess	112.4	-	17.5	26.3	18.7	3.8	6.4	1.2	5.1	2.5	8.4	6.7	15.8
Gibson	151.6	5.6	21.8	27.4	18.8	6.7	12.5	1.7	7.2	3.7	10.2	10.1	25.9
Knox	102.1	5.6	13.8	19.7	13.0	4.1	10.1	0.9	3.9	3.4	7.6	6.1	13.9
Martin	335.8	5.8	53.5	88.4	49.2	14.6	14.3	3.7	14.0	2.5	32.0	17.1	40.7
Parke	235.5	5.7	36.0	57.0	32.4	8.7	12.6	2.2	11.3	3.7	23.1	11.9	30.9
Pike	144.0	3.1	19.5	29.6	20.5	5.3	9.5	1.0	7.5	3.3	10.4	11.0	23.3
Posey	137.0	11.3	18.5	26.5	17.2	4.4	7.2	1.4	6.3	3.7	9.6	11.7	19.2
Putnam	212.2	11.4	32.6	48.9	31.5	9.4	10.9	2.1	9.3	2.2	18.6	10.5	24.8
Sullivan	147.0	5.7	20.1	28.6	22.8	5.2	11.9	1.8	6.4	3.6	10.1	8.0	22.8
Vanderburgh	60.0	2.8	8.0	12.2	7.9	3.3	3.8	0.6	2.9	1.6	5.2	3.6	8.1
Vermillion	118.7	14.1	14.9	21.6	14.7	5.0	8.1	1.1	5.0	1.5	7.5	8.6	16.6
Vigo	128.9	5.7	17.1	27.1	19.1	4.6	7.8	1.3	5.9	3.4	9.3	8.3	19.3
Greene	245.3	0.2	39.9	65.1	35.6	9.1	11.9	2.4	11.2	2.9	23.3	11.7	32.0
Total	2,271.5	80.0	332.7	512.2	322.6	89.9	134.2	22.5	102.0	39.9	187.6	135.0	312.9
						KNOBS UNIT							
Brown	462.6	3.9	125.8	132.1	51.7	26.8	4.1	25.4	14.1	0.6	27.6	13.9	36.6
Clark	285.3	11.8	73.6	76.8	32.1	16.8	2.6	14.0	8.5	1.1	15.9	8.6	23.5
Crawford	307.1	5.6	81.4	85.8	35.2	16.7	2.4	15.6	8.6	1.8	19.8	10.7	23.5
DuBois	330.2	4.2	76.7	85.4	40.1	20.9	4.0	18.0	11.5	3.7	18.7	14.8	32.2
Floyd	122.9	4.4	31.7	33.8	13.7	7.5	1.0	6.9	3.6	0.4	7.3	3.2	9.4
Harrison	380.8	8.1	95.9	103.0	44.7	21.4	3.1	20.7	12.0	2.6	23.4	15.1	30.8
Jackson	372.1	4.2	91.2	96.0	40.6	24.6	3.9	21.7	12.4	3.6	22.3	17.1	34.5
Lawrence	350.9	2.2	83.2	88.7	41.7	20.9	3.2	20.9	11.1	4.5	23.7	19.9	30.9
Monroe	402.4	4.3	104.9	110.4	45.5	24.1	3.1	19.3	12.5	2.4	27.5	16.3	32.1
Morgan	269.5	3.1	70.2	72.2	29.9	17.5	2.4	11.9	8.4	1.5	16.4	12.8	23.2
Orange	316.4	4.7	73.3	77.1	35.5	21.2	2.4	18.2	9.4	5.8	20.0	21.2	27.6
Owen	347.2	3.6	93.6	96.6	39.2	20.7	2.9	17.1	10.1	1.4	21.0	13.2	27.8
Perry	450.1	11.3	117.6	123.6	50.7	26.7	3.8	23.7	14.0	2.4	26.9	15.0	34.4
Scott	154.2	0.9	38.4	39.8	16.6	9.6	1.2	7.9	4.8	3.0	9.5	10.0	12.5
Spencer	203.2	3.0	39.1	43.8	27.3	15.6	1.9	14.0	7.7	3.2	12.1	13.2	22.3
Warrick	163.0	1.0	34.7	36.5	22.8	11.1	1.7	8.4	4.7	2.3	10.6	11.1	18.1
Washington	465.2	4.6	119.4	123.5	56.1	31.2	4.4	28.0	14.7	1.9	26.2	15.0	40.2
Total	5,383.1	80.9	1,350.7	1,425.1	623.4	333.3	48.1	291.7	168.1	42.2	328.9	231.1	459.6
						UPLAND FLATS UNIT							
Dearborn	73.4	-	16.4	13.9	6.6	8.5	5.4	7.5	2.9	-	5.6	0.2	6.4
Fayette	40.1	-	8.5	8.3	3.4	4.6	2.5	3.8	1.3	0.5	3.4	0.3	3.5
Franklin	131.8	-	29.2	27.2	13.3	18.0	6.4	10.6	5.9	0.9	8.5	1.1	10.7
Jefferson	126.2	0.1	27.7	27.5	16.2	13.6	5.5	9.0	6.5	0.1	8.5	0.9	10.6
Jennings	175.5	-	37.2	36.2	21.8	22.5	8.5	15.5	6.8	0.5	11.6	0.9	14.0
Ohio	24.6	-	4.9	5.1	2.7	4.2	1.0	2.3	0.9	-	1.8	-	1.7
Ripley	98.2	-	20.6	20.2	10.3	10.6	5.0	8.0	4.8	0.8	7.4	1.4	9.1
Switzerland	42.9	-	9.8	11.1	3.7	2.6	1.9	4.0	1.6	-	3.9	0.6	3.7
Union	27.4	-	5.5	5.4	2.7	2.8	1.6	2.5	1.2	0.7	1.6	0.6	2.8
Total	740.1	0.1	159.8	154.9	80.7	87.4	37.8	63.2	31.9	3.5	52.3	6.0	62.5
						NORTHERN UNIT							
Adams	45.0	-	5.9	9.0	3.0	2.7	1.8	.9	3.2	8.3	1.4	5.7	5.1
Allen	97.4	0.5	12.5	17.7	6.3	6.9	4.7	3.7	6.9	13.1	3.0	9.5	12.6
Bartholomew	114.3	-	16.2	21.5	7.0	14.6	5.0	7.6	8.9	7.2	2.9	6.9	16.5
Benton	1.7	-	0.2	0.7	0.1	0.1	0.3	-	0.1	-	0.1	0.1	-
Blackford	21.5	0.2	2.9	4.5	1.5	2.2	0.7	0.9	1.5	2.9	0.4	0.5	3.3
Boone	18.7	-	3.7	4.9	1.6	1.8	0.8	0.5	1.5	0.1	0.6	0.6	2.6
Carroll	35.4	0.3	7.1	8.3	3.2	2.1	1.5	1.0	2.3	0.2	1.5	1.9	6.0
Cass	56.1	0.3	7.9	12.4	3.7	7.1	2.2	3.2	4.6	2.7	1.5	1.3	9.2
Clinton	22.6	0.2	2.1	3.8	1.2	2.7	1.5	0.8	2.6	0.5	0.6	1.5	5.1
Decatur	71.7	0.3	9.7	14.1	4.1	8.7	3.3	5.1	5.6	4.3	1.8	4.8	9.9
DeKalb	60.8	0.2	5.8	11.3	3.6	4.8	3.0	2.0	4.5	9.7	1.9	5.9	8.1
Delaware	34.0	-	4.3	6.4	1.8	5.7	1.1	3.0	2.5	0.8	1.1	1.6	5.7
Elkhart	60.6	0.2	8.4	13.0	3.6	4.4	3.7	2.6	5.3	5.5	1.6	2.6	9.7
Fountain	84.4	0.5	10.3	15.6	5.8	13.0	3.6	5.1	6.3	5.6	2.1	5.2	11.3
Fulton	47.4	0.3	7.6	11.2	3.5	3.9	2.3	2.3	2.8	4.5	1.6	1.2	6.2
Grant	36.3	-	4.7	7.5	2.3	5.5	1.3	2.9	2.6	2.7	1.1	0.8	4.9
Hamilton	38.4	-	6.4	8.1	2.9	2.9	1.6	1.3	2.7	6.6	0.9	1.2	3.8
Hancock	20.4	0.2	1.8	3.4	1.4	3.5	0.5	0.6	2.4	0.6	0.6	1.0	4.4
Hendricks	38.2	-	5.6	7.6	2.8	1.7	2.2	1.7	2.8	2.3	1.8	4.3	5.4
Henry	38.6	0.2	6.0	8.4	3.1	4.9	1.1	2.3	2.7	0.2	1.6	1.1	7.0
Howard	18.6	-	2.1	3.6	1.0	1.3	1.1	0.4	1.5	2.7	0.4	2.6	1.9
Huntington	50.1	0.2	8.7	10.7	3.4	4.4	2.5	1.7	3.6	4.5	1.8	2.3	6.3
Jasper	55.7	0.2	9.5	14.8	4.3	3.5	2.3	2.3	3.6	4.1	2.2	1.9	7.0
Jay	63.0	-	6.6	12.4	3.8	9.3	2.5	3.6	5.2	6.6	1.4	2.6	9.0
Johnson	35.4	-	4.9	8.5	2.5	3.1	2.1	1.7	2.5	2.2	1.2	1.5	5.2
Kosciusko	74.0	0.2	10.7	14.8	4.6	8.6	2.5	3.2	5.8	4.4	2.5	5.3	11.4
LaGrange	45.2	0.2	8.0	10.2	3.6	3.2	1.8	1.4	3.0	1.9	1.5	4.5	5.9
Lake	29.4	-	5.9	7.0	2.3	1.0	0.9	0.7	1.4	6.0	0.5	1.1	2.6
LaPorte	67.8	-	12.2	18.9	5.0	4.1	2.5	2.0	3.7	6.5	2.7	1.9	8.3
Madison	27.8	0.4	1.5	3.9	1.2	6.5	1.0	2.8	2.8	1.0	0.7	1.4	4.6
Marion	36.8	0.1	4.8	7.8	2.4	4.1	1.7	2.6	3.3	1.5	1.1	1.4	6.0
Marshall	71.0	0.2	11.5	17.0	5.7	6.1	2.8	3.0	5.0	2.4	2.1	5.2	10.0
Miami	49.5	-	7.9	10.8	3.8	5.6	2.3	2.5	3.8	2.2	1.7	3.1	5.8
Montgomery	52.6	-	9.6	14.0	4.6	3.2	2.2	1.8	3.3	2.1	2.9	1.8	7.1
Newton	36.1	-	6.0	9.2	2.7	2.0	1.8	0.7	3.3	1.1	1.3	2.1	5.9
Noble	58.9	0.1	10.2	14.9	4.8	5.0	2.3	2.7	3.8	5.3	1.9	1.1	6.8
Porter	64.0	-	10.6	14.8	5.4	4.5	3.4	2.7	4.9	2.1	2.7	2.4	10.5
Pulaski	59.3	-	10.3	12.6	4.6	7.1	2.2	2.2	4.5	2.6	2.4	2.6	8.2
Randolph	42.2	-	6.1	10.3	2.7	5.0	2.0	2.2	3.1	3.3	1.3	1.3	4.9
Rush	35.7	-	4.4	5.3	2.2	4.9	1.7	1.8	3.0	3.4	1.0	1.9	6.1
St. Joseph	58.0	0.2	9.9	13.7	4.1	3.6	3.1	2.2	4.6	4.2	1.9	2.5	8.0
Shelby	28.5	0.5	1.5	4.0	1.7	4.0	1.2	1.5	3.1	3.0	0.6	1.3	6.1
Starke	68.4	0.1	9.5	16.1	4.8	5.7	2.3	2.2	3.9	11.3	2.7	1.6	8.2
Steuben	54.1	0.4	6.9	13.2	4.2	4.8	2.1	2.8	3.5	7.3	1.7	1.1	6.1
Tippecanoe	40.4	0.2	6.8	8.7	3.1	4.6	2.0	2.2	2.8	0.4	1.7	1.3	6.6
Tipton	17.3	-	1.9	3.6	1.2	1.9	1.3	0.7	1.1	2.7	0.3	0.9	1.7
Wabash	56.0	0.2	7.6	11.3	3.9	3.8	3.1	2.0	4.4	6.1	2.1	3.2	8.3
Warren	82.0	0.1	8.9	12.7	4.7	5.2	2.7	2.8	3.8	5.4	2.7	5.4	7.6
Wayne	53.0	0.2	7.6	11.9	3.6	4.6	1.8	2.3	4.3	2.3	2.1	2.9	9.4
Wells	54.4	-	7.6	10.7	3.9	4.3	3.5	2.4	3.9	5.0	1.7	4.8	6.6
White	31.2	-	7.4	9.3	3.0	2.3	0.9	0.6	1.7	0.2	1.4	0.9	3.5
Whitley	50.8	-	8.2	11.3	3.6	4.4	2.6	2.3	3.9	4.0	1.7	1.2	7.6
Total	2,490.7	6.9	384.4	537.4	174.9	240.9	110.4	113.5	183.9	193.6	82.0	132.8	350.0
STATE TOTAL	10,885.4	167.9	2,207.6	2,629.6	1,201.6	751.5	330.5	490.9	485.9	279.2	650.8	504.9	1,185.0

See footnotes on page 4.

White oak, black oak, hickory, northern red oak, and hard maple are the most abundant sawtimber-size trees in Indiana, comprising over half the total board-foot volume. All these species increased in volume since the last survey in 1950.

The sampling error for the State's growing-stock volume of 3.5 billion cubic feet is ± 3.1 percent at one standard error (the 67-percent confidence limit). Sampling error increases as volume decreases: for 20 million cubic feet the probable error would be within ± 40.8 percent (± 8 million cubic feet).

These volume statistics are from the Second Forest Survey of Indiana made between September 1966 and June 1967 by the North Central Forest Experiment Station and the Indiana Department of Natural Resources, Division of Forestry.

ARNOLD J. OSTROM
Associate Mensurationist

1968
Revised 1969

Figure 1. — Growing stock volume in Indiana counties, 1967.

FOOTNOTES: Table 1.

1 *Net volume of live merchantable sawtimber and poletimber trees from the stump to a variable 4-inch top diameter outside bark of the central stem. Does not include limbs or cull tree volume.*

2 *Species: Softwoods — Primarily eastern redcedar, tamarack, jack pine, shortleaf pine, red pine, white pine, Scotch pine, Virginia pine, and baldcypress. White oak group — white oak, swamp white oak, bur oak, swamp chestnut oak, chinkapin oak, chestnut oak, and post oak. Red oak group — northern red oak, cherrybark oak, Shumard oak, black oak, scarlet oak, southern red oak, shingle oak, and pin oak. Other hardwoods — primarily sweetgum, blackgum, aspen, basswood, black walnut, black cherry, and elm.*

FOOTNOTES: Table 2.

1 *Net volume of live merchantable sawtimber trees (softwoods 9.0 inches d.b.h. or larger and hardwoods 11.0 inches d.b.h. and larger) from the stump to a point in the central stem at which utilization for sawn products is limited by large branches, forks, or other defects, or by a diameter outside bark of 7.0 inches for softwoods and 9.0 inches for hardwoods.*

2 *See footnote 2 for table 1.*

3 *International ¼-inch rule.*

U. S. FOREST SERVICE

RESEARCH NOTE NC-59

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Lake States Pulpwood Production Drops Seven Percent, 1967

ABSTRACT. — This twenty-second annual report shows the Lake States pulpwood harvest decreased to about 4 million cords from a record high of 4¼ million cords in 1966. Pulpwood receipts remained high in Wisconsin but decreased in Michigan and Minnesota. Minnesota shipped 106,000 cords more to Wisconsin than in 1966. As a result, only Minnesota's 1967 pulpwood production was higher than the previous year.

After a sharp rise in 1966, the Lake States pulpwood harvest declined to 3,965,000 cords in 1967, a decrease of 7 percent (table 1). This decrease was partially due to a leveling off of national paper and board inventories after a large buildup in 1966. The national output of paper and board, 46.6 million tons in 1966, dropped to 45.9 million tons in 1967. This was the first decline since 1957.

Pulpwood production varied among the three Lake States in 1967. Michigan showed the greatest decline, its harvest down 14 percent from the 1966 level. Production in Wisconsin decreased 8 percent, while the Minnesota harvest actually inched upward 3 percent.

The roundwood cut, which made up 95 percent of the region's total pulpwood production in 1967, totaled 3.75 million cords. The remaining 5 percent consisted of mill residues such as wood chips, slabs, and veneer cores. Shipment of these residues to local, central states, and Canadian pulp mills was up 40,000 cords from 1966.

The aspen roundwood cut, which constitutes the largest portion of the pulpwood harvest in the Lake States, dropped 10 percent in 1967. It fell short of the 1966 cut by 131,000 cords in Michigan, 71,000 cords in Wisconsin, and 20,000 cords in Minnesota. The pine harvest, 152,000 cords less than in 1966, showed a large decline in all three States. The hemlock cut also decreased 65,000 cords, with three-fifths of the change occurring in Michigan. On the other hand, spruce and tamarack output, mostly from Minnesota, increased 42,000 and 33,000 cords, respectively.

The sudden interest in tamarack may reflect recognition of its high density and good yields using the Kraft process. For example, the density of tamarack is 31 pounds per cubic foot (moisture-free weight, green volume) whereas the density of jack pine is 25 pounds per cubic foot. Assuming both species will yield 48 percent unbleached Kraft pulp,[1] the weight of moisture-free pulp produced per cord of rough logs will be about 1,160 pounds for tamarack, compared to only 935 pounds for jack pine. Thus, the yield from tamarack, using the Kraft process, may be nearly a fourth greater than the yield from jack pine. Tamarack yield also compares favorably with hemlock, balsam fir, and spruce under similar pulping conditions. In

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[1] *Based on data from Pulp Yields for Various Processes and Wood Species, Research Note FPL-031, U.S. Dept. of Agriculture, Forest Products Laboratory. 1964.*

Table 1.—*Production and imports of pulpwood, Lake States, 1967*
(In standard cords, unpeeled)

Species and destination	Production by states[1/]				Imports			
	Minnesota	Wisconsin	Michigan	Region total	Other U.S. [2/]	Canada	Total imports	Total receipts
Aspen								
Minn.	542,386	500	-	542,886	-	7,743	7,743	550,629
Wis.	49,056	737,864	327,002	1,113,922	-	1,689	1,689	1,115,611
Mich.	-	378	318,720	319,098	42	3,439	3,481	322,579
Total	591,442	738,742	645,722	1,975,906	42	12,871	12,913	1,988,819
Balsam fir								
Minn.	48,432	-	-	48,432	-	-	-	48,432
Wis.	27,595	47,578	64,382	139,555	-	-	-	139,555
Mich.	-	-	25,975	25,975	-	20,277	20,277	46,252
Exported[3/]	-	-	56	56	-	-	-	-
Total	76,027	47,578	90,413	214,018	-	20,277	20,277	234,239
Birch, white								
Minn.	1,285	-	-	1,285	-	-	-	1,285
Wis.	1,983	40,825	4,746	47,554	-	-	-	47,554
Mich.	-	-	6,265	6,265	-	-	-	6,265
Total	3,268	40,825	11,011	55,104	-	-	-	55,104
Hemlock								
Minn.	-	-	-	-	-	-	-	-
Wis.	-	42,269	57,789	100,058	-	-	-	100,058
Mich.	-	-	2,115	2,115	-	-	-	2,115
Total	-	42,269	59,904	102,173	-	-	-	102,173
Pine								
Minn.	144,078	-	-	144,078	-	35,081	35,081	179,159
Wis.	57,609	174,058	75,934	307,601	105,424	2,642	108,066	415,667
Mich.	-	-	117,335	117,335	-	-	-	117,335
Total	201,687	174,058	193,269	569,014	105,424	37,723	143,147	712,161
Spruce								
Minn.	106,712	-	-	106,712	674	7,920	8,594	115,306
Wis.	89,672	13,438	55,354	158,464	4,229	145,076	149,305	307,769
Mich.	23	-	19,509	19,532	-	61,260	61,260	80,792
Exported[3/]	21,250	-	122	21,372	-	-	-	-
Total	217,657	13,438	74,985	306,080	4,903	214,256	219,159	503,867
Tamarack								
Minn.	1,591	-	-	1,591	-	-	-	1,591
Wis.	38,274	2,478	1,325	42,077	-	-	-	42,077
Mich.	-	-	-	-	-	-	-	-
Total	39,865	2,478	1,325	43,668	-	-	-	43,668
Misc. hardwoods								
Minn.	17,743	-	-	17,743	-	7,443	7,443	25,186
Wis.	20,809	241,718	38,997	301,524	-	-	-	301,524
Mich.	-	-	160,640	160,640	356	-	356	160,996
Exported[3/]	-	4,293	-	4,293	-	-	-	-
Total	38,552	246,011	199,637	484,200	356	7,443	7,799	487,706
Total roundwood								
Minn.	862,227	500	-	862,727	674	58,187	58,861	921,588
Wis.	284,998	1,300,228	625,529	2,210,755	109,653	149,407	259,060	2,469,815
Mich.	23	378	650,559	650,960	398	84,976	85,374	736,334
Exported[3/]	21,250	4,293	178	25,721	-	-	-	-
Total	1,168,498	1,305,399	1,276,266	3,750,163	110,725	292,570	403,295	4,127,737
Residues, softwood								
Minn.	4,724	-	-	4,724	-	-	-	4,724
Wis.	1,635	6,193	2,604	10,432	124,070	-	124,070	134,502
Mich.	-	-	-	-	-	-	-	-
Exported[3/]	1,081	4,172	-	5,253	-	-	-	-
Total	7,440	10,365	2,604	20,409	124,070	-	124,070	139,226
Residues, hardwood								
Minn.	16,825	14,217	-	31,042	282	-	282	31,324
Wis.	11,793	81,143	31,394	124,330	16	-	16	124,346
Mich.	-	-	33,748	33,748	3,677	-	3,677	37,425
Exported[3/]	-	5,412	-	5,412	-	-	-	-
Total	28,618	100,772	65,142	194,532	3,975	-	3,975	193,095
All wood material								
Minn.	883,776	14,717	-	898,493	956	58,187	59,143	957,636
Wis.	298,426	1,387,564	659,527	2,345,517	233,739	149,407	383,146	2,728,663
Mich.	23	378	684,307	684,708	4,075	84,976	89,051	773,759
Exported[3/]	22,331	13,877	178	36,386	-	-	-	-
Total	1,204,556	1,416,536	1,344,012	3,965,104	238,770	292,570	531,340	4,460,058

1/ Vertical columns of figures under box heading "Production by States" present the amount of pulpwood cut in each State.
2/ Mostly Western States.
3/ Pulpwood shipped to mills outside of Region.

addition, the average price of tamarack per rough cord (f.o.b. cars) in northern Minnesota during 1967 was lower than the average for the other softwood pulping species except pine, which was 50 cents to 1 dollar a cord less than tamarack.[2]

Lake States pulp mills received nearly 4½ million cords of pulpwood, 3/10 million cords less than in 1966. Receipts were down 23 percent in Michigan and 10 percent in Minnesota, but up 1 percent in Wisconsin. The Lake States supplied 89 percent of the roundwood, Canada 6 percent, and western states 5 percent (table 2).

[2] *Based on data from Minnesota Forest Products Marketing and Pricing Review, Office of Iron Range Resources and Rehabilitation, 1967.*

Several shifts in procurement patterns were noted in the region. Wisconsin mills received 106,000 more cords of pulpwood from Minnesota than in 1966, but 7,000 cords less from Michigan, their principal source of out-of-state wood. Of the increased volume of wood shipped to Wisconsin from Minnesota, 31,000 cords were tamarack, normally a little-used species. Imports from states outside the region rose 49,000 cords, including 35,000 cords of softwood chips. These mill residues from western states accounted for 5 percent of the pulpwood consumed in Wisconsin. Canadian imports declined 11 percent in 1967. The amount of spruce purchased from Canada, after rising 65,000 cords in 1966, fell 59,000 cords in 1967. However, pine purchases were up 28,000 cords.

Table 2. — *Geographic origin and destination of pulpwood received by Lake States mills, 1967*

Species	Percent of pulpwood originating from:					Percent of pulpwood received by mills in:		
	Minn.	Wis.	Mich.	Canada	Other U. S.	Minn.	Wis.	Mich.
Aspen	30	37	32	1	*	28	56	16
Balsam fir	32	20	39	9	-	21	59	20
Birch	6	74	20	-	-	2	86	12
Hemlock	-	41	59	-	-	-	98	2
Pine	28	25	27	5	15	25	58	17
Spruce	39	3	15	42	1	23	61	16
Tamarack	91	6	3	-	-	4	96	-
Misc. hardwoods 1/	8	49	41	2	*	5	62	33
Residues	10	31	20	-	39	11	78	11
All wood material	27	32	30	6	5	22	61	17
Previous year (1966)	24	32	33	7	4	22	57	21

1/ Mostly dense hardwoods.
* Less than 1/2 of one percent.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-60

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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POOR RETURNS FROM OZARK WOODLAND GRAZING

ABSTRACT.—Sixty-three percent of the area in Missouri's National Forests produces forage at the rate of about 50 pounds per acre per year. Forage production on the other 37 percent ranges from a low near 75 pounds per acre in the pine stands to a high of about 200 pounds in the redcedar stands.

Cattle are often allowed to graze wooded areas in the Missouri Ozarks. This practice began when the Ozark region was open range. The question has often been asked, "Is there enough good forage in the woods to warrant the expense of using it and the possible risk of damaging the land for other uses?" This question plagues the National Forest administrator as well as the private landowner in the Missouri Ozarks.

An extensive survey revealed that oak-pine, post-blackjack oak, white oak, and black-scarlet oak stands, which make up two-thirds of the wooded areas in Missouri's National Forests, produce approximately 50 pounds of cattle forage per acre per year (table 1).

A 1,000-pound cow with calf at side requires approximately 50 pounds desirable vegetation per day: only half of this is actually eaten, the rest is made up of plant parts too coarse to eat or trampled. Consequently, a 1,000-pound cow requires 9,000 pounds of desirable vegetation for a 6-month grazing season. Thus, approximately 180 acres of oak-dominated woodland would be needed to feed

Table 1.—*Production of forage in several forest types on National Forest land in Missouri Ozarks*

(In pounds per acre — ovendry)

Forest type	Approximate area (percent)	Grass	Forbs	Total
Redcedar	7	175	26	201
Mixed hardwood	12	66	75	141
Redcedar-hardwood	2	85	32	117
Pine	16	33	43	76
Oak-pine	15	20	32	52
Post-oak--blackjack oak	8	19	32	51
White oak	10	16	32	48
Black-oak--scarlet oak	30	14	26	40
Total	100			

the cow for a 6-month grazing season. Assuming the calf weighed 350 pounds at the end of the season and would bring 30 cents per pound, the gross return to land, labor, management, and capital would be 58 cents an acre per season. This return is small, considering the investment and risk. Although obviously not a detailed profitability analysis, this does indicate a low income.

Pine stands produce approximately 50 percent more forage than the oak types, and would return about 88 cents an acre. Redcedar-hardwood stands would return about $1.36 per acre and mixed hardwood stands of elm, maple, blackgum or ash in creek bottoms would return approximately $1.64 an acre.

Redcedar stands, which occupy only about 7 percent of the area, produce more high quality cattle food than other forest types (table 1) and would carry 1 cow per 45 acres for a 6-month grazing season. Using the same assumptions as before, each acre would return about $2.33 toward land, labor, management and capital. Even this return is low in a commercial operation considering the risks involved.

These data and calculations indicate returns to woods grazing are small on National Forest land in Missouri. Consequently, management for high quality timber should be considered for good timber-producing sites and reduction of tree cover and grass range establishment considered for low volume timber-producing sites, that are presently covered with scrub timber and brush. Research has shown that grass range establishment is possible[1] and profitable[2] on certain specified sites. The problem remaining is to determine which of the many other wooded sites in the Ozarks can be practically and economically converted to grass and which should be left under wooded cover and how both alternatives affect watershed and wildlife values.

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[1] *Crawford, H. S., and Bjugstad, A. J. Establishing grass range in the southwest Missouri Ozarks. U.S.D.A. Forest Serv. Res. Note NC-22, 4 p., illus. 1967.*

[2] *Ehrenreich, John H., and Ralston, Robert A. Forage and timber production alternatives on shallow soils in the Ozarks. Soc. Amer. Forest. Proc.: 80-83, illus. 1963.*

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U. S. FOREST SERVICE

RESEARCH NOTE NC-61

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

GROSS BASAL AREA GROWTH OF NORTHERN WHITE-CEDAR IS INDEPENDENT OF STAND DENSITY OVER A WIDE RANGE

ABSTRACT. — A 20-year study in a Wisconsin swamp stand of northern white-cedar indicates that after a second thinning gross basal area growth is independent of stand densities ranging from 90 to 225 square feet of basal area per acre. Mortality, net growth, and ingrowth were also independent of density in the thinned plots.

Little is known about the effect of various stand densities on the growth of northern white-cedar (*Thuja occidentalis* L.) despite the fact that this swamp conifer occupies over 1½ million acres of commercial timber land in the Lake States. Data for the first decade following an initial thinning in one Wisconsin stand show that gross basal area growth was greater at high densities than at low densities.[1] However, data now available for this same stand during the second decade, following a second thinning, indicate that gross growth is independent of stand densities ranging from 90 to 225 square feet of basal area per acre. Other growth characteristics also show differences between the decade following the first thinning and that following the second.

Procedures

The study area is in a fertile swamp near Pembine in northeastern Wisconsin.[2] The area is dominated by an essentially even-aged stand of northern white-cedar and a few balsam fir (*Abies balsamea* (L.) Mill.) and black spruce (*Picea mariana* (Mill.) B.S.P.). When the stand was first thinned in 1947, most of the trees were about 65 years old, 5 inches in diameter, and 30 feet tall. The site index is 37 feet at 100 years, which is average for swamp stands of white-cedar.

The study consists of twenty ½-acre compartments, four of which are check areas which have never been thinned. These uncut compartments had an average basal area of 181 square feet per acre in 1947, 224 square feet in 1957, and 253 square feet in 1967. The other 16 compartments form four groups which were originally thinned in 1947 to the following average basal areas: 90, 110, 130, and 150 square feet per acre. The second thinning in 1957 reduced the basal area in these compartments to the same levels. In both thinnings an attempt was made to leave a vigorous and uniformly spaced stand of well-formed, dominant and codominant white-cedar (fig. 1). Growth data were obtained in 1957 and 1967 by remeasuring the single 1/10-acre sample plot within each compartment.

Gross Growth

During the decade following the first thinning, gross basal area growth was lower on the lower density compartments (90 to 110 square feet of basal area per acre) than on those at higher densities (130 to 180 square feet). In contrast, during the decade following the second thinning, gross growth was independent of stand density, which ranged from 90 to 225 square feet (fig. 2). However, the overall rate

[1] *Skilling, D. D. Growth of swamp conifers following an improvement cut. U.S. Forest Serv., Lake States Forest Exp. Sta., Sta. Paper 71, 10 pp., illus. 1959.*

[2] *Grateful acknowledgement is due Wisconsin's Division of Conservation for providing part of the Miscauno Wildlife Area as the study area and for assistance in the field.*

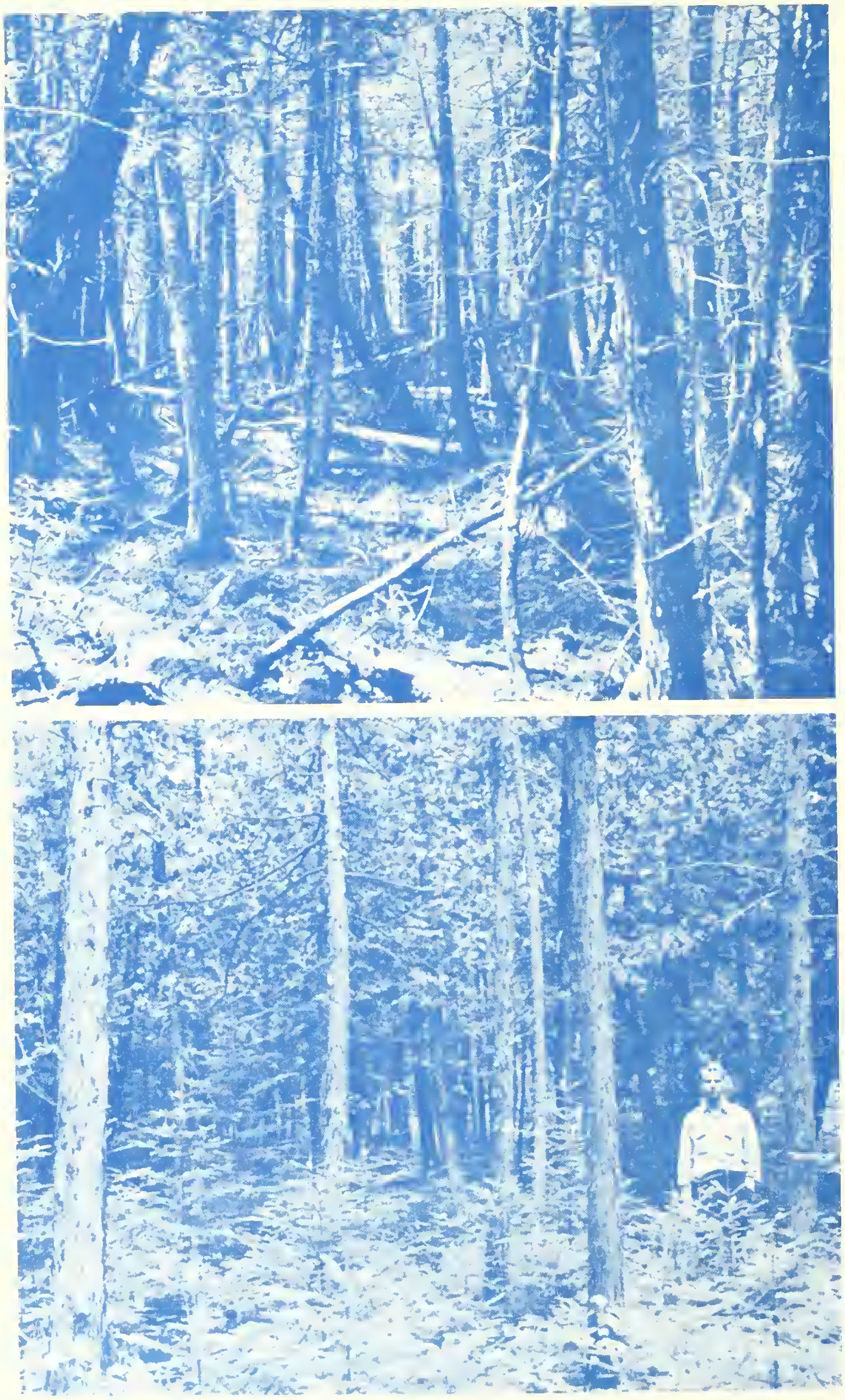

Figure 1. — Views of the northern white-cedar stand in 1967 showing an unthinned check plot (top) and a plot thinned to 90 square feet of basal area per acre (bottom). Note the larger and straighter stems on the thinned plot. (F-518212 - 518213)

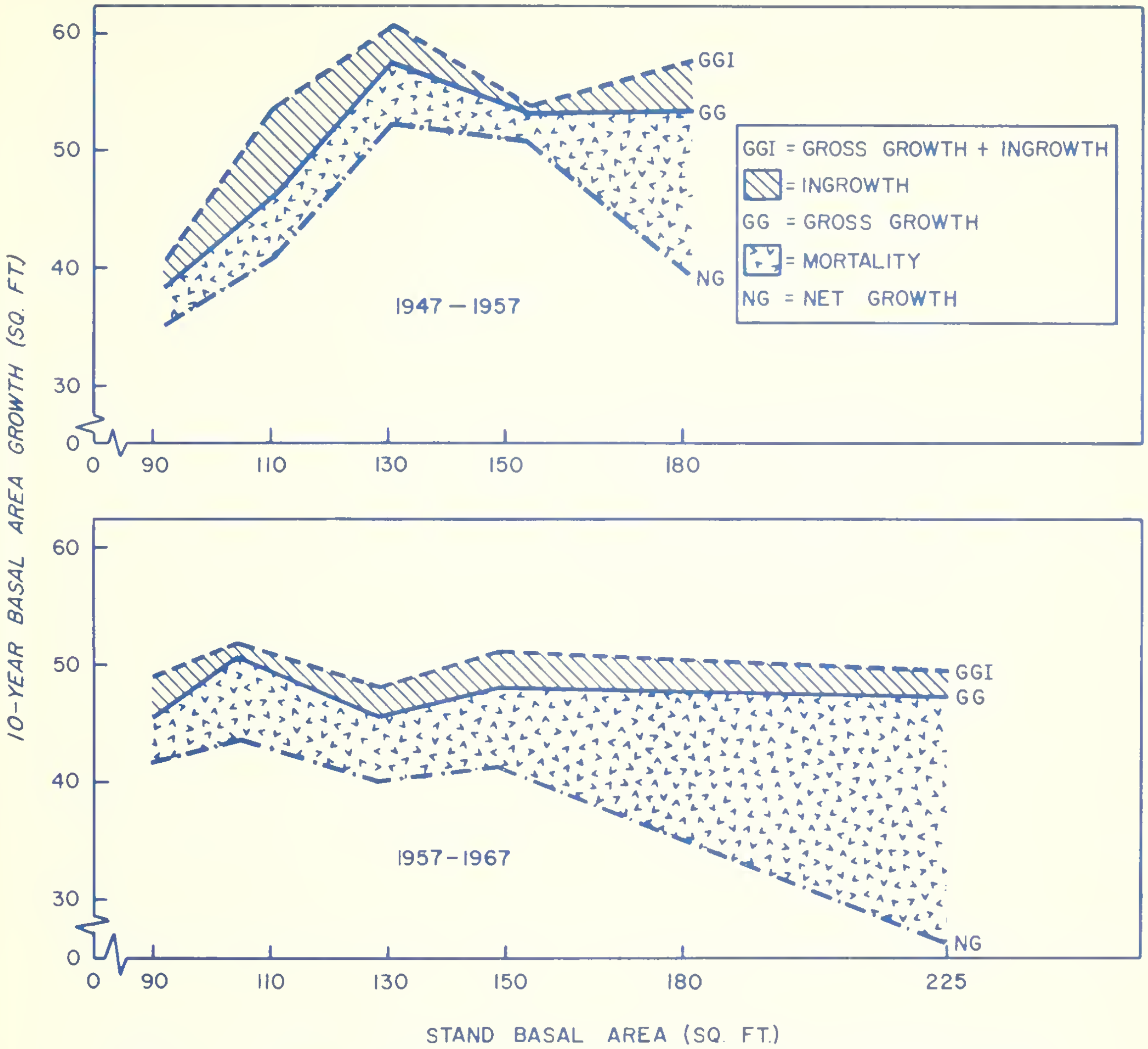

Figure 2. — Average 10-year growth per acre of the northern white-cedar stand as related to average density during the decades following an initial thinning in 1947 (top) and a second thinning in 1957 (bottom).

of gross basal area growth declined during the second decade.

As suggested by Kramer and Kozlowski[3], gross growth may have been less at the lower stand densities than at the higher densities after the first thinning because sudden exposure of the trees increased total respiration more than total photosynthesis. After a decade, however, the crowns of trees growing at the lower densities had apparently enlarged enough to respond quickly to a second thinning. As evident in this study, these differential responses to thinning mean that growth-density relations can be unreliable when based only on data from an initial thinning in a dense stand approaching maturity.

The decrease in the overall rate of gross basal area growth between the first and second decade is most likely due to increasing stand age. Now over 85 years old, the stand has probably passed its point of maximum basal area growth. It is therefore likely that gross growth will continue to decline in subsequent decades.

In contrast to basal area growth, diameter growth was maintained at about the same rate during the second decade. As reported for the first decade[4], diameter growth during the second decade was greatest on the larger trees in the lower density compartments. For example, a 7-inch tree grew an average of 1.4 inches in diameter between 1957 and 1967 on plots having 90 to 110 square feet of basal area, compared to 0.9 inch on plots with 130 to 150 square feet.

Mortality

Since the thinned plots had relatively little mortality[5] in basal area during both decades, net growth was not much less than gross growth on these areas (fig. 2). Thus mortality and net growth are apparently independent of density in thinned stands of northern white-cedar. In contrast, the much higher mortality on the denser, unthinned compartments greatly reduced their net basal area growth, particularly during the second decade (fig. 2).

The relatively high mortality in the unthinned compartments is due to the greater proportion of old-growth balsam fir. For example, fir contributed 60 percent of the total mortality on the unthinned plots during the second decade; whereas white-cedar, which made up 85 percent of the basal area, accounted for less than 30 percent of the mortality, most of which occurred in suppressed trees. Of course, death of the old-growth fir and suppressed white-cedar is to be expected with increasing stand age, because neither has the life expectancy of vigorous white-cedar.

Ingrowth

Data for both decades indicate that total ingrowth in basal area (minimum diameter 2.6 inches) is independent of stand density (fig. 2). However, the ingrowth of northern white-cedar tended to increase with density whereas the reverse was true for balsam fir. White-cedar ingrowth was greater at the higher densities because more small trees were left on the denser plots. Ingrowth of balsam fir came from advance reproduction which grew best on the lower density plots. Thus these plots had more stems of balsam fir that reached the minimum diameter than did the higher density plots.

Conclusions

The findings of this 20-year study indicate that after an initial thinning stands of northern white-cedar can be rethinned to a basal area at least as low as 90 square feet per acre without diminishing gross growth or increasing mortality. For middle-aged stands growing in swamps, it also appears that good diameter growth can be maintained through successive thinnings which favor dominant and codominant white-cedar. Assuming a market exists for small products, thinning will not only increase total yield but also will result in obtaining a final harvest of higher quality.

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[3] *Kramer, Paul J., and Theodore T. Kozlowski. Physiology of trees. P. 516. New York: McGraw-Hill Book Company, Inc. 1960.*

[4] *See footnote 1.*

[5] *Only two plots (basal area 130 square feet) had heavy wind-caused mortality during the second decade; this loss was apparently due mainly to location of the plots and thus is disregarded in the text and in figure 2.*

U. S. FOREST SERVICE

RESEARCH NOTE NC-62

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

EARLY GROWTH OF EASTERN WHITE PINE SEED SOURCES IN THE LAKE STATES

ABSTRACT. — In 5-year-old test plantations in Minnesota, Wisconsin, and Michigan, eastern white pine seedlings from seed sources that are fast-growing in one location are not necessarily fast-growing in other locations. Until more intensive studies of the Lake States seed sources can be made, foresters should confine collection of white pine seed to local stands.

Early results of an eastern white pine seed source study show the need for widespread testing in the search for sources of superior tree seed. In 5-year-old test plantations in Minnesota, Wisconsin, and Michigan it is apparent that seedlings from seed sources that are fast-growing in one location are not necessarily fast-growing in other locations. Until more intensive studies of Lake States seed sources can be carried out, foresters should confine collection of white pine seed to local stands.

This study was started in 1955 by the Northeastern Forest Experiment Station. Cooperators have already reported early results of the growth of the seed sources planted in North Carolina (Sluder 1963), Lower Michigan (Wright *et al* 1963) and the Central States (Funk 1965).

Methods

Seed collected from 17 sources throughout the natural range of the species (table 1) was sown in 1958 in the Toumey Nursery in Watersmeet, Michigan. In the spring of 1960 the 2-0 stock was transplanted to the Hugo Sauer Nursery near Rhinelander, Wisconsin. The four test plantings reported here were established with the 2-2 stock in 1962 at Cass Lake, Minnesota; Wabeno, Wisconsin; Manistique, Michigan; and Pine River, Michigan. The plantings are laid out in a randomized complete block design with 24 replicates of 1-tree plots.

Nursery Results

The five fastest growing seed sources at the end of the first year in the nursery were from Tennessee, Lower Michigan, southern Wisconsin, Georgia, and Nova Scotia (table 2). The slowest growing sources were from Minnesota, Maine, Upper Michigan, and Pennsylvania.

The same height growth pattern was also noted at the end of the second growing season in the nursery.

By the end of the fourth growing season in the nursery the Lower Michigan, southern Wisconsin, and Tennessee sources were still among the fastest growing, but the local northern Wisconsin source and an Ontario source had moved into the top five (table 2). The Nova Scotia and Georgia sources dropped below average.

Table 1. — *Location of eastern white pine seed sources*

Source number[1/]	Location of origin	Lat.	Long.	Mean Jan. temp[2/]
		°N	°W	°F
1650 (28)	Lake County, Minn.	48.0	91.8	9
1622 (19)	Cass County, Minn.	47.4	94.5	6
1629	Washington County, Minn.	45.2	92.8	11
1623 (18)	Forest County, Wis.	45.9	88.9	11
1651 (31)	Sauk County, Wis.	43.5	90.0	17
1624 (15)	Allamakee County, Iowa	43.3	91.3	16
1656 (29)	Houghton County, Mich.	47.1	88.7	14
1670 (33)	Newaygo County, Mich.	43.5	85.7	22
1636 (25)	Algoma District, Ontario	46.2	82.6	10
1635 (23)	Pontiac, Quebec	47.5	77.0	1
1637 (20)	Luneburg, Nova Scotia	44.4	64.6	26
1638 (14)	Penobscot, Maine	44.0	68.6	20
1639 (12)	Franklin County, N.Y.	44.4	73.4	15
1640 (6)	Monroe County, Penn.	41.1	75.4	25
1632 (16)	Ashland County, Ohio	40.8	82.3	29
1634 (3)	Greene County, Tenn.	36.0	82.8	36
1633 (1)	Union County, Georgia	34.8	84.1	39

1/ Numbers in parentheses are numbers assigned by the Northeastern Forest Experiment Station.

2/ U.S. data interpolated from maps in "Climate and Man." U.S. Dep. Agr. 1941 Yearbook. Canadian data from Canadian Meteorological Division Climatic Summaries.

In the first winter following transplanting in the Hugo Sauer Nursery, seed sources differed in winter injury, which showed up as needle browning and discolored terminal buds. As might be expected, the trees from the Tennessee and Georgia sources showed the greatest incidence of injury (table 2). The source from Nova Scotia — a maritime climate source — showed less damage than the southern Appalachian sources but distinctly more damage than any of the other sources. The six sources showing the most winter injury were all from areas where the mean January temperature exceeds 20°F. Of the remaining 11 sources, 10 were from areas where the mean January temperature is less than 18°F.

Plantation Results

There are differences between plantations and between seed sources in mortality 5 years after planting (table 3). Plantation mortality ranged from 11 to 18 percent, with the highest mortality occurring in the plantations with the lowest mean January temperature. Mortality by seed source over all plantings ranged from 6 to 33 percent. There tended to be a relationship between seed source mortality and seed source winter injury as measured in the nursery. The six sources showing the highest winter injury (table 2) were all included in the ten highest mortality sources. There is no obvious reason why the other two high-mortality sources (from Ontario and Minnesota) survived so poorly.

The mean height of the plantations 5 years after field planting ranged from 51 centimeters at Pine River, Michigan, to 87 centimeters at Manistique, Michigan (table 3). Only in the tallest planting, Manistique, were no significant differences found between seed sources.

No source or group of sources was consistently best in all four Lake States plantings. Source 1634 from Tennessee was the tallest in Lower Michigan, but was never better than the fourteenth tallest in the other three plantings. Source 1636 from Ontario was tallest in Minnesota but was only thirteenth tallest in Lower Michigan. The best overall sources (both of which were from only slightly south of the plantations) were from Sauk County, Wis. (1651), and Newaygo County, Mich. (1670). The poorest source was from Nova Scotia.

Table 2. — *Summary of data of eastern white pine seedlings and transplants in the Toumey and Hugo Sauer Nurseries*

Source number	Location	Height above cotyledons1/ 1958 1-0 stock	Height above cotyledons1/ 1959 2-0 stock	Winter injury2/ 1960 2-1 stock	Height3/ 1961 2-2 stock
		Mm	Mm	Percent	Cm
1650	Minnesota	7.2	36	7	13
1622	Minnesota	6.2	28	4	13
1629	Minnesota	7.6	31	6	14
1623	Wisconsin	7.5	34	2	19
1651	Wisconsin	8.4	37	4	17
1624	Iowa	7.0	32	4	15
1656	Michigan	6.3	26	4	13
1670	Michigan	8.9	38	17	19
1636	Ontario	7.6	36	7	17
1635	Quebec	8.1	35	2	12
1637	Nova Scotia	8.1	40	32	15
1638	Maine	6.3	25	17	15
1639	New York	7.1	35	5	16
1640	Pennsylvania	6.9	28	17	15
1632	Ohio	7.6	32	3	15
1634	Tennessee	9.1	42	82	16
1633	Georgia	8.3	38	79	13
Mean		7.5	33.7	17.1	15.1
$S_{\bar{x}}$		0.36	2.62	2.74	.79
Seed source F-value		6.00 *	3.42 *	84.46 *	5.74 *

1/ Measured to the nearest millimeter.
2/ Percentage of all trees showing damage symptoms. Damage scored as present or absent for each tree.
3/ Measured to the nearest 2.5 millimeters.
* Differences among means significant at .05 level.

The three southern Appalachian sources (1633, 1634, and 1640) include the two tallest at Pine River, Mich., the three tallest in southern Lower Michigan (Wright *et al.* 1963), the three tallest in the Central States (Iowa, Illinois, Indiana, Ohio, and Kentucky) (Funk 1965), and the three tallest in North Carolina (Sluder 1963). But none of these three sources is in the tallest five in the Wisconsin and Minnesota plantings.

Moreover, comparing the ranking of the 12 sources common to this study, the Central States study, and the North Carolina study (3-year results), one finds that the ranking at Pine River, Mich., more closely resembles the Central States and North Carolina plantings than do either the Wisconsin or Minnesota plantings.

The data show effectively no change in seed source ranking northward from North Carolina until one passes north and west of Lower Michigan. Then in a relatively short distance (Pine River, Mich. to Wabeno, Wis.) the relative growth rate of the seed sources changes sharply. This emphasizes that generalizations regarding growth rate based on test plantations located within a limited area should not be extended beyond that area.

Only one significant correlation was found between nursery heights and plantation heights; the 1-0 growth was correlated with the 1966 heights in the Pine River, Mich., planting ($r = .55$ with 15 degrees of freedom).

Thus, the sources from milder climates show the fastest growth rate in protected nursery beds but then lose their superiority when exposed to severe winters. These faster growing sources then regain their superiority only when moved back into milder climatic regions.

Table 3. — *Mortality in 1966 and total height in the test plantations*

Source number	Location	Percent mortality, all plantings	Height--seed source mean as a percent of plantation mean[1/]			
			Cass Lake, Minn.	Wabeno, Wis.	Manistique, Mich.	Pine River, Mich.
1650	Minnesota	9	107	103	97	83
1622	Minnesota	10	109	97	97	89
1629	Minnesota	22	110	107	111	111
1623	Wisconsin	13	106	114	97	99
1651	Wisconsin	6	119	124	110	102
1624	Iowa	13	102	112	98	102
1656	Michigan	10	89	93	101	80
1670	Michigan	12	115	108	114	109
1636	Ontario	25	120	103	106	89
1635	Quebec	10	115	98	90	88
1637	Nova Scotia	17	74	77	86	98
1638	Maine	18	89	78	96	90
1639	New York	10	88	113	102	102
1640	Pennsylvania	16	96	94	98	117
1632	Ohio	10	95	119	108	113
1634	Tennessee	19	75	78	88	123
1633	Georgia	33	76	75	99	108
Mortality, percent:						
Mean		15	18	17	13	11
$S_{\bar{x}}$		0.74	--	--	--	--
Height, centimeters:						
Mean			69.6	58.6	86.7	51.3
$S_{\bar{x}}$			5.84	4.66	5.87	3.66
Seed source F-value		4.95 *	3.32 *	4.48 *	1.43	2.95 *

1/ Height was measured to the nearest centimeter.
* Differences among means significant at .05 level.

Seed Collection Recommendations

The growth differences among the Lake States seed sources indicate that we cannot be satisfied to collect seed from any white pine stand in this area. Instead, many stands must be tested to locate enough superior sources of seed for reforestation in the Lake States.

For the more severe climates of Minnesota, Wisconsin, and Upper Michigan we should obtain and test seed from stands in areas where the mean January temperature is less than 20°F. This would include white pine stands in all of Minnesota, Wisconsin, and Upper Michigan and the northern parts of Lower Michigan and Ontario.

For planting in southern and western Lower Michigan, seed sources from the southern Appalachians offer enough promise to warrant further investigation.

In the meantime foresters in the Lake States would be well-advised to use seed from stands no more than 100 miles from the planting site.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-63

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

ACORN MOISTURE CONTENT CRITICAL FOR CHERRYBARK OAK GERMINATION

ABSTRACT.—Cherry bark oak acorns exposed to air lose moisture rapidly resulting in delayed or complete lack of germination.

Cherrybark oak (*Quercus falcata* var. *pagodaefolia* Ell.) grows fast on the bottomlands of the mid-Mississippi Valley, has good form, and prunes itself well. But it occurs in that area only as an occasional tree. Whether this low population is due to inadequate germination, unfavorable seedbed, or other identifiable causes is not known. However, a preliminary survey showed that site is apparently not a limiting factor in southern Illinois. We suspected that low germination might restrict the tree's occurrence in this region, which is the northern limit of its range. A study showed that cherrybark oak acorns exposed to air lose moisture rapidly resulting in delayed or complete lack of germination. This could explain the infrequent occurrence of cherrybark oak in southern Illinois, where dry falls are common, and suggests that nurserymen take precautions to prevent acorn drying.

The Study

Acorns were collected from several cherryb oaks in early October. The acorns were loose in th cups, but had not begun to fall. They were put in plastic bags and placed in cold storage the same day.

The following March, 80 acorns were removed from cold storage, weighed, placed in paper trays, and exposed to the air at room temperature. This procedure was repeated every 2 days until the first group had been exposed for 20 days, thus making 11 groups for a total of 880 acorns. At this point the acorns were reweighed and half of each group was planted an inch deep in vermiculite-filled flats in a greenhouse. The flats were kept moist, and were checked each day until germination ceased.

The remaining half of each group was placed in a drying oven at 110°C. until weight stabilized. The ovendry weights were used to determine the moisture content after storage and again after exposure. The moisture content was 40.5 percent when the acorns were removed from storage, and 6.3 percent after 20 days of air drying.

Results

Acorns air-dried for more than 4 days did not germinate. We found that two-thirds of the acorn moisture was lost during this initial 4-day period, and virtually all of the moisture loss occurred in the first 6 days (fig. 1). This emphasizes that moisture content is critical for cherrybark oak germination and that acorns will dry rapidly without favorable moisture conditions.

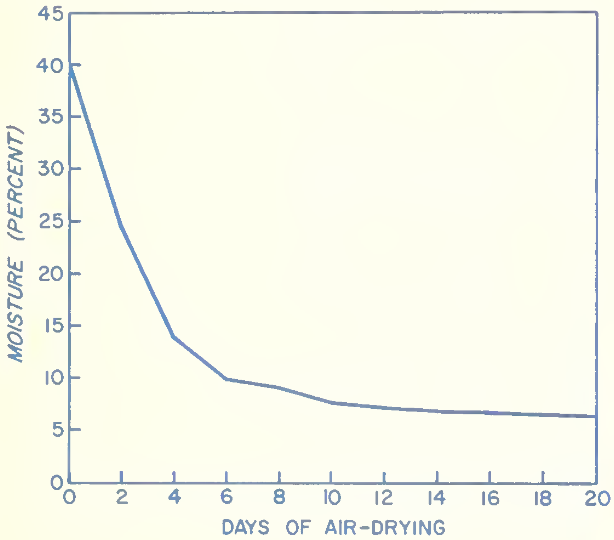

Figure 1. — Moisture percent (based on ovendry weight) as related to number of days of air-drying.

The first seedling emerged 15 days after sowing in the group with no exposure. In the group air-dried for 2 days, a seedling emerged on the 17th day. However, it took 24 days for a seedling to germinate from the group air-dried for 4 days (fig. 2). Although the acorns exposed for 2 days eventually produced as many seedlings as the ones that were not exposed, the seedlings developed more slowly (fig. 3).

These results show that stratified cherrybark oak acorns can lose moisture rapidly and that this loss is accompanied by delayed germination and reduced germinative capacity. At this stage of the investigation, we do not know whether fresh acorns and stratified acorns behave similarly; if rapid drying and embryo destruction occur in fresh acorns as well as stratified ones, the dry falls common to southern Illinois may explain the infrequent occurrence of cherrybark oak there.

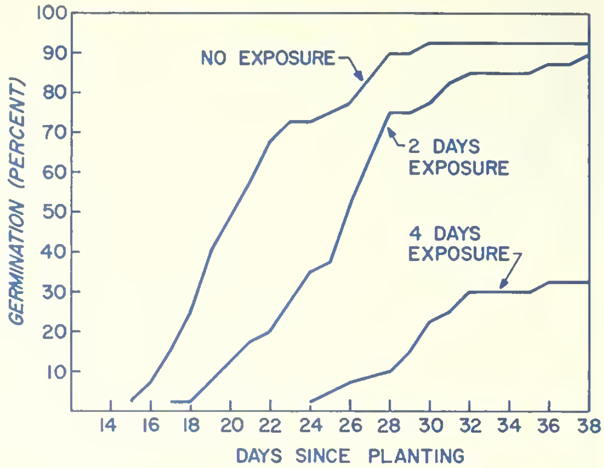

Figure 2. — Effect of period of exposure to air at room temperature on germination.

Figure 3. — Difference in development of cherrybark oak seedlings 30 days after sowing. Right: acorns exposed 2 days. Left: acorns sown directly from storage. (F-518331)

The results show that, for nursery production, care should be taken to collect cherrybark oak acorns immediately after seedfall, or even to collect the acorns directly from the trees. The acorns should be sown immediately in the fall, or promptly placed in moist cold storage for spring sowing.

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ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

FUEL EVALUATION FOR A MISSOURI PINE PLANTATION RELEASED BY AERIAL SPRAYING

ABSTRACT. — Fuel changes resulting from aerial herbicide application to control hardwoods competing with 13-year-old underplanted pine in Missouri are described. Fuel hazard is generally maximum about the fifth year after treatment and is affected by relative pine and hardwood densities.

Stands of low-grade, undesirable hardwoods are being converted to shortleaf pine on many acres of Missouri forest land. Hardwoods are controlled largely by broadcast applications of herbicides either for planting site preparation or in later release of the pine. The increased fuel hazard during the following 10 years or so is of concern to those responsible for forest fire control. In 1955 we established a study to learn how forest fuels change during this period.

The Study

The 40-acre study area, in Dent County, Missouri, was planted to shortleaf pine in 1942. Between that year and 1955 all hardwoods merchantable as sawtimber were cut and many culls were girdled. Cutting and the absence of fire allowed oak sprouts to develop. In June 1955 five treatment blocks of about 8 acres each were established. In four of the blocks, the pines were released from the developing sprouts and from scattered larger, unmerchantable trees with an aerial application of herbicides. One block was left untreated. Two of the treated blocks were resprayed in June 1957.

Fuel weight data were collected between January and March 1960 and again in 1963 on a transect through each of the five blocks:

1. Forest floor weights (litter, all duff that could be collected with a minimum of mineral soil, and decomposing wood less than ½-inch thick that could be crushed between fingers) were based on 20 subsamples per transect. Each subsample consisted of material collected from five spots, each 3.8 inches in diameter.

2. Dead fallen wood up to 6.0 inches in diameter was collected from 100 locations per transect, each location containing 18 square feet. Wood thicker than 6 inches was excluded because it was scarce and because its effect on fire behavior would be limited and localized. Dead woody fuel less than 1.5 inches in diameter was classified on the basis of the height above ground of the major portion (by weight) (fig. 1).

3. Grass and herbaceous material was clipped on 25 circular subplots per transect, each subplot containing 9.6 square feet.

4. The weights of pine crown fuels were estimated on the basis of results from a previous study.[1]

All weights were computed on an ovendry, tons-per-acre basis.

Pine basal area was estimated in 1963 with a wedge prism on alternate sampling points from which dead fallen wood was collected.

[1] *Crosby, John S. and Robert M. Loomis. How thinnings affect fuel weights in shortleaf pine stands in southeast Missouri. J. Forest. 65(12): 901-902. 1967.*

Figure 1. — These dead woody fuels less than 1.5 inches in diameter were classified as higher than 12 inches above the forest floor. (F-518181)

Results and Discussion

On some areas within each treatment block, the pine had been relatively free from competition and grew well so that by the time of treatment the stands were nearly closed. On other areas, pines were few and small and hardwoods were numerous. Since treatment killed only hardwoods, important fuel differences occurred between areas poorly stocked and well stocked with pine (fig. 2). Fuel changes also differed between treated and untreated areas. But the differences occurring between the blocks sprayed once and those sprayed twice were small and are ignored in the following discussion.

Eight years after treatment, pine basal area (a single indicator representing relative pine and hardwood densities) averaged 30 square feet per acre for the untreated areas and 75 square feet for all treated areas. Considering treated areas only, the pine basal area was 30 square feet in stands poorly stocked with pine and 125 square feet for those well stocked with pine (table 1).

The herbicide treatment caused a greater difference in weight of dead fallen woody fuels than for any other fuel fraction except living pine crowns. The untreated stand averaged 0.8 ton per acre, whereas the treated areas averaged 3.7 tons per acre (table 1). Weights were consistently less for all wood-size classes on the untreated area. The difference between the well stocked and poorly stocked pine stands in the treated area was even greater — 4 tons per acre.

The average forest floor weights for the treated (5.1 tons per acre) and untreated (5.0 tons) areas were about the same (fig. 3). However, forest floor weights within the treated area varied with the degree of pine stocking. The litter and duff weight for the dense pine was 5.6 tons, about 2 tons per acre more than for the poorly stocked pine.

Figure 2. — Two areas 5 years after treatment. (*Left*) On this area, which was poorly stocked with pine and heavily stocked with hardwoods, most small hardwoods are already down. The primary fuels are a poorly developed forest floor, including grass and herbaceous materials, and hazardously arranged dead fallen woody fuel. (*Right*) This area was well stocked with pine and poorly stocked with hardwoods. The primary fuels are the well developed forest floor and a small amount of dead and down woody fuel. (F-518182-518183)

Table 1. — *Average fuel weights 5 to 8 years after herbicide treatment of competing hardwoods in a 13-year-old pine plantation, Dent County, Missouri (In tons per acre)*

Kind of fuel	Untreated area (30 BA[1])	Treated area: Average (75 BA)	Treated area: Pine poorly stocked (30 BA)	Treated area: Pine well stocked (125 BA)
Herbaceous grasses and herbs	0.0	0.1	0.1	0.1
Forest floor:				
Litter	2.1	2.1	1.4	2.2
Duff	2.9	3.0	2.2	3.4
Total	5.0	5.1	3.6	5.6
Dead fallen wood, diameter in inches:				
0.0-0.5	.2	.8	1.8	.7
0.6-1.5	.3	1.2	2.4	.9
1.6-3.0	.1	1.2	1.8	.8
3.1-6.0	.2	.5	.5	.1
Total	.8	3.7	6.5	2.5
Pine crowns 8 years after treatment:				
Foliage	.7	1.5	.7	2.1
Branch wood	2.7	5.3	2.7	6.0
Total	3.4	6.8	3.4	8.1
Combinations:				
Grasses, herbs, & litter	2.1	2.2	1.5	2.3
Grasses, herbs, litter, duff, wood 0.0-3.0 inches	5.6	8.4	9.7	8.1
Grasses, herbs, litter, duff, wood 0.0-6.0 inches pine foliage	6.5	10.4	10.9	10.3
Grasses, herbs, litter, duff, wood 0.0-6.0 inches, pine foliage & branch wood	9.2	15.7	13.6	16.3

[1] Pine basal area (BA) in square feet at age 21, 8 years after treatment.

Grasses and herbaceous fuels were patchy and most prevalent on the poorly stocked, treated pine areas, where much of the poorly developed forest floor consisted of the unattached dead grass and herbs. Ehrenreich[2] reported that these fuels amounted to 1,200 pounds per acre 1 year after treatment, 300 pounds 2 years after treatment, and 200 pounds 3 years after treatment. The amount and duration of grasses and herbs probably vary among different areas. The amount of this production is inversely related to tree crown density.

[2] *Ehrenreich, John H. Releasing understory pine increased herbage production. Central States Forest Experiment Station, Sta. Note 139, 2 p. 1959.*

The living pine crown weight showed the desirable release response: 8 years after treatment there was about twice as much foliage and branch wood on treated (6.8 tons per acre) as on untreated (3.4 tons) areas. The poorly stocked treated areas had the same crown weight as the untreated area, but there were 8.1 tons per acre on the well stocked, treated areas.

Figure 3. — The untreated area had a relatively uniform fuel situation, the primary fuel being the forest floor. (F-518184)

Although woody fuel weights did not change appreciably between 1960 and 1963, the vertical arrangement of the fuel was different. Five years after treatment, most of the fallen woody fuel less than 1.5 inches in diameter was still above the forest floor on about 90 percent of the treated area. By the eighth year, most of this fuel was on or within the forest floor on more than half the treated area, and on all the untreated area. Arrangement was probably most hazardous on the treated area about 5 years after treatment, with total hazard decreasing from then on, although 10 years after treatment the treated area still had an obviously greater hazard in both weight and arrangement than the untreated area.

Another study showed that 2 years after herbicide treatment of hardwoods, a significant amount of small branch wood was falling; by the seventh year, almost all branch wood and small saplings as well as most small pole-sized trees were down.[3] Some

[3] *Loomis, Robert M., and John S. Crosby. The breakup of dead hardwood trees and the fuel hazard following timber stand improvement operations in southeast Missouri Ozarks. (Manuscript in preparation.)*

large poles remained as standing snags after 10 years, and probably some sawtimber-sized trees will still be standing as snags after 15 years. Maximum hazard for most treated areas was considered to be from about the third to seventh year after treatment.

In the current study the amount of fuel increase on the treated area was enough to materially influence fire intensity, but the arrangement of the fuel and its exposure would cause most concern. Within the untreated area, the annual fall of branch wood is light and the wood usually incorporates into the forest floor in a short time. However, on treated areas the much larger amount of wood that falls is initially arranged in depths up to 3 or 4 feet. These fuels are especially hazardous because: they are exposed to rapid drying, a high percentage is likely to be available fuel, they ignite easily from fire in the forest floor, they may contribute to an intense fire and provide burning embers that are carried upward by convection to cause spotting ahead, and they may interfere with movement of men and machines engaged in suppression.

The effect of fuel weights on fire intensity and resistance to control and the subsequent effects on living vegetation depend upon both fuel composition and burning conditions. Byram[4] states that fire intensity varies with the amount of available fuel, the rate of spread, and the heat capacity of the fuel. Because both the amount of available fuel and the rate of spread increase as fuels become drier, the potential fire intensity on the study area will vary with burning conditions.

As drying progresses after a complete wetting, the more exposed and finest fuels dry to flammability first. Moreover, as the quantity of flammable fuels increases these fuels when burned can dry additional fuels so they will also burn. Although a precise estimate of available fuel increments as drying progresses is not possible, some steps in fuel addition can be postulated from this study in the fuels 5 to 8 years after treatment.

Under minimum conditions for burning, only the litter, grasses, and herbs would likely be consumed. For the four area situations, the fuel weights would not be very different, ranging from about 1.5 to 2.3 tons per acre (table 1).

[4] *Byram, George M. Forest fire behavior.* In *Forest fire: control and use. By Kenneth P. Davis, 584 p., illus. New York, Toronto [etc.]: McGraw-Hill Book Co.*

As drying proceeds, it is likely that the forest floor duff and fallen woody fuels up to about 3 inches in size would become available, increasing available fuel to between 5.6 and 9.7 tons per acre (table 1). The lowest amount was on the untreated area and greatest on poorly stocked pine areas.

If a fire was hot enough to burn the pine crowns, the foliage could add about 0.7 to 2.1 tons per acre to the available fuel on the areas studied. With more severe conditions, branch wood could also be burned. Under the most severe conditions, the probable available fuel could amount to approximately 9.2 to 16.3 tons per acre. (Although some live hardwood crown branch wood and some standing dead woody fuels might also be burned, these were not included in weight estimates.)

With the more common burning conditions, the poorly stocked pine area would have the most available fuel. But, with very severe conditions permitting crown fire, the well stocked pine area has the most available fuel, the greatest fire intensity potential, and the possibility for the most damage.

Conclusions

An increased fuel hazard due to broadcast herbicide treatment of hardwoods is primarily controlled in kind, amount, and duration by number, size, and species of dead and of living trees per unit area. A typical sequence of events can be expected following treatment: Site exposure increases almost immediately, with the opened crown canopy allowing faster drying by sun and wind. Grass and herbaceous growth may increase greatly 1 year after treatment; but this production may drop quickly to a small amount, depending upon rate of increase of tree crown cover. Most branch wood, saplings, and small poles fall between 2 and 7 years after treatment. Maximum hazard will probably occur about the fifth year. A hazardous vertical fuel arrangement of fallen wood less than 1.5 inches in diameter, present by the fifth year, is much less critical by the eighth year. Some large poles may remain standing as snags even after 10 years and some sawtimber-sized trees will probably be standing as snags after 15 years.

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1968

U. S. FOREST SERVICE

RESEARCH NOTE NC-65

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

A COMPUTER PROGRAM TO EVALUATE TIMBER PRODUCTION INVESTMENTS UNDER UNCERTAINTY

ABSTRACT.—A computer program has been written in Fortran IV to calculate probability distributions of present worths of investments in timber production. Inputs can include both point and probabilistic estimates of future costs, prices, and yields. Distributions of rates of return can also be constructed.

Several computer programs designed to evaluate investments in timber production are now generally available.[1] Each requires that point estimates of costs, prices, and physical yields be provided as inputs. Present worths and, perhaps, internal rates of return are then calculated. This Note describes a new computer program that generates probability distributions of present worths from combinations of point and probabilistic estimates that define investments in timber production.

At the beginning of an investment period, a forecast of a cost or income is subject to error. The likely extent of that error can be quantified by substituting several possible values for the usual point estimate. For example, if low, most likely, and high estimates of the future market price for pulpwood are made, a mathematical function consistent with these estimates can be constructed. In the NCSUBPR (*N*orth *C*entral *SUB*jective *PR*obabilities) computer program, beta probability distributions are fit to multiple-valued estimates of this type.[2]

Annual payments, one-time or nonrecurring payments, and prices (for as many as nine products) can be entered into the program either as point estimates or as low, most likely, high estimates. Physical yields, which can be separately specified for intermediate and final harvests, can be entered either as point estimates or as normally distributed variables. In the latter case, the standard deviation is entered as a proportion of the yield. (This value might be taken from experimental work or subjectively estimated, say, as one-sixth the range of likely yields.) Several discount rates and rotation lengths can also be specified if repeated analyses of a single set of input data are desired.

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[1] *For example, Dennis L. Schweitzer, Allen L. Lundgren, and Robert F. Wambach. A computer program for evaluating long-term forestry investments. U.S.D.A. Forest Serv. Res. Pap. NC-10, 34 p., illus. N. Cent. Forest Exp. Sta., St. Paul, 1967; and Clark Row. Determining forest investment rates-of-return by electronic computer. U.S.D.A. Forest Serv. Res. Pap. SO-6, 13 p., illus. S. Forest Exp. Sta., New Orleans, 1963.*

[2] *Letting L and H represent the low and high estimates and A and B two mathematical parameters, the beta probability distribution can be written as*

$$Prob(x) = \frac{(A+B+1)!}{A!\ B!} (x-L)^{A} (H-x)^{B}$$

See page 129 in Alexander M. Mood and Franklin A. Graybill. Introduction to the theory of statistics (2nd ed.) 443 p., illus. McGraw-Hill, 1963.

We can illustrate the use of the NCSUBPR program with the problem of deciding whether oak sawtimber or pulpwood on a 40-year rotation is a better investment. When the input data (table 1) are entered into the computer, each multiple-valued estimate is associated with either a beta or normal distribution. Then a variant of the Monte Carlo technique is used to combine these individual distributions with the point estimate of annual costs into a cumulative probability distribution of present worth for one rotation (table 2). This measure of desirability of an investment summarizes all of the estimates of future costs, prices, and yields. If they are imprecisely estimated, as in the present example, the distribution will reflect the odds that each of several values of present worth is correct.

After a separate estimate of present worth for each alternative has been generated, the data can be plotted (fig. 1). If a 3 percent discount rate were appropriate, we might conclude that sawtimber should be produced.

Table 1. — *Input data illustrating use of NCSUBPR computer program*

Estimated costs (from expert opinion)		
Annual costs including taxes	$.25/acre	
Initial prescribed burning to encourage sprouting		
Range	$ 5.00 - $20.00/acre	
Most likely	$10.00/acre	
Estimated prices (from price reporting service)		
Pulpwood price		
Range	$.50 - $2.00/cord	
Most likely	$.93/cord	
Sawtimber price		
Range	$5.00 - $12.71/MBM	
Most likely	$9.02/MBM	
Estimated yields (from normal yield tables)		
Product	Yield at age 40	Standard deviation
Pulpwood	30.71 cords	29.4%
Sawtimber	8.60 MBM	47.4%

Table 2. — *Probability distribution of present worth generated by NCSUBPR computer program for producing oak sawtimber on 40-year rotation (discount rate = 3 percent)*

Probability of exceeding present worth	Present worth (dollars)
1.00	- 32.78
.95	- 16.87
.90	- 12.37
.85	- 9.09
.80	- 6.27
.75	- 3.75
.70	- 1.44
.65	.72
.60	2.96
.55	5.03
.50	7.27
.45	9.57
.40	11.77
.35	14.25
.30	16.76
.25	19.60
.20	22.82
.15	26.62
.10	31.30
.05	38.30
.00	70.18

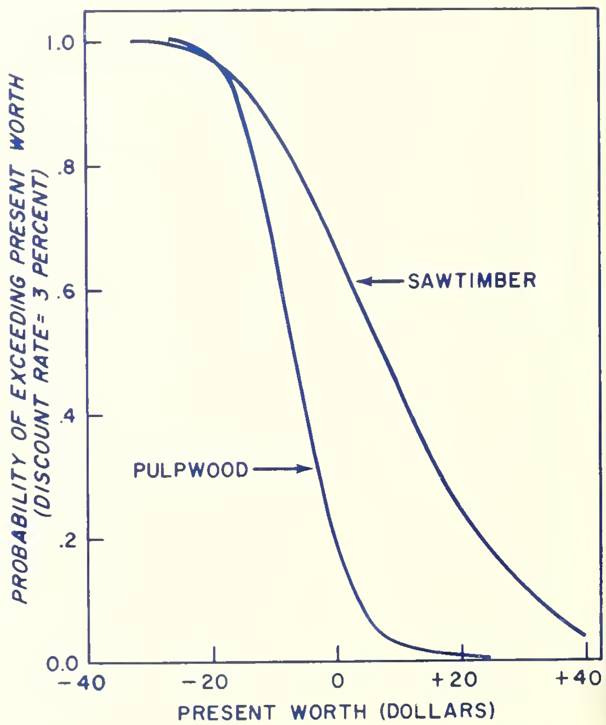

Figure 1. — Probabilities of exceeding specified present worths when producing oak sawtimber and pulpwood in 40-year rotations (discount rate = 3 percent).

The graph suggests there is a 2-in-3 chance of discounted costs at least equalling discounted returns when producing sawtimber. Another way of saying this is that our investment funds have a 2-in-3 chance of earning a 3 percent internal rate of return. If we use the program to evaluate our alternatives at a number of discount rates, each computer run will indicate the chance of achieving a particular rate of return. This approach permitted developing probability distributions of rates of return (fig. 2).

The NCSUBPR program was written in Fortran IV for Control Data Corporation 6400 and 6600 computers. Core storage of 30,000 data words plus compiler requirements and a Fortran compiler capable of utilizing block COMMON, DATA, and DECODE statements are required to run the program. Input is by punched cards and the output is printed. Complete program documentation and a listing of the source deck are available from the North Central Forest Experiment Station.

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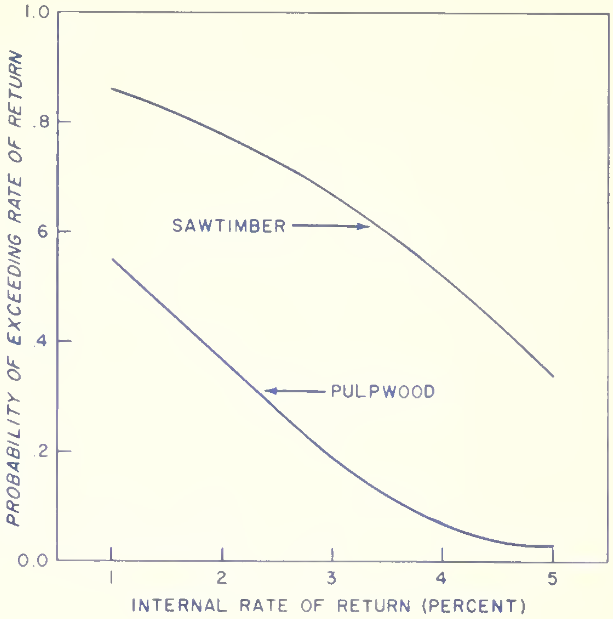

Figure 2. — Probabilities of exceeding specified rates of return when producing oak sawtimber and pulpwood in 40-year rotations.

U. S. FOREST SERVICE

RESEARCH NOTE NC-66

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

DEER BROWSE PRODUCTION: RAPID SAMPLING AND COMPUTER-AIDED ANALYSIS

ABSTRACT. — Describes field techniques by which winter deer-browse production can be sampled with reasonable accuracy and moderate effort; and presents a computer program which simplifies and expedites the tabulation of the browse data. The method will be useful to both land managers and scientists doing research on the habitat of the white-tailed deer.

Determining the potential value of forest stands for wildlife habitat is a complex and time-consuming process. This Note, which is based on our experience in sampling woody material used as winter browse by white-tailed deer, is a contribution towards simplifying the collection and analysis of data on browse production.

After the variables to be measured have been chosen, the principal steps in estimating browse production are: developing a sampling scheme, collecting data in the field, and analyzing the data. We have concentrated on measuring the total quantity of browse available, past browse utilization, the number of stems of each browse species, and the basal area of the overstory as estimated by prism from each plot center.

Field plots must be large enough to permit adequate sampling of major browse species but small enough so that boundaries can be readily established in dense undergrowth. The quality of the plot estimates must be balanced against the cost of making those estimates. After some experimentation, we chose a ¼-milacre (.00025 acre) plot as the most efficient size, for larger plots often require excessive time to count and clip. (A smaller plot might be necessary when working with low, dense browse.) Such a plot can be outlined easily with a pair of plot sticks 3.3 feet long. They are held at right angles to form two boundaries of a square plot, with their intersection at the sample point. Square plots seem best adapted to sampling browse in forest stands, but a circular plot is often more efficient in low or open vegetation.

Although sampling intensity could be varied with the nature of the forest stands, we settled for the convenience of a constant number of plots per stand. Since most trees and shrubs are not uniformly distributed throughout a stand, the variation between plots within a stand is often large. Furthermore, the utilization of browse material by deer also varies greatly both between years and between areas of similar plant composition for any given year. Therefore, a sampling error of about 20 percent of the mean seems a reasonable goal. To attain this precision, 30 to 40 plots per stand are usually adequate.

Sample plots can be quickly laid out. Along one boundary of the stand, points are established from which to start transects. Then the plots are laid out along each transect at predetermined intervals. If a more sophisticated sampling scheme is desired, the transects could be established at random intervals on the stand boundary, or the plots at random intervals on the transects, or both. For our purposes, an ordinary grid with uniform intervals was satisfactory.

On each plot the first step is to count the number of stems rooted in the plot for each browse species. It is usually easiest to record the most abundant species first. Past browsing is noted by assigning one of four browsing categories based on the percentages of the terminal twigs which were browsed in the previous winter: (1) no browsing, (2) up to one-third of the stems browsed, (3) one-third to two-thirds browsed, and (4) over two-thirds of the stems browsed.

When the browsing index has been recorded, the browse in the plot is clipped. Our definition of woody browse as all current annual growth between 1 and 7 feet above the ground provides a maximum estimate. This includes browse which extends into the (three-dimensional) plot from stems rooted outside. However, twigs less than 1 inch long are not clipped, for they are seldom browsed and contribute little to total production. Their elimination greatly reduces the time required to clip the plots.

The browse material is placed in bags by species and either weighed immediately to determine fresh green weight or dried and then weighed to provide air-dry or ovendry weight.

A form to facilitate field measurements and the subsequent analysis of these data is shown in figure 1. Standard alphabetic abbreviations are utilized to identify the sampled trees and shrubs (table 1).

The field data are transferred from these forms onto standard 80-column punch cards for analysis by a specially prepared computer program. The field form does not have to rigidly follow the one illustrated, for the user can specify either fewer or more digits for each measurement. However, the *order* of the input variables is fixed as shown.[1] Plot size and, if desired, a factor (which must be a constant) for converting green weights to dry weights are also punched.

Other characteristics of the computer program are that:

1. A single plot or stand can contain as many as 50 species.
2. Any number of plots can be included in a stand.
3. The measurements for a single plot can be recorded on any number of punch cards.
4. Plot size must be constant within a stand but can be varied between stands.
5. Any number of stands can be processed in a single computer run.

[1] *Although table headings are always printed with the indicated names for the program variables, any other measurements could be recorded in their place. For example, stand stocking, percent germination by species, and shoot length and weight could be substituted.*

Stand ________________________________

Location ____________________ Acreage __________ Type __________

Remarks ________________________________

Date ____________________ Crew ____________________

Plot No.			BA		Species				No. stems			BC	Browse wt.					Species				No. stems			BC	Browse wt.				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

BA--basal area of overstory from plot center using a prism (in tens of square feet).
No. stems--stems rooted in plot, taller than 12 inches but less than 1.5 inches d.b.h.
BC--browsing category: 0 = no browsing, 1 = less than 1/3 terminals browsed, 2 = 1/3 to 2/3 browsed, 3 = more than 2/3 terminals browsed.
Browse wt.--either fresb or dry weight (in grams).

Figure 1. — Sample form for recording field data.

Table 1. — *Standard abbreviations for some commonly browsed trees and shrubs of the northern Lake States*

Abbreviation 1/ and scientific name 2/	Common name	Abbreviation 1/ and scientific name 2/	Common name
ABBA - *Abies balsamea*	Balsam fir	POTR - *Populus tremuloides*	Quaking aspen
ACRU - *Acer rubrum*	Red maple	PRPE - *Prunus pensylvanica*	Pin cherry
ACSA - *Acer saccharum*	Sugar maple	PRSE - *Prunus serotina*	Black cherry
ACSP - *Acer spicatum*	Mountain maple	PRVI - *Prunus virginiana*	Chokecherry
ALRU - *Alnus rugosa var. americana*	Speckled alder	PRPU - *Prunus pumila*	Sand cherry
AMLA - *Amelanchier laevis*	Juneberry	QUAL - *Quercus alba*	White oak
BELU - *Betula lutea*	Yellow birch	QUBO - *Quercus borealis*	No. red oak
BEPA - *Betula papyrifera*	Paper birch	QUEL - *Quercus ellipsoidalis*	Jack oak (no. pin)
CACA - *Carpinus caroliniana*	Bluebeech or hornbeam	QUVE - *Quercus velutina*	Black oak
COAM - *Corylus americana*	Hazelnut	RHTY - *Rhus typhina*	Staghorn sumac
COCO - *Corylus cornuta*	Beaked hazelnut	RHGL - *Rhus glabra*	Smooth sumac
COAL - *Cornus alternifolia*	Alternate-leafed dogwood	SAAL - *Sassafras albidum*	Sassafras
COST - *Cornus stolonifera*	Red-osier dogwood	SANI - *Salix nigra*	Black willow
DIPA - *Dirca palustris*	Leatherwood	SACA - *Sambucus canadensis*	Common elderberry
FAGR - *Fagus grandiflora*	American beech	SAPU - *Sambucus pubens*	Red-berried elder
FRAM - *Fraxinus americana*	White ash	THOC - *Thuja occidentalis*	White-cedar
FRNI - *Fraxinus nigra*	Black ash	TACA - *Taxus canadensis*	Canada yew
ILVE - *Ilex verticillata*	Winterberry	TIAM - *Tilia americana*	Basswood
OXVI - *Ostrya virginiana*	Ironwood or hophornbeam	TSCA - *Tsuga canadensis*	Eastern hemlock
PIBA - *Pinus banksiana*	Jack pine	ULAM - *Ulmus americana*	American elm
PIRE - *Pinus resinosa*	Red pine	VILE - *Viburnum lentago*	Nannyberry
PIST - *Pinus strobus*	White pine		
POGR - *Populus grandidentata*	Large-toothed aspen		

1/ Abbreviations are formed from the first two letters of the genus name followed by the first two letters from the species name. When a particular combination has already been used, a new combination should be made using other letters. Initially, unidentified species were designated by the first two letters of the genus name followed by Sp. This resulted in some duplication with legitimate names so the letters XX are now used to designate an unidentified species (or group of species) in any genus; for example, BEXX indicates Betula spp.

2/ Names follow C.O. Rosendahl, 1955. Trees and shrubs of the Upper Midwest. 411 pp. University of Minnesota Press, Minneapolis.

Output generated by the computer program includes both summaries of the field measurements and simple statistics (fig. 2). The first table provides plot summaries and serves as a permanent record of the data. The second is similar, but the summaries are by species rather than plots. The final table provides means, standard errors of the means, and the coefficients of variation for basal area, stem count, and browse weight, using plots as the sampling units.

The computer program is written in Fortran II specifically for the computers of the University of Minnesota. Other machines can be used if they permit three-dimensional arrays and a variable data format (not in source program), and have a core storage capacity of 8,000 data items in addition to compiler requirements. Listings of the Fortran source deck and program documentation are available from the Biometrical Section of this Station.

The time required for field work varies greatly with the vegetation, but approximates 1.5 man-days per stand. The computer program has been used successfully to summarize field data on a number of stands in Wisconsin and Michigan. It has vastly reduced the time required to calculate the availability of browse and other measures.

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1968

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE (U.S.D.A.)

BROWSE ANALYSIS

T44N R5W SWSE-28 SE-26 NOV. 9, 1964 41 ACRES(EST.) MD ACTUAL MD CH1
(WEIGHT INCLUDES OVERHANGING BRANCHES)

NSRC = 5 PLOT SIZE = .00025 ACRES FIELD TO DRY WEIGHT CONVERSION FACTOR = .5300

DATA FORMAT = (I3, F2.0, 5(A4, F3.0, F1.0, F5.2))

INDIVIDUAL PLOT SUMMARIES (RECORDED WEIGHTS - RECORDED BASAL AREA TIMES 10)

PLOT	BASAL AREA	PLOT STEMS	AVE BROWSE DAMAGE	RECORDED PLOT WEIGHT	SPECIES OCCURING ON PLOT
101	9.00000E+01				
102	1.10000E+02	0.	0.	5.00000E-01	FRNI
103	1.20000E+02	3.00000E+00	2.00000E+00	0.	ACRU
104	5.00000E+01	1.00000E+00	3.00000E+00	5.00000E-01	BERA
105	1.00000E+02	1.20000E+01	2.00000E+00	5.00000E-01	ACSA ACSR PRSE
106	8.00000E+01				
107	9.00000E+01	2.00000E+00	0.	1.00000E+00	PRSE
108	1.00000E+02	0.	3.00000E+00	5.00000E-01	ACSA
109	9.00000E+01	2.00000E+00	3.00000E+00	5.00000E-01	ACSP
110	8.00000E+01	5.00000E+00	3.00000E+00	4.00000E+00	ACSP
201	9.00000E+01	6.00000E+00	1.50000E+00	1.10000E+01	COCO ACSR
202	7.00000E+01	4.00000E+00	0.	1.00000E+00	OSVI
203	1.00000E+02	1.00000E+00	1.50000E+00	2.00000E+00	ACSP OSVI
204	7.00000E+01	2.00000E+00	3.00000E+00	5.00000E-01	ACSA ACSP
205	1.10000E+02	2.00000E+00	3.00000E+00	1.00000E+00	ACSA ACRU ACSP
206	1.20000E+02	7.00000E+00	1.66667E+00	1.00000E+00	ACRU BERA TSCA
207	1.20000E+02	1.20000E+01	2.66667E+00	4.00000E+00	ACRU ACSA BERA
208	3.00000E+01	2.00000E+00	2.00000E+00	2.50000E+00	ACRU BERA ALXX
209	1.10000E+02	2.00000E+00	1.50000E+00	5.00000E-01	ACSA FRNI
210	9.00000E+01				
211	1.20000E+02				
212	9.00000E+01	1.40000E+01	3.00000E+00	6.00000E+00	ACSA
213	8.00000E+01	6.00000E+00	1.00000E+00	2.00000E+00	ACSA OSVI ACRU
214	1.40000E+02				
215	8.00000E+01	4.00000E+00	1.50000E+00	6.00000E+00	ACSA OSVI
216	1.20000E+02	2.00000E+00	0.	2.00000E+00	ACSA OSVI
301	7.00000E+01				
302	1.00000E+02	6.00000E+00	0.	5.00000E-01	ACSA OSVI
303	8.00000E+01	1.00000E+01	2.50000E+00	1.00000E+00	ACSA ACRU
304	9.00000E+01				
305	7.00000E+01	7.00000E+00	3.00000E+00	2.00000E+00	ACSA
306	7.00000E+01				
307	7.00000E+01				
308	7.00000E+01	1.30000E+01	2.00000E+00	1.50000E+00	ACSA FRXX ACSP
309	1.10000E+02	4.00000E+00	2.50000E+00	1.50000E+00	ACSA ACRU
310	7.00000E+01	4.00000E+00	1.00000E+00	1.00000E+00	ACSA ACRU BEPA
401	1.10000E+02				
402	7.00000E+01	2.00000E+00	1.50000E+00	0.	FRXX TIAM
403	6.00000E+01	6.00000E+00	5.00000E-01	1.00000E+00	ACSA PRSE
404	9.00000E+01	1.00000E+00	0.	0.	ACSA

8.950000E+01 = AVERAGE BASAL AREA 40 = TOTAL NUMBER PLOTS 12 = TOTAL NUMBER SPECIES

INDIVIDUAL SPECIES SUMMARIES (WEIGHT IN GRAMS)

SPR	NUMBER OF PLOTS	PERCENT OF PLOTS	TOTAL STEMS	STEMS PER ACRE	PCT STAND STEMS	AVE BROWSE DAMAGE	TOTAL DRY WEIGHT	DRY WEIGHT PER STEM	DRY WEIGHT PER ACRE	PCT STAND DRY WT
FRNI	2.00000E+00	5.0000	1.00000E+00	1.00000E+02	.7042	0.	2.65000E-01	2.65000E-01	2.65000E+01	.9009
ACRU	9.00000E+00	22.5000	2.10000E+01	2.10000E+03	14.7887	2.22222E+00	2.12000E+00	1.00952E-01	2.12000E+02	7.2072
BERA	5.00000E+00	12.5000	8.00000E+00	8.00000E+02	5.6338	2.80000E+00	1.32500E+00	1.65625E-01	1.32500E+02	4.5045
ACSA	1.80000E+01	45.0000	6.80000E+01	6.80000E+03	47.8873	2.05556E+00	1.11300E+01	1.63676E-01	1.11300E+03	37.8378
ACSP	8.00000E+00	20.0000	1.90000E+01	1.90000E+03	13.3803	3.00000E+00	4.50500E+00	2.37105E-01	4.50500E+02	15.3153
PRSE	3.00000E+00	7.5000	7.00000E+00	7.00000E+02	4.9296	0.	5.30000E-01	7.57143E-02	5.30000E+01	1.8018
COCO	1.00000E+00	2.5000	6.00000E+00	6.00000E+02	4.2254	0.	4.77000E+00	7.95000E-01	4.77000E+02	16.2162
OSVI	6.00000E+00	15.0000	7.00000E+00	7.00000E+02	4.9296	0.	3.71000E+00	5.30000E-01	3.71000E+02	12.6126
TSCA	1.00000E+00	2.5000	1.00000E+00	1.00000E+02	.7042	0.	0.	0.	0.	0.0000
ALXX	1.00000E+00	2.5000	-0.	0.	0.0000	0.	5.30000E-01	0.	5.30000E+01	1.8018
FRXX	2.00000E+00	5.0000	3.00000E+00	3.00000E+02	2.1127	0.	5.30000E-01	1.76667E-01	5.30000E+01	1.8018
TIAM	1.00000E+00	2.5000	1.00000E+00	1.00000E+02	.7042	3.00000E+00	0.	0.	0.	0.0000
			1.42000E+02	1.42000E+04	100.0000	8.16667E+00	2.94150E+01	2.07148E-01	2.94150E+03	100.0000

SELECTED STATISTICS ON AN ACRE BASIS (PLOT IS SAMPLING UNIT)

	MEAN	STANDARD ERROR OF MEAN	ERROR AS PER-CENT OF MEAN
BASAL AREA	8.950000E+01	3.543683E+00	3.959423E+00
NUMBER STEMS	1.420000E+04	2.529619E+03	1.781422E+01
DRY WEIGHT (GRAMS)	2.941500E+03	7.275785E+02	2.473495E+01
DRY WEIGHT (LHS)	6.484903E+00	1.604037E+00	2.473495E+01

Figure 2. — Sample computer printout generated by browse program.

U. S. FOREST SERVICE

RESEARCH NOTE NC-67

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

USING D.B.H. AND BUTT LOG QUALITY TO ESTIMATE TREE YIELDS BY SAW LOG GRADE

ABSTRACT. — Presents a shortcut method of predicting sugar maple tree yields by saw log grade from d.b.h. and butt log grade.

Tree quality is as important as quantity in judging the value of trees. Grading logs in standing trees is one way to estimate quality. This paper analyzes the results of grading sugar maple trees for saw logs and suggests that d.b.h. and butt log grade can be used to estimate saw log yields by grade when evaluating sugar maple stands.

Ninety trees from two old-growth sugar maple stands in Upper Michigan were felled, measured, and graded according to U.S.D.A. Forest Service hardwood factory saw log specifications.[1] The trees were selected from 10 random plots to cover the existing d.b.h. and butt-log quality range. The tree stems were diagrammed, photographed, and "paper bucked" for highest saw-log grade yield. Total log yields by grade were calculated, and tree values were derived from these yields by applying the log prices on the stump using recent National Forest data for Upper Michigan.[2]

Multiple regression analysis was used to find a simple method of estimating saw log yields by grade and tree values. Differences between paper bucked estimates and regression equation estimates were used to measure the success of the method in predicting both log yields by grade and tree values based on these log yield predictions.

Multiple regression analyses of the data showed that d.b.h. and butt log grade can be used to predict saw log yields by grade (table 1). This is because log grades occur in definite patterns in trees of various heights. Trees yielding five variable-length logs had a dominating log-grade pattern of 1-2-2-3-3; 4-log trees 1-2-3-3; 3-log trees 2-3-3; and 2-log trees 3-3 (table 2). Tree values can be derived from the predicted log yields when log prices on the stump are known.

These saw log yield and value estimates describe the stands that were sampled and are based only on paper bucking; so even though estimates of the reliability of the equations are included, the equations should be field tested against actual saw log yields. If this is done, the constants may change in the prediction equations, but the general form of these equations should remain the same.

The equations are to be used for predicting yields and value of stands, and the calculations per tree used only to get the stand values. In this way, individual exceptional trees tend to cancel each other and overall prediction will be good.

MATTI J. HYVARINEN
Wood Technologist

1968

[1] *Vaughan, C. L., Wollin, A. C., McDonald, K. A., and Bulgrin, E. H. Hardwood log grades for standard lumber. U.S.D.A. Res. Pap. FPL 63, 52 p., illus. Forest Products Laboratory, Madison, Wis., 1966.*

[2] *Personal communication from N. O. Nelson, Forest Service Region 9, Milwaukee, Wis. 1968.*

Table 1. — *Tree prediction equations for old-growth sugar maple saw log yields and value*

Equation	R^2	Standard error of estimate
$Y_1 = 0.5589\, X_1^{2}\, X_2^{-1} - 78.46$	0.79	45 board feet
$Y_2 = 0.329\, X_1^{2} - 178.3 X_2 - 464.1\, X_2^{-1} + 618.5$	.50	54 board feet
$Y_3 = 0.1518\, X_1^{2}\, X_2 + 22.11$	.37	59 board feet
$V = P_1 Y_1 + P_2 Y_2 + P_3 Y_3$	1/ .87	3.25 dollars 1/

where

Y_1 = Grade 1 saw log volume in board feet, Scribner Decimal C, for trees 15.5 to 25.5 inches in d.b.h.

Y_2 = Grade 2 saw log volume in board feet, Scribner Decimal C, for trees 12.0 to 25.5 inches in d.b.h.

Y_3 = Grade 3 saw log volume in board feet, Scribner Decimal C, for trees 11.0 to 25.5 inches in d.b.h.

X_1 = d.b.h. in inches

X_2 = butt log grade

V = tree value, dollars

P_1 = Grade 1 saw log price on the stump, dollars per board foot

P_2 = Grade 2 saw log price on the stump, dollars per board foot

P_3 = Grade 3 saw log price on the stump, dollars per board foot

1/ if P_1 = .081 dollars/board foot
P_2 = .036 dollars/board foot
P_3 = .008 dollars/board foot

Table 2. — *Effect of tree size and log position on log grade distribution (based on number of logs in each log grade)*

Log position	Average length	Log grade 1	Log grade 2	Log grade 3	Total
	Feet	Percent	Percent	Percent	Percent
TWO VARIABLE LENGTH LOGS PER TREE					
Top	9.2	0	0	100	100
Butt	14.0	0	0	100	100
All	11.6	0	0	100	100
THREE LOGS					
Top	11.4	0	4	96	100
2nd	14.0	0	37	63	100
Butt	14.4	26	41	33	100
All	13.3	9	27	64	100
FOUR LOGS					
Top	10.5	0	4	96	100
3rd	11.3	0	28	72	100
2nd	13.1	11	62	27	100
Butt	12.8	51	40	9	100
All	11.9	16	33	51	100
FIVE LOGS					
Top	8.7	0	0	100	100
4th	11.9	0	0	100	100
3rd	11.4	0	71	29	100
2nd	13.7	29	71	0	100
Butt	10.9	71	29	9	100
All	11.3	20	34	46	100
All trees	12.1	14	32	54	100

U. S. FOREST SERVICE

RESEARCH NOTE NC-68

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

INDIANA SAWMILLS RECEIVE 232 MILLION BOARD FEET OF SAW LOGS IN 1966

ABSTRACT. — Indiana's 480 active sawmills received 232 million board feet of saw logs in 1966. More than one-quarter was red oak. Eighty-six of these mills each sawed more than 1 million board feet. Of 1,100 mills active in 1949, only 30 sawed this much. Sixteen counties each produced more than 5 million board feet and collectively accounted for 47 percent of the lumber sawn in 1966.

From a peak of more than 1 billion board feet at the turn of the century, Indiana lumber production declined to a low of 70 million in 1932, and then slowly increased to 178 million in 1966 (fig. 1). Most of the lumber manufactured in 1966 was hardwood. Almost half (47 percent) of the total 1966 lumber production was concentrated in 16 counties, each of which produced more than 5 million board feet of lumber (fig. 2).

Indiana sawmills received 232 million board feet (International ¼-inch Log Rule) of saw logs in 1966. Only 16 million board feet came from out-of-state including nearly 6 million from Michigan, 4 million from Illinois, and 3 million from Ohio.

More than a quarter of the 1966 saw log volume acquired was red oak (includes black oak) (table 1). Other major species procured were white oak, hard maple, yellow-poplar, soft maple, and walnut. Northern Indiana (fig. 3) accounted for 46 percent of the lumber output. Three-fifths or more of the hard maple, walnut, basswood, and ash lumber was sawn in this Unit. Of the Northern Unit's 140 active sawmills, 41 cut over 1 million board feet per year.

The 230 active mills in Indiana's Knobs Unit received 74 million board feet of saw logs in 1966. Although this region contains almost half of the State's active sawmills, four-fifths of them are small, cutting less than 500 thousand board feet annually. Principal species cut were red oak, white oak, yellow-poplar, hard maple, and beech. Sixty percent of all blackgum and sweetgum lumber was manufactured in this Unit.

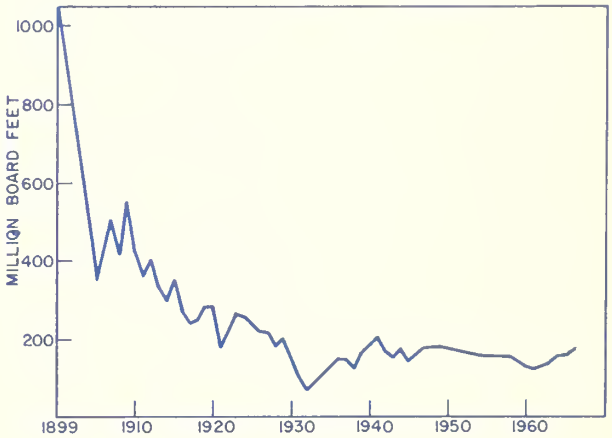

Figure 1. — Lumber production in Indiana, 1899 to 1966 (Sources: Lumber production in the United States 1799-1946, U.S. Dep. Agr. Misc. Public. 669, 1948; Lumber production and mill stocks, Annu. Rep. U.S. Dep. Com. Bur. Census, Annu. Reports: 1947, 1949, 1954, 1958, 1960-66).

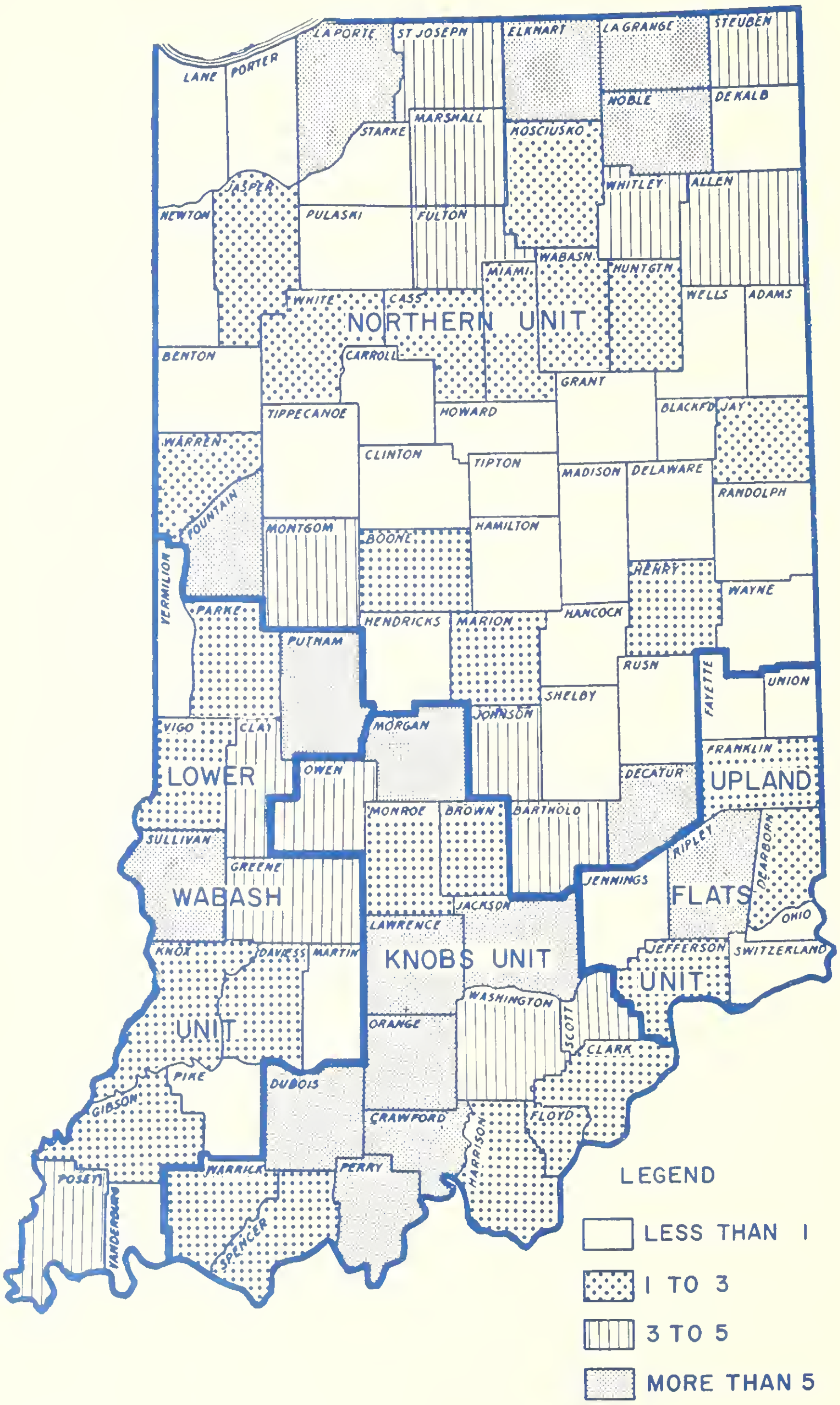

Figure 2. — Lumber production, in million board feet, in Indiana counties, 1966.

Table 1. — *Indiana saw log receipts by species and Survey Units, 1966*
(Million board feet, International ¼-inch Log Rule)

	State total	Lower Wabash Unit	Knobs Unit	Upland Flats Unit	Northern Unit
SOFTWOODS					
Cypress	.1	.1	-	-	-
White and red pine	*	-	*	*	*
Virginia pine	.2	-	.2	*	-
Other softwoods	.1	-	*	.1	-
All softwoods	.4	.1	.2	.1	*
HARDWOODS					
Ash	11.2	1.7	1.7	.6	7.2
Basswood	4.2	.2	.3	.1	3.6
Beech	10.1	.9	4.0	1.1	4.1
Cherry, black	2.3	.3	.6	.1	1.3
Cottonwood	12.1	3.6	2.4	.5	5.6
Elm	3.0	.5	.7	.1	1.7
Gum, black	1.3	.3	.8	.1	.1
Gum, sweet	3.0	.5	1.8	.5	.2
Hickory	7.2	1.6	2.6	.5	2.5
Maple, hard	22.9	1.5	5.4	.3	15.7
Maple, soft	15.7	3.1	3.4	.4	8.8
Oak, red	65.9	9.3	28.3	4.1	24.2
Oak, white	25.1	1.9	8.5	1.6	13.1
Sycamore	11.2	2.2	3.3	.8	4.9
Yellow-poplar	17.1	4.6	7.3	.8	4.4
Walnut	14.9	1.0	2.1	2.5	9.3
Other hardwoods	4.4	2.6	.5	.1	1.2
All hardwoods	231.6	35.8	73.7	14.2	107.9
All species	232.0	35.9	73.9	14.3	107.9

* Less than 50,000 board feet.

Sixty-one sawmills in the Lower Wabash and 49 in the Upland Flats Unit together procured 50 million board feet of saw logs in 1966. In addition to oak, the major species cut were yellow-poplar, cottonwood, and soft maple in the Lower Wabash Unit, and walnut and beech in the Upland Flats Unit.

Although 1,100 sawmills were operating in Indiana in 1949, the number of active mills dwindled to 480 by 1966. However, 86 of the mills active in 1966 each sawed more than 1 million board feet, while only 30 mills produced this amount in 1949.

The saw log receipt statistics in this report resulted from a canvass of Indiana sawmills conducted by the Forestry Division of the Indiana Department of Natural Resources. the Indiana Extension Foresters, and the North Central Forest Experiment Station. All known active sawmills in Indiana were included in the canvass, so the statistics are not subject to sampling error.

1968

JAMES E. BLYTH
Market Analyst

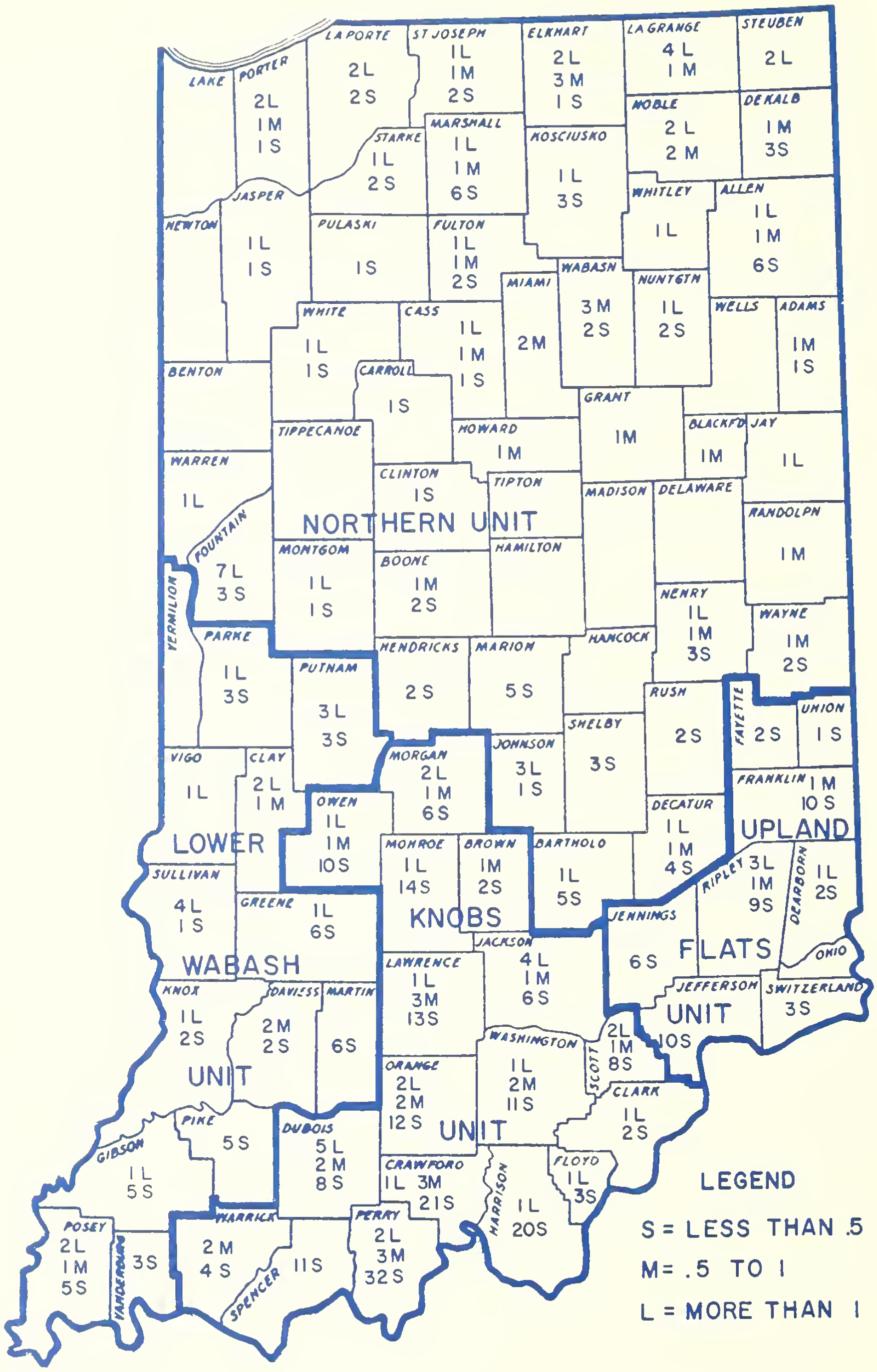

Figure 3.—Number of active sawmills in Indiana counties by production size-class (million board feet of lumber produced), 1966.

U. S. FOREST SERVICE

RESEARCH NOTE NC-69

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Hardwood Veneer Timber Volume In Upper Michigan

ABSTRACT. — Forests in Upper Michigan contain approximately 1.5 billion board feet of veneer logs of which three-fourths is hard maple and yellow birch. About 14 percent of the hardwood sawtimber is suitable for veneer logs.
OXFORD: 905.2(774):832.20:176.1. *Acer saccharum*: **176.1** *Betula alleghaniensis*

Veneer mill operators are vitally interested in the volume and species composition of the hardwood veneer timber resource. Some information is provided by forest surveys, including species and tree grade data for hardwood sawtimber. However, current forest survey procedures do not provide an estimate of either the portion of this sawtimber that is suitable for veneer logs or the relation between tree grade and veneer log volume. Reported here are the results of a study designed to provide this supplemental information on the hardwood sawtimber resource. Because its forests were recently (1966) surveyed[1] and provide an important source of veneer logs, Upper Michigan was selected for this initial study.

[1] *At the time of this writing the full State report had not yet been published.*

Procedure

Permanent forest survey sample plots in Upper Michigan having one or more hardwood sawtimber trees were selected for study. Hardwood sawtimber trees on 168 of these plots were examined and scaled for veneer logs. These veneer logs were classified as follows:

a. *Standard veneer logs.* Logs at least 8½ feet long and 12 inches d.i.b. (diameter inside bark, small end), and meeting external requirements for veneer logs as described in *A Guide to Hardwood Log Grading.*[2]

b. *Substandard veneer logs.* Logs and bolts not meeting both the diameter and length requirements for standard logs but with a minimum diameter of 9 inches (inside bark, small end) and a minimum length of 4 feet. The external requirements are identical to those for standard logs.

[2] *Ostrander, M. D., et al. A guide to hardwood log grading. U.S.D.A. Forest Serv. N.E. Forest Exp. Sta., p. 34. 1965.*

The standard veneer log specifications are those most commonly accepted by industry. However, many veneer mills are currently using bolts shorter than 8 feet. This, coupled with the recent development of equipment that permits the use of small-diameter logs, may result in greater use of previously unacceptable small logs. Consequently these "substandard" veneer logs also were tallied.

Only external characteristics of the trees were used to estimate internal defects. This procedure will not indicate some internal defects, notably mineral stain and black heart of maple. However, such defects are relatively unimportant in the predominantly second-growth stands.

The volume of hardwood veneer logs on the sample plots was compiled for each species and tree grade (log grade for the best 12 feet of the first 16-foot saw log). This volume was then expressed as a percentage of the hardwood saw-log volume by species and tree grade. Finally, these percentages were applied to the hardwood sawtimber volumes for the 1966 forest survey to obtain an estimate of the volume of standard and substandard veneer logs by species and tree grade.

Table 1. — Volume of standard and substandard veneer logs on commercial forest land in Upper Michigan by species, 1966 (In million board feet)[1]

Species	Standard veneer logs[2/]	Substandard veneer logs[2/]
Hard maple	838.4	278.4
Yellow birch	280.2	122.6
Elm	89.8	81.4
Aspen	75.0	88.7
Soft maple	68.7	102.9
Basswood	66.0	59.4
Beech	63.4	53.2
Paper birch	8.6	25.8
Other hardwoods[3/]	30.3	73.0
All species	1,520.4	885.4

1/ International 1/4-inch rule.
2/ For specifications, see text.
3/ Includes ash, oak, and cherry.

Standard Veneer Log Volumes

Hard maple is the major hardwood veneer log species in Upper Michigan with over half of the standard veneer log volume (table 1). Hard maple and yellow birch dominate the supply picture for hardwood veneer logs (fig. 1).

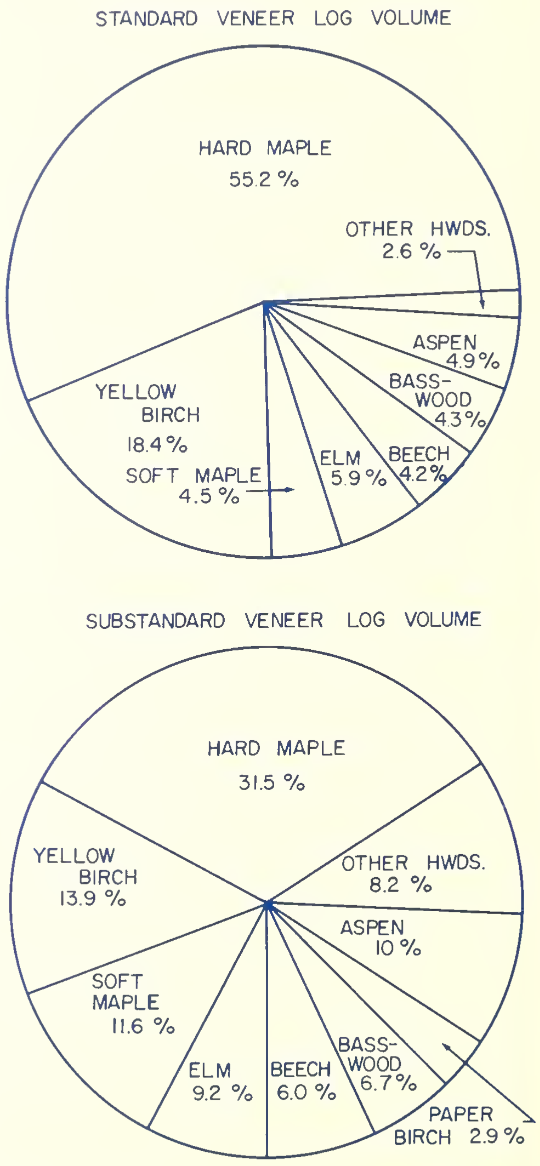

FIGURE 1. — Hard maple and yellow birch dominate veneer log volume in Upper Michigan.

As would be expected, practically all (83 percent) of the veneer log volume is found in grade 1 trees. Of the grade 1 trees examined, three out of every five contain at least one standard veneer log. But because they are generally smaller, only 13 percent of the grade 2 trees contain standard veneer logs. Hard maple is the only species having veneer logs in grade 3 trees.

About 14 percent of the hardwood sawtimber volume in Upper Michigan meets veneer log specifications (table 2). Hard maple, yellow-birch, and basswood are relatively high-quality trees with approximately 20 percent of their saw-log volume suitable for veneer logs.

Table 2. — Volume of standard and substandard veneer logs as a percent of sawlog volume on commercial forest land in Upper Michigan by species and tree grade, 1966

Species and log type 1/	As percent of volume in tree grade			As percent of total sawlog volume
	1	2	3	
Hard maple				
Standard	37.2	9.2	2.9	18.6
Substandard	3.9	9.3	5.5	6.2
Yellow birch				
Standard	39.0	4.4	*	20.1
Substandard	7.6	10.8	9.6	8.8
Elm				
Standard	42.5	5.6	*	16.8
Substandard	5.0	25.2	18.7	15.2
Aspen				
Standard	20.9	8.1	*	6.5
Substandard	1.6	11.6	6.2	7.6
Soft maple				
Standard	24.0	5.6	*	7.2
Substandard	7.8	13.4	10.1	10.7
Basswood				
Standard	41.7	*	*	20.6
Substandard	5.2	35.6	26.2	18.5
Beech				
Standard	18.5	1.8	*	7.9
Substandard	8.8	7.3	2.9	6.7
Paper birch				
Standard	13.8	*	*	2.5
Substandard	5.8	4.3	11.0	7.5
Other hardwoods 2/				
Standard	26.3	*	*	6.0
Substandard	3.0	21.0	14.9	14.4
All species				
Standard	34.1	6.4	1.1	14.4
Substandard	5.2	11.9	8.4	8.4

* Negligible.

1/ For log specifications, see text.

2/ Includes ash, oak, and cherry.

Substandard Veneer Log Volumes

Approximately 8 percent of the hardwood sawtimber in Upper Michigan meets the requirements for substandard veneer logs (table 2). Some of this volume is found in grade 1 trees, often in conjunction with a standard veneer log. Most of it, however, is found in grade 2 trees. These are often small-diameter but high-quality trees that will eventually contain standard veneer logs.

Hard maple and yellow birch also dominate the substandard veneer-logs picture in Upper Michigan (fig. 1). However, the lesser used species, notably soft maple, elm, and aspen, assume some prominence among the substandard veneer logs.

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1969

U. S. FOREST SERVICE

RESEARCH NOTE NC-70

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Development of White and Norway Spruce Trees from Several Seed Sources 29 Years After Planting

ABSTRACT. — A 29-year-old test of trees grown from seven white spruce and six Norway spruce seed sources and planted in Wisconsin and Minnesota demonstrates the importance of seed-source selection and indicates that trees from some Norway spruce sources equal or surpass the native white spruce.

OXFORD: 232.12(77):174.7 Picea abies + 174.7 Picea glauca

The spruces are important sources of pulpwood, but they have been planted much less widely than the pines in the Lake States. It was recognized early that there might be important intraspecies variation among spruces which could strongly affect planting success. Accordingly, in 1936 the Lake States (now North Central) Forest Experiment Station established a limited seed source study of white spruce (*Picea glauca* (Moench) Voss) and Norway spruce (*Picea abies* (L.) Karst.).

About The Study

Between 1928 and 1931, seeds were obtained representing seven sources each of white spruce and Norway spruce (only six sources of Norway spruce are discussed in this report, however) (table 1). The seeds were sown in the spring of 1932 in the Hugo Sauer Nursery of the U.S.D.A., Forest Service, near Rhinelander, Wisconsin. In the spring of 1936, the stock was lifted as 2-2 transplants and outplanted at five localities in Michigan, Minnesota, and Wisconsin. The trees were planted in 10-tree plots replicated 10 times at random except on the Nicolet National Forest in northeastern Wisconsin where all the available stock was set out in 100-tree plots with various numbers of replications.

Unfortunately, 1936 brought the most severe drought and summer temperatures on record in the Lake States. Mortality on most of the plantings was so great that no meaningful data could be obtained from them. The Nicolet planting, however, had been established under a partial overstory of aspen (*Populus tremuloides* L.) and suffered relatively low mortality. On the Superior National Forest, even though drought and heat were severe, enough trees remained to warrant further observations. Only these two plantations are considered here.

After some early damage by snowshoe hares, the Nicolet plantation was enclosed by a rabbit-proof fence in 1940. The planted spruces were given a series of releases ending in 1953 with the girdling of all remaining overstory trees. The Superior plantation was given no special aftercare. In September 1964, height, diameter, and survival were measured on 18 trees on each plot in the Nicolet plantation.

Measurements made on the Superior National Forest planting in northeastern Minnesota 19 years after planting are analyzed here for the first time.

Table 1. — Origin of spruce seed collections

Seed source number	Place of origin	Collection date	Kind of collection[1/]
WHITE SPRUCE			
32-33	19 miles west of Port Arthur, Ontario	1928	2
39	Victor Hill Road, Superior National Forest, Minn.	1928	1
255	Chippewa National Forest, Minn.	1928	4
256	Near Angus, Ontario	1929	4
257	Near Douglas, Ontario	1929	4
270	Black Hills, South Dakota (through seed dealer at Custer, S.D.)	1931	3
273	Near Florence, Wis.	1930	4
NORWAY SPRUCE			
131	Northern Europe, purchased from dealer	1929?	4?
132[2/]	Siberia?, purchased from dealer	1929?	4?
134	Mozyr District, White Russia, USSR	1929?	3
135	Bryansk Forest Experiment Station, USSR	1929?	3
137	Gomel District, White Russia, USSR	1929?	3
138	Forest Research Station, University of Belgrade, Yugoslavia	1929	3?

1/ 1 = individual tree; 2 = small group; 3 = limited locality; 4 = general and mixed.

2/ Previous reports had listed this as Siberian spruce (*Picea obovata*). It now appears to be a collection of *P. abies* of uncertain origin.

Results

NORTHEASTERN WISCONSIN

Survival 29 years after planting ranged from 44 to 71 percent for white spruce and from 53 to 70 percent for Norway spruce (tables 2 and 3). Enough trees from all seed sources of both species remain to produce adequately stocked stands.

Both tree height and diameter varied significantly by seed souces. Trees from Douglas, Ontario, source grew best of all the white spruce, and trees from the Custer, South Dakota, source grew poorest. The rankings of the white spruce seed sources were the same whether all trees measured were considered or only the tallest one-third of the trees (table 2).

For Norway spruce, trees from Mozyr, White Russia, grew best and those from Belgrade, Yugoslavia, the poorest.

When both species are compared we find that the best six seed sources include three of Norway spruce and three of white spruce.

Table 2. — Survival, mean height and d.b.h. of white spruce trees from various seed sources 29 years after planting or 33 years from seed on the Nicolet National Forest, Wisconsin

WHITE SPRUCE						
Survival			Height		D.b.h.	
Seed source number	Plots measured	Survival	18 trees/ plot	6 tallest trees/plot	18 trees/ plot	6 tallest trees/plot
		Percent	Feet	Feet	Inches	Inches
257	6	57 b[1]	28.1 a	34.1 a	4.6 a	5.9 a
255	4	58 b	24.3 ab	30.4 ab	4.1 ab	5.3 ab
32-33	6	71 a	24.2 ab	29.4 ab	4.0 ab	4.8 b
273 [2]	1	62 ab	24.1 ab	28.3 b	4.5 a	5.3 ab
256	2	44	23.1 b	28.0 b	4.1 ab	5.2 ab
039	2	64 ab	21.6 b	26.3 b	3.7 b	4.6 b
270	6	61 b	16.2	21.2	2.7	3.7
Seed source F-value		13.49	19.12	17.69	25.49	18.76
$S_{\bar{x}}$		2.24	1.08	1.22	1.15	.20

1/ Numbers followed by the same letter suffix (a or b) do not differ significantly at the 5-percent level (Tukey's test).

2/ Only one replication of this source--not included in analyses of variance.

Table 3. — Survival, mean height and d.b.h. of Norway spruce trees from various seed sources 29 years after planting or 33 years from seed on the Nicolet National Forest, Wisconsin

NORWAY SPRUCE				
Seed source number	Plots measured	Survival	Height	D.b.h.
		Percent	Feet	Inches
134	4	53	28.8 a[1]	4.4
135	6	69	28.1 a	4.1 a
137	6	63	27.8 a	4.0 a
132	5	64	23.1 b	3.9 a
131	6	70	21.4 b	3.6 b
138	7	60	19.0 b	3.6 b
Seed source F-value		NS	17.37	7.17
$S_{\bar{x}}$		--	.97	.03

1/ Numbers followed by the same letter suffix (a or b) do not differ significantly at the 5-percent level (Tukey's test).

NORTHEASTERN MINNESOTA

White spruce survival ranged from 23 to 44 percent (table 4) and was much lower than for trees from the same sources planted in northeastern Wisconsin. Most mortality occurred in the first year following planting. Stocking for most sources is less than desirable.

Trees from the Chippewa National Forest seed source made the best height growth but not signficantly more than the sources from Douglas, Ontario, and the Superior National Forest. The Custer, South Dakota, source was poorest in both mean height and diameter.

The Norway spruce survival was somewhat better than that of white spruce and ranged from 33 to 50 percent. Stocking was adequate for most seed sources.

Table 4. — Survival, mean height and d.b.h. of white spruce and Norway spruce seed sources 19 years after planting on the Superior National Forest, Minnesota

Seed source number	Survival	Height	D.b.h.
WHITE SPRUCE			
	Percent	Feet	Inches
255	41	14.7 a[1/]	2.2 a
257	45	14.5 a	2.2 a
039	27	14.4 a	2.2 a
256	26	12.9 b	1.8 ab
32-33	18	12.6 b	1.9 ab
270	27	10.4 b	1.4 b
Seed source F-value	NS	7.05	6.30
$S_{\bar{x}}$	--	.61	.13
NORWAY SPRUCE			
134	33	16.1 a	2.47 a
135	50	15.1 a	2.27 ab
137	50	14.7 ab	2.16 ab
132	45	12.3 bc	1.74 bc
138	42	11.7 c	1.73 bc
131	41	10.4 c	1.32 c
Seed source F-value	NS	16.46	10.96
$S_{\bar{x}}$	--	.54	.12

1/ Numbers followed by the same letter suffix (a, b, or c) do not differ significantly at the 5-percent level (Tukey's test).

There were significant differences in growth among the Norway spruce sources. Trees from Mozyr, White Russia, seed grew fastest in both height and diameter.

As was the case in Wisconsin the six fastest growing seed sources include three of white spruce and three of Norway spruce.

Conclusions and Recommendations

These rather limited studies of white spruce and Norway spruce indicate significant variations in height and diameter development due to seed source. The results with white spruce also indicate the necessity of considering plantation location when making seed-source recommendations.

For northeastern Wisconsin it appears that white spruce of some Ontario and Minnesota sources will equal or surpass stock from local sources. The faster growth of Ontario white spruce has also been indicated in more recent studies.[1]

In northeastern Minnesota, trees from local and other Minnesota sources of white spruce seem to be the best choices for planting based on development after 19 years in the field. Trees from the best Ontario sources, however, are not significantly poorer.

In both Wisconsin and Minnesota, it is also evident that Norway spruces of some White Russian origins will do as well or better than the best white spruce.

The results reported here give clues to the choice of spruce species and seed sources for planting in the northern Lake States. Recommendations must be qualified because of the limited number of seed sources and planting localities represented. Results should be brought into much sharper focus by the more comprehensive seed-source studies now underway.

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1969

[1] *Nienstaedt, Hans. 1968. White Spruce* (Picea glauca *(Moench) Voss) seed source variation and adaptation to 14 planting sites in northeastern United States and Canada. 16th N.E. Forest Tree Impr. Comm. Proc. (In press).*

U. S. FOREST SERVICE

RESEARCH NOTE NC-71

RTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Do Pine Gall Weevils Affect Cone Production in Red Pine?

ABSTRACT. — Red pine branchlets with and without weevil galls did not differ significantly in production of conelets.

OXFORD: 416.13—145.719.91 *Podapion gallicola*: **181.522:174.7** *Pinus resinosa*

The pine gall weevil (*Podapion gallicola* Riley) causes galls to develop on the branches of several species of pine. In north-central United States, red pine (*Pinus resinosa* Aiton) is its most common host. Female beetles lay eggs in a cavity in the bark of young branchlets in early summer, and 12 to 15 months later a gall of hypertrophied xylem tissue begins to form. The galls continue to enlarge even after the beetles have emerged as adults about 3 years after oviposition.[1] Conceivably, either the galls or the insects could upset the biochemical processes of a branchlet during the period of flower bud initiation and hence influence the number of pistillate flowers that form in the buds. The study reported here was designed to find out.

[1] *Wilson, L. F. Life history and some habits of the pine gall weevil,* Podapion gallicola *Riley, in Michigan. Can. Entomol. 97: 962-969. 1965.*

Methods

In brief, the procedure was to (1) measure branchlets and classify them according to the numbers and kinds of weevil galls present, (2) count conelets borne on the branchlets, and (3) compare numbers of conelets on branchlets with and without galls.

Galls with weevil larvae in them were classified as active galls, and those lacking larvae were classified as abandoned galls. The number of galls with and without insects was considered important in the experiment because insects might excrete substances that influence flower initiation. Galls were classified at time of sampling even though some abandoned galls may have been active when flower primordia were formed 12 to 13 months before. So the classification may have a slight bias.

The study was done in September 1968 in a 65- to 70-year-old red pine stand in Bayfield County, Wisconsin. Twenty trees with well developed midcrowns were randomly selected, and in each tree two midcrown branches were randomly selected from the west quadrant. All branchlets except those on the basal one-fourth of each branch were used. Basal branchlets were disregarded to reduce variability in branchlet lengths and conelet numbers.

Results and Discussion

Thirty percent of all branchlets and 50 percent of all conelet-bearing branchlets were galled. Seventy percent of the galled branchlets were longer than 20 inches; only 16 percent of the ungalled branchlets were this long. Moreover, as would be expected, conelet production increased with branchlet length (fig. 1), so only galled and ungalled branchlets of similar size were compared.

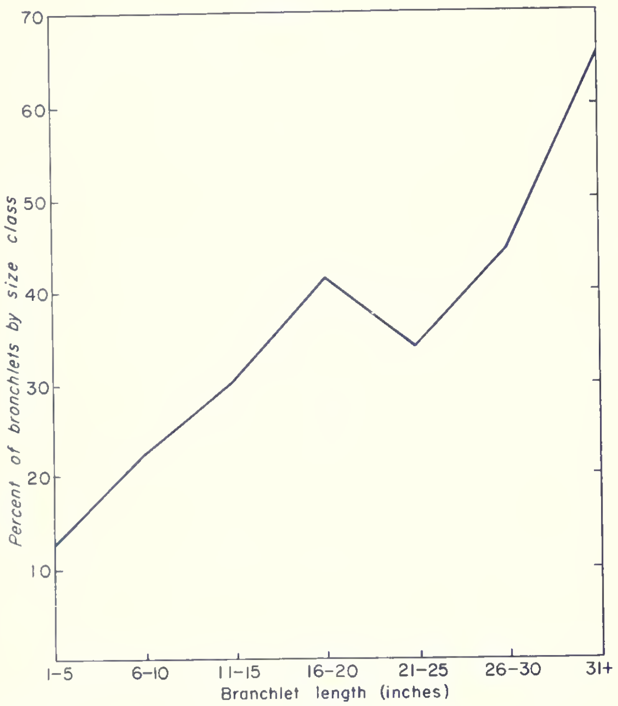

FIGURE 1. — Percent of branchlets bearing two or more conelets by branchlet sizes.

Data from the 20 trees were first analyzed to find out if there were differences in average conelet production between galled and ungalled branchlets, and between branches within trees and among trees. Differences, if any, were minor, so data from all branche and trees were pooled. This permitted a more detailed, specific test for differences in cone let production with different numbers of ac tive and abandoned galls (table 1). There

Table 1. — Number of conelets on branchlet with different numbers of active an abandoned galls

Number of galls		Sum of conelets on 8 branchlets
Active	Abandoned	
0	0	19
0	1	9
0	2	26
1	0	10
1	1	18
1	2	16
2	0	22
2	1	17
2	2	13

were no significant differences in conele production on branchlets having either active or abandoned galls. Similar studies in a 70 year-old red pine stand in Cass County, Min nesota, gave identical results.

The findings indicate that, on red pine weevil galls have little or no influence on a branchlet's capacity to produce cones. These findings will probably also apply to other species of pine that are similarly infested with pine gall weevils. So unless galls interfere with branchlet strength or longevity, man agers of pine seed orchards and seed-produc tion areas need not be concerned about gal weevil infestations.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-72

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Fifteen-Year Growth of a Thinned White Spruce Plantation

ABSTRACT. — Mean annual increment at age 38 in a thinned white spruce plantation was 102 cubic feet or 0.85 cords per acre per year. Periodic annual increment during the 15 years after thinning seemed to be maximum for residual basal areas between 100 and 120 square feet per acre.
OXFORD: 562.2:174.7 *Picea glauca*: **(775):242**

White spruce does not occur naturally in pure stands, and most of the existing spruce plantations are still too young to provide useful yield estimates. However, growth following experimental thinning in a 23-year-old plantation on the Menominee Indian Reservation in northeastern Wisconsin gives some idea of their potential productivity. This is one of the oldest spruce plantations in the Lake States. The thinning study artificially created a range of stocking levels, and growth records were kept from 1949 to 1964.

The plantation was established in 1926 on a sandy loam soil which had previously been farmed. Initial spacing was extremely close, about 2 x 4 feet (5,400 trees per acre). The original intention of the planters was to thin the stand repeatedly for Christmas trees, but only a few trees were actually removed for this purpose. Survival was surprisingly good and in 1949 stocking still averaged more than 4,000 live trees per acre.

Method

The thinning treatments were installed during the 1948-49 dormant season in a 6 x 2 chain portion of the plantation which was subdivided into two blocks. Each block contained six 1/10-acre square plots. Treatments were assigned randomly within each block. In each block one plot was left unthinned and the other plots were thinned from below to one of five assigned densities, i.e. 750, 1,000, 1,250, 1,500, or 1,750 trees per acre. D.b.h. was measured on all trees to the nearest 1/10-inch, and total height was measured to the nearest foot on a large sample of the trees. The stand was measured in 1949, 1956, and 1964, but only the total 15-year growth will be discussed here.

No isolation strips were provided between the plots. This, together with limited replication and site variation within the study area makes a formalized statistical treatment of the data inappropriate. Summaries of the observations indicate the effect of thinning on growth, but the reader is not advised to generalize too broadly from these indications.

Results

Stand and growth data (tables 1 and 2) can be summarized briefly as follows:

1. During the 15-year period (23 to 38 years after planting) mortality was high in the unthinned stands. They were severely overcrowded at 23 years, and nearly half of the trees had died from suppression by the 38th year. Mortality in the thinned stands was much lighter, but there was no obvious or consistent relationship between mortality and thinning intensity.

2. Net basal area growth during the 15-year period averaged 8.3 square feet per acre per year on the thinned plots, but there was no clear relationship between growth and number of trees per acre. Net annual basal area growth on the unthinned plots averaged only 6.0 square feet per acre, indicating that there was not enough expression of dominance to offset the effects of overcrowding.

3. Diameter growth on thinned plots was inversely proportional to the number of trees per acre. By 1964, average d.b.h. ranged from 7.2 inches on one of the heavily thinned plots to 4.7 inches on one of the unthinned plots.

4. Height growth was apparently unaffected by thinning intensity. Much of the variation that was observed is probably due to site changes within the study area.

5. Net cubic foot volume growth averaged 180 cubic feet per acre per year from 1949 to 1964; mean annual increment averaged 102 cubic feet per acre.

6. Periodic annual increment for the 15-year period averaged 1.94 cords per acre. Mean annual increment was 0.85 cords per acre.

7. Volume growth appeared unaffected by the number of trees per acre, but there was some indication that volume growth was related to basal area after thinning (Figs. 1, 2). Actual observations were plotted, and curves were fitted by the least squares method. Much of the variation around the curves can be accounted for by the site variation on the study area. However, because of the small sample, no attempt was made to remove the effect of site. It appears that volume growth increased with higher residual basal area up to about 100 or 120 square feet and then dropped off. Much more information will be needed, of course, before the exact shape and level of these curves can be defined.

Table 1. — Stand conditions in 1949 and 1964; and 15-year growth in d.b.h., basal area, and height

Plot No.	Number of trees per acre: After thinning in 1949	Number of trees per acre: Still alive in 1964	Mortality (In percent)	Total basal area per acre (In sq. ft.): After thinning in 1949	Total basal area: Live trees in 1964	Total basal area: 15-yr. net growth	Average d.b.h. (In inches): After thinning in 1949	Average d.b.h.: 1964	Average d.b.h.: Net change	Average height (all trees) (In feet): After thinning in 1949	Average height: 1964	Average height: 15-yr. growth
THINNED												
1	740	690	6.8	67.9	192.9	125.0	4.1	7.2	3.1	24.9	50.1	25.2
2	760	660	13.2	54.7	161.6	106.9	3.6	6.7	3.1	23.2	46.6	23.4
3	910	850	6.6	44.8	165.6	120.8	3.0	6.0	3.0	19.0	40.4	21.4
4	1,000	970	3.0	41.4	157.5	116.1	2.8	5.5	2.7	18.9	43.2	24.3
5	1,230	1,140	7.3	51.8	173.8	122.0	2.8	5.3	2.5	18.8	42.5	23.7
6	1,250	1,210	3.2	60.0	195.4	135.4	3.0	5.4	2.4	18.5	45.3	26.8
7	1,500	1,400	6.7	75.4	194.3	118.9	3.0	5.0	2.0	20.2	42.0	21.8
8	1,500	1,390	7.3	101.6	235.4	133.8	3.5	5.6	2.1	22.5	46.2	23.7
9	1,740	1,500	13.8	103.2	229.7	126.5	3.3	5.3	2.0	21.1	44.5	23.4
10	1,760	1,640	6.8	95.8	236.0	140.2	3.2	5.1	1.9	21.4	44.0	22.6
UNTHINNED												
11	3,770	2,010	46.7	141.2	240.2	99.0	2.6	4.7	2.1	19.8	40.1	20.3
12	3,890	1,880	51.7	154.7	236.6	81.9	2.7	4.8	2.1	18.7	40.5	21.8

Table 2. — Standing volume in 1949 and 1964, and volume growth in cubic feet and cords[1]

Plot No.	Number trees per acre after thinning in 1949	Volume in cubic feet: After thinning in 1949	Volume in cubic feet: Standing in 1964	Volume in cubic feet: Net periodic annual growth 1949-1964	Volume in cubic feet: Net mean annual growth (for 38 years) 1/	Volume in cords: After thinning in 1949	Volume in cords: Standing in 1964	Volume in cords: Net periodic annual growth 1949-1964	Volume in cords: Net mean annual growth (for 38 years) 2/
1	740	1,009	4,106	206	110	6.8	40.5	2.25	1.06
2	760	696	3,359	177	99	3.2	32.4	1.95	.85
3	910	532	3,189	177	99	1.1	29.2	1.87	.77
4	1,000	457	2,805	157	91	0.7	24.5	1.59	.65
5	1,230	576	3,049	165	94	0.8	26.1	1.69	.69
6	1,250	722	3,597	192	104	2.2	31.6	1.96	.83
7	1,500	869	3,354	166	94	1.8	28.1	1.75	.74
8	1,500	1,330	4,481	210	112	6.2	40.2	2.27	1.06
9	1,740	1,333	4,082	183	101	5.4	35.3	1.99	.93
10	1,760	1,156	4,140	199	107	3.6	35.0	2.09	.92
11	3,770	1,558	4,062	167	107	3.1	32.3	1.95	.85
12	3,890	1,721	4,121	160	108	4.5	33.5	1.93	.88
Average	--	--	--	180	102	--	--	1.94	0.85

1/ Cubic foot volume is total volume for the entire stem of all trees, and cordwood volume is in rough cords to a variable top diameter inside bark of not less than 3.0 inches for all trees 3.6 inches or larger at breast height based on volume tables 3 and 5 respectively, Gevorkiantz, S. R. and L. P. Olsen. Composite volume tables for timber and their application in the Lake States. U.S.D.A. Tech. Bull. 1104, 51 p.

2/ Mean annual growth = $\frac{\text{Standing volume in 1964 + Volume removed in 1949}}{38}$

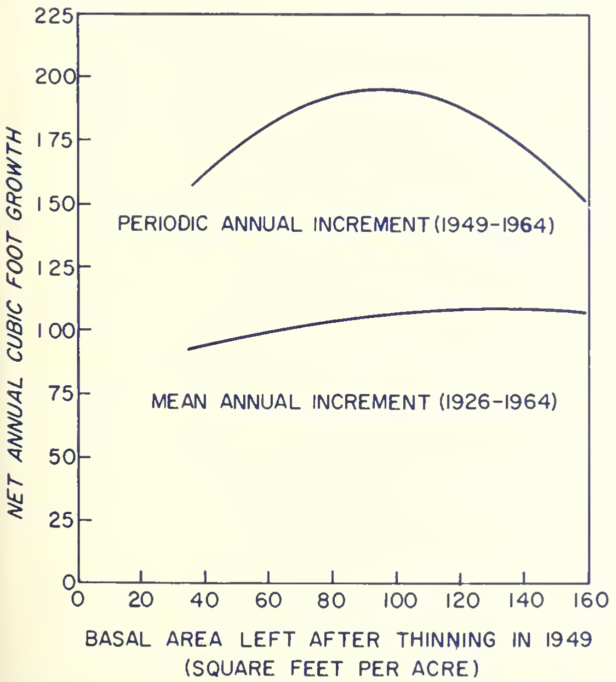

FIGURE 1. — Mean annual increment and periodic annual increment in cubic feet per acre, in relation to basal area stocking in 1949.

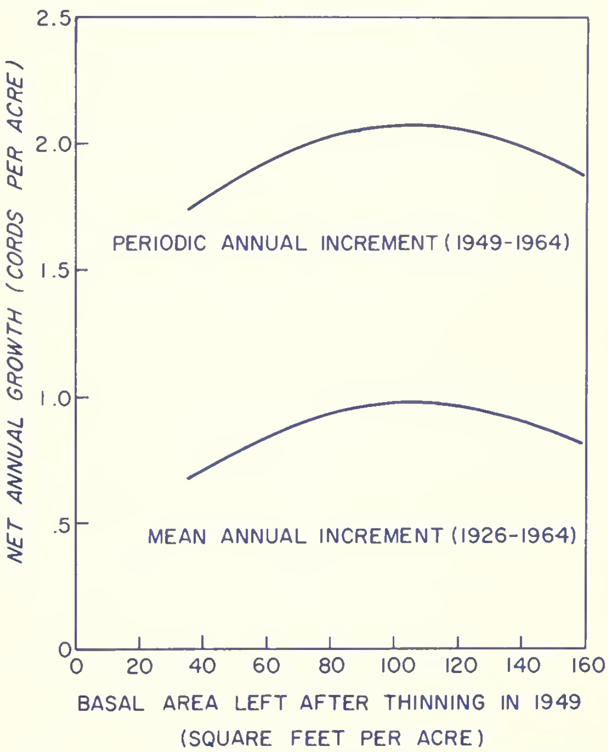

FIGURE 2. — Mean annual increment and periodic annual increment in cords per acre, in relation to basal area stocking in 1949.

Conclusions

White spruce is considered a slow grower when young, but the growth figures reported here indicate that this species is a better producer than was previously thought. Even though this plantation grew at high density for 23 years, the heavily thinned plots responded well and by 1964 (38 years after planting) many of the trees exceeded 8 inches in diameter and 50 feet in height. Merchantable volume per acre averaged about 36 cords. If volume production is our criterion, white spruce might be a good choice for reforestation on certain sites.

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1969

U. S. FOREST SERVICE

RESEARCH NOTE NC-73

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Scleroderris Canker in the Lake States — A Situation Report, 1968

ABSTRACT. — The history of Scleroderris canker in the Lake States Region is reviewed. U.S.D.A. Forest Service studies on the distribution, degree of infection, rate of spread, and general biology of the disease organism are described.

On National Forest land in Upper Michigan and northern Wisconsin, where the disease is most serious, 66 percent of the red pine plantations and 88 percent of the jack pine plantations are infected with *Scleroderris lagerbergii.* **In infected stands Scleroderris canker is the main identified cause of tree mortality.**

The life cycle of *S. lagerbergii* **is described as well as proposed control methods and future studies planned.**

OXFORD: 443.2:443.3—172.8 *Scleroderris lagerbergii* **(77)**

In 1951 several red pine (*Pinus resinosa* Ait.) plantations in Upper Michigan began to exhibit poor growth and tree mortality from an unknown cause. By 1960 the problem had expanded to approximately 5,000 acres of red pine and jack pine (*Pinus banksiana* Lamb.) plantations in both Upper Michigan and northern Wisconsin. The fungus responsible for damaging these plantations was identified in 1964 as *Scleroderris lagerbergii* Gremmen, which causes the disease Scleroderris canker. This was the first report of this disease in the United States (Ohman 1966).

Although recognized only recently in the United States, *S. lagerbergii* has a long history of damage to several species of pine and spruce in European forest nurseries and plantations (Bjorkman 1963, Read 1963, and Roll-Hansen 1964). On several occasions the disease has reached epidemic levels in Scotch pine nurseries in Sweden (Kohh 1964).

Since 1964, personnel of the North Central Forest Experiment Station, the Northeastern Area of State and Private Forestry, and Region 9 of the National Forest System have been studying the distribution, degree of infection, rate of spread, and general biology of the causal organism. This paper is a brief summary of that work.

In the Lake States Region, Scleroderris canker damages red, jack and Scotch pine (*Pinus sylvestris* L.) stands. Although the disease is primarily one of planted trees, both natural and planted stands are infected. The problem is most serious in red and jack pine plantations because large acreages have been planted to these species. Black spruce (*Picea mariana*), white spruce (*P. glauca*), red spruce (*P. rubens*), and white pine (*Pinus strobus*) have been found infected with Scleroderris canker in Quebec, but so far no infections in these species have been reported in the Lake States (Smerlis 1968).

In this region Scleroderris canker has been found only in northern Wisconsin and Michigan. In Wisconsin most of the infected plantations have been on the Nicolet and Chequamegon National Forests; only a few infected plantations have been found on either State or private land. In Michigan the infected plantations are primarily in the Upper Peninsula, although there are a few infected plantations in the Lower Peninsula. The heaviest infection areas are on the Ottawa and Hiawatha National Forests, but many State and private plantations are also severely infected.

Based on the evidence now available, it is likely that National Forest plantations were first infected with seedlings received from a nursery in northern Michigan. However, the source of the original infection is not known. Several nurseries and plantations in nearby Ontario are infected with Scleroderris canker, but it is unlikely that their role in the introduction of this disease to the United States can be assessed now.

A 1965 survey of 2- to 10-year-old plantations on National Forest land in Upper Michigan and northern Wisconsin showed 66 percent of the red pine plantations and 86 percent of the jack pine plantations infected with Scleroderris canker (Skilling and Cordell 1966). Severity of infection varied from only a few infected trees to complete kill of trees over large areas from this disease. The disease was most severe on cold and open sites.

To determine the rate of spread of Scleroderris canker within infected plantations on National Forest land, plots in 31 infected red pine plantations have been examined annually since 1966. These plantations were 4 to 10 years old, with 1 to 45 percent of the plot trees infected at the beginning of the study.

Scleroderris canker has increased from 12 to 17 percent in the infected stands during the first 2 years of the study (table 1). How the rate of infection will increase in the future will not be known for some time. Observations of field infection indicate that Scleroderris infection is much greater during "wave years" when environmental conditions are optimum for spore dispersal. The spread study should provide information on this aspect of epidemiology. From 1966 to 1968 Scleroderris canker has been the main identified cause of tree mortality on the 31 plantations sampled.

Table 1. — Increase in Scleroderris canker on infected red pine plantations on National Forests in the Lake States, 1966-68

National Forest	Plantations	Infected trees		
		1966	1967	1968
	Number	Percent	Percent	Percent
Ottawa	8	11	13	14
Hiawatha	8	16	20	22
Nicolet	7	6	7	8
Chequamegon	8	14	22	23
Average	31	12	16	17

The life cycle of *S. lagerbergii* is now fairly well known. Primary infection is by windblown ascospores. These spores are released from fruiting bodies called apothecia during periods of moist weather. Although the spores are disseminated from April to October, most are released during June and July. The ascospores probably germinate on either buds or needles; the fungus later grows through the bud or needle into the branches. Infected branch tips are usually dead by the following summer. These dead branch tips are one of the early signs of Scleroderris infection. The fungus grows down the branch until it reaches the main stem of the tree. On young trees the main stem is girdled quickly, killing the tree within a few months. On larger trees the branch infections may be arrested before reaching the main stem, possibly due to competition from other saprophytic fungi, or the infected branches may be broken off by snow. Stem infections on large trees result in a canker. This canker may eventually be overgrown but frequently will deform the stem. A few months after a branch dies, fruiting bodies called pycnidia appear near the base of the dead needle fasicles. Asexual spores called conidia ooze out of these pycnidia during wet weather. Although not windborne, they can be transported by rain splash to other areas on the same tree, resulting in new infections. These multiple infections lower the vigor of the trees and eventually kill them. Apothecial fruiting bodies appear in early summer on branches that have been dead for 1 to 2 years. The apothecia are also usually found at the base of dead needle fasicles and are often closely associated with the pycnidial stage. The ascospores mature from late April to June and are discharged following rainfall.

The tree mortality now occuring in our red pine plantations is probably the result of a small number of infected trees present in the nursery stock when the plantations were established. These trees have produced the inoculum for subsequent infection of the remaining stand. A controlled burn study was established in 1966 to determine whether Scleroderris canker could be eradicated from an infected plantation. The area was broadcast burned before replanting with healthy stock. Unfortunately, the results were inconclusive, primarily because infection was too sparse in the original plantation. Tests are now underway to determine whether manual removal of infected trees from plantations will reduce the rate of spread.

Several nurseries located in areas where Scleroderris canker is present are now testing the fungicide maneb to prevent nursery infection. Other fungicides are also being field tested as alternatives to maneb for protecting nursery stock. Some of these chemicals are highly toxic to *S. lagerbergii* and may be valuable for future use.

In addition to sanitation studies and tests of nursery fungicides, research is in progress to determine how the spores of the fungus enter the host tree and what environmental factors are related to infection. The Forest Pest Control Division of State and Private Forestry will continue to evaluate the spread of Scleroderris canker in infected areas to determine the effect of this disease on red pine plantations. Also, plans are to determine whether the inoculum sources that have accumulated in past years in infected areas present a threat to new plantations when the trees are no longer protected by nursery spraying. And finally, an effort will be made to more precisely evaluate the impact of Scleroderris canker on the National Forest planting program by determining how many plantations have failed due to the disease.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-74

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

New Farm Fencing Declines — Use of Treated Posts Up

ABSTRACT. — Describes the amount and type of farm fencing installed on commercial farms in the Central and Appalachian States during the years 1963-1966.

OXFORD: 831.51:764(74/77)

The changing pattern of farming, advances in the chemical treatment of wood, and a general decrease in the local availability of naturally durable tree species have affected the farm market for wooden posts. The increasing use of purchased rather than home-grown posts and a corresponding increase in the use of commercially treated posts was reported in a 1956 study by Gill, Hundley, and Clarke.[1] The same study indicated that the operators of large farms purchased a greater percentage of their posts than did persons with smaller farms. Thus, by 1956, it was evident that increases in farm size and the shortage of naturally durable tree species were helping the fence post market.

Reported here are more recent statistics on the types and amounts of fencing constructed on commercial farms[2] in two regions and what these statistics may imply in terms of the future demand for wooden posts used on farms.

The Study

Statistics on fences were collected as part of a survey of farm structures done in cooperation with Doane Agricultural Service, Inc. Two groups of States were surveyed: the Central Region, including Illinois, Indiana, Iowa, and Missouri, and the Appalachian Region, including Alabama, Delaware, Georgia, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia.

More than 1,300 operators of commercial farms in the 17 States were contacted by mail during the summer of 1966. The operators were members of the Doane Farm Panel, a group selected by stratified sampling techniques to represent commercial farms. Panel members were asked to indicate the amount of each of ten basic fence types constructed on their farms during the period January 1963 to July 1966.

Amount and Type of Fence Constructed on Commercial Farms

Commercial farm operators erected an average of 710 lineal feet of fence per year during the 3½-year study period. Assuming a 15-foot spacing between posts, each farm used about 47 fence posts per year. This amounted to about 0.18 posts per acre of commercial farmland each year over the entire study area. Farms in the Central Region used an average of 0.21 posts per acre, per year, as compared to 0.15 for the Appalachian Region (table 1).

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[1] *Gill, T. G., Hundley, N. G., and Clarke, J. T., Market survey of treated wood products used in a nine-State area. Washington, D.C.: Timber Eng. Co., p. 12. 1956.*

[2] *Commercial farms are defined for this study as farms having total farm product sales of $2,500.00 or more in 1964.*

Table 1.—*Estimated amount of fence used on commercial farms by State and region, 1963-1966*

State	Total fence erected per year: Length	Total fence erected per year: Posts	Fence erected per farm per year[1/]: Length	Fence erected per farm per year[1/]: Posts	Posts per acre per year
	Thousand feet	Number (Thousands)	Feet	Number	Number
CENTRAL REGION					
Illinois	124,333	8,289	1,230	82.0	0.29
Indiana	51,804	3,454	780	52.0	.22
Iowa	72,174	4,812	560	37.3	.15
Missouri	79,930	5,329	1,090	72.7	.20
Total	328,241	21,884			
Average			890	59.3	0.21
APPALACHIAN REGION					
North Carolina	34,270	2,285	430	28.7	0.20
Ohio	25,720	1,715	390	26.0	.12
All other States in region[2/]	190,360	12,691	620	41.3	.16
Total	250,350	16,691			
Average			560	37.3	0.15

1/Based on average 15-foot spacing between posts.
2/All other States were weighted as a group since the sample size in individual States was insufficient for separate weighting.

Barbed wire fence with wood posts was the most frequently erected of the ten types, accounting for about 38 percent of all fencing reported. Woven wire fence with wooden posts (28 percent) and barbed wire fence with a combination of wood and metal posts (15 percent) ranked second and third in popularity. These three most popular types accounted for more than 80 percent of all farm fencing.

Estimated Numbers of Wood and Metal Posts

The numbers and percentages of wood and metal posts were estimated on the basis of type of fence. In 6 of the 10 fencing types, it was clearly specified whether posts were made of wood or of metal. In the other four, however, there was some doubt as to the numbers of posts made of wood and metal. These included the fences that utilized a combination of wood and metal posts, and the "unspecified" category.

Within the 17-State area about 66 percent of all farm fencing had wooden posts, 14 percent had metal, and 19 percent were in the "combination wood and metal" and "unspecified" categories (table 2). Assuming that fences in the last two categories included wood and metal posts in equal numbers, the ratio of wood to metal was about 3 to 1 (table 3). About 88 percent of all posts used in the Appalachian Region were wood, compared to only 67 percent for the Central Region.

Summary and Discussion

All told, about 38.5 million posts were used annually on commercial farms in the 17-state study area. This figure includes reused posts as well as new ones if they were used in new farm fences. Farms in the Central Region used more posts per farm and per acre of commercial farmland than did those in the

Table 2. — *Estimated total length of fence constructed by type of posts used, 1963-1966*

Type of post	Central Region		Appalachian Region		Total	
	Amount of fence		Amount of fence		Amount of fence	
	Thousand feet	Percent	Thousand feet	Percent	Thousand feet	Percent
Wood	590,711	51	750,412	86	1,341,124	67
Metal	209,067	18	81,453	9	290,521	14
Wood and metal	329,399	29	18,946	2	348,345	17
Unspecified	19,663	2	25,414	3	45,077	2
Total	1,148,840	100	876,225	100	2,025,067	100

Table 3. — *Estimated number of wood and metal posts used per year in two farming regions, 1963-1966*

Type of post	Central Region		Appalachian Region		Total	
	Posts1/		Posts1/		Posts1/	
	Thousands	Percent	Thousands	Percent	Thousands	Percent
Wood	14,576	67	14,717	88	29,292	76
Metal	7,307	33	1,973	12	9,281	24
Total	21,883	100	16,690	100	38,573	100

1/Based on 15-foot spacing.

Appalachian Region, although the difference between regions was much smaller on a per-acre basis. The type fence built varied with types of farming between States and regions.

Wood posts outnumbered metal by about 2 to 1 in the Central Region and by more than 7 to 1 in the Appalachian Region.

Comparing these newer statistics with those obtained by Gill, Hundley, and Clarke in their 1956 study[1] total fence post use in the four States of Illinois, Indiana, Missouri, and Ohio seems to be declining by about 5 percent per year. Changes in farming including increased farm and field size, increased use of mechanical equipment, and the trend to confinement housing for animals have contributed to this decline. The increased use of treated wood and steel posts, which have long service life, has also been a factor.

During the 12-year period of decline in total numbers of posts used, the number of posts treated by commercial wood preserving plants increased by over 40 percent. Since farm fencing is the dominant use of treated wood posts, it appears that treated posts are capturing more of a declining total farm market. As the total market continues to decline, and, given the extended service life of treated posts, major increases in production and use of treated posts will depend on securing other markets.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-75

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Bark Characteristics Indicate Age and Growth Rate of Yellow Birch

ABSTRACT. — Yellow birch trees with peeling or smooth bark tend to be younger and faster growing than rough-barked trees of similar diameters and should be selected as crop trees or superior tree candidates.

OXFORD: 811.79:523.9:559:815.2:176.1 *Betula alleghaniensis*

Published marking guides for oaks and yellow-poplar and northern hardwoods show bark characteristics to be reliable indicators of tree vigor (Burkle and Guttenberg 1952, Arbogast 1957). Kennedy and Wilson (1954) have also shown that there is a strong relationship between bark type and age in subalpine fir with the cork-barked trees being consistently older than trees with smooth bark. In a recent publication we suggested that smooth-barked yellow birches 12 inches d.b.h. and larger tend to be faster growing than rough-barked trees (Clausen and Godman 1967). We now have data showing that this difference is apparent even in smaller trees and that smooth-barked yellow birches also are younger than rough-barked trees of similar diameter.

In the bark type called smooth or peeling in this paper, the outer layers of the bark usually separate into thin, papery curls (fig. 1). These layers often slough off with age leaving an essentially smooth bark. The rough type of bark does not exfoliate or peel in younger trees but breaks up into plates in older trees (fig. 2). Large, smooth-barked trees may have a small amount of rough bark near the ground line while rough-barked trees have this type of bark extending high up on the stem. Rough bark appears to be less common than the smooth type and may not occur in all stands.

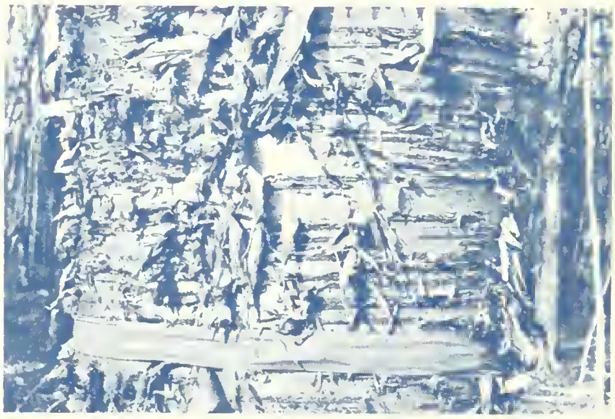

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Figure 1. — Peeling bark of tree 15.2 inches in diameter at breast height (ribbon).

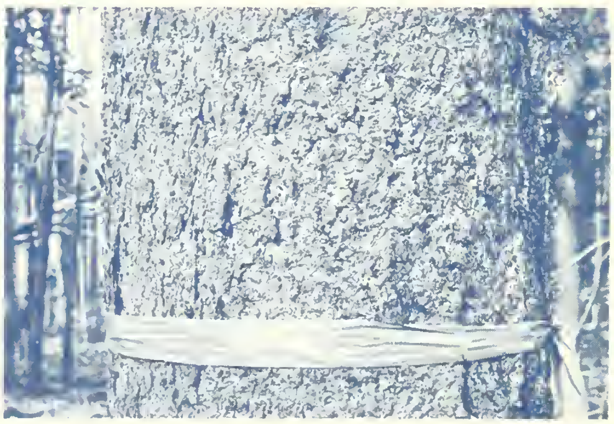

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Figure 2. — Rough bark of tree 14.8 inches in diameter at breast height (ribbon).

Methods

Pairs of yellow birches, one smooth-barked and one rough-barked, were selected in northern hardwood stands on the Argonne Experimental Forest in northern Wisconsin. To be included, members of each pair had to: (1) have breast height diameters differing 1 inch or less from each other, (2) be of the same crown class, and (3) be located within 150 feet of each other. The trees making up the nine pairs ranged from 3 to 15 inches d.b.h. and were all strong codominants (table 1). Members of most pairs were less than 100 feet apart.

The trees were felled and a stem section was taken at breast height from each tree. Annual rings were counted in order to determine the number of years each tree required to reach 4 inches in diameter at breast height and tree age at this height. Diameter growth for each 10-year period from the bark toward the center was measured to the nearest 0.01 inch along four radii, two on the largest diameter and two at right angles to it. Bark thickness was measured to the nearest 0.01 inch on the same four radii and on four additional radii midway between the other measurements.

Results

The most striking result of this study was the difference in age between the members of each pair. All the rough-barked trees were older than their smooth-barked counterparts, ranging as high as 3.7 times as old (table 1). The rough-barked trees on the average took twice as long to reach 4 inches in diameter at breast height as did trees with smooth or peeling bark (56.8 years versus 28.0 years). Although the rough-barked trees tended to be slow starters, partly because they were established before the stands were cut 60 to 65 years ago, the smooth-barked member of pair No. 4 was as slow as the rough-barked trees in pairs 3 and 5.

The average annual diameter growth of the smooth-barked trees was 0.172 inch compared with 0.092 inch for the rough-barked trees, and all the smooth-barked trees were faster growing than their rough-barked counterparts (table 1). Although diameter growth in the last decade in general was less than expected from the average annual diameter growth, the smooth-barked trees with an average of 1.29 inch were still growing more than twice as fast as the rough-barked trees with 0.59 inch. Most of the

Table 1. — *Average age at 4 inches d.b.h., bark thickness, and growth of nine pairs of yellow birch*

Pair number	Bark type	D.b.h.	Age at breast height	Age at 4 inches d.b.h.	Bark thickness	Diam. growth/year	Diam. growth last 10 yrs.
		Inches	Years	Years	Inches	Inches	Inches
1	Smooth	15.2	78	26.2	0.259	0.195	1.08
	Rough	14.8	162	77.0	.491	.091	.72
2	Smooth	13.6	55	17.9	.234	.247	1.48
	Rough	14.3	136	55.1	.356	.105	.56
3	Smooth	11.6	56	21.9	.269	.207	1.30
	Rough	11.8	206	37.2	.584	.057	.56
4	Smooth	10.6	83	40.2	.250	.128	.68
	Rough	9.6	192	85.4	.609	.050	.17
5	Smooth	9.5	53	24.0	.194	.179	1.30
	Rough	10.0	77	38.9	.272	.130	.47
6	Smooth	8.0	52	30.0	.188	.154	1.42
	Rough	7.8	80	48.1	.166	.098	.48
7	Smooth	6.8	50	27.1	.125	.136	.71
	Rough	7.1	93	56.4	.172	.076	.30
8	Peeling	5.5	43	36.5	.072	.128	1.91
	Nonpeeling	5.5	66	55.9	.172	.083	.84
9	Peeling	3.3	19	1/ 14.2	.075	.174	1.76
	Nonpeeling	3.1	23	1/ 15.1	.090	.135	1.19

1/ Years to reach 2 inches d.b.h.

trees had grown considerably faster at some earlier period of their lives. The best diameter growth in any decade for the smooth-barked trees ranged from 1.65 to 3.04 inches and averaged 2.22 inches; corresponding values for the rough-barked trees were 0.59 to 2.35 inches and 1.42 inch. One rough-barked tree grew faster than its smooth-barked counterpart in its best decade and thus had the potential for good diameter growth but had become a very slow-growing tree in the most recent decade.

With the exception of pair No. 6, the rough-barked trees all had thicker bark than their smooth-barked counterparts (table 1). Although bark thickness, as expected, increased with diameter, the regression equations for smooth- and rough-barked trees were not significantly different from each other. Since bark thickness is closely related to age ($r = 0.948^{**}$) the rough-barked trees had thicker bark primarily because they were so much older than smooth-barked trees of similar diameters.

The smooth bark averaged 4.0 percent of the d.b.h. The rough bark, on the other hand, averaged 7.3 percent. Using the conversion factor given by Gevorkiantz and Olsen (1955), we found average bark volume to be 8.0 percent for the smooth-barked trees and 14.6 percent for the rough-barked trees. The latter figure agrees well with the 14 percent listed by Gevorkiantz and Olsen (1955) for yellow birch of these sizes. Adjustment for individual trees is, therefore, important when using these volume tables since the smooth-barked trees all had less than 14 percent bark while rough-barked trees had as much as 25 percent bark. Unless adjustments are made for excessive bark thickness in tree volume calculations, the buyer of standing timber may be paying for a lot of useless bark.

Bark thickness also affects basal area calculations since these usually are based on diameter outside bark. The area of the stem sections occupied by bark averaged 7.2 percent in the smooth-barked trees and 12.7 percent in the rough-barked trees. The bark area did not exceed 10 percent in any smooth-barked tree but was as high as 23.4 percent in rough-barked trees. Thus, when stand volume computations include basal area there will be a serious overestimate if many of the yellow birches have thick bark.

Implications

The results of this study demonstrate that external bark characteristics indicate age and growth rate in yellow birch as well as the volume of wood that can be expected for trees of a given size. Trees with peeling or smooth bark tend to be younger and faster growing — possibly due to genetic traits — normally have had a shorter period of suppression during their establishment period, and should yield more wood for a given stem size than rough-barked trees. Smooth-barked trees, therefore, should be favored as crop trees wherever possible and should be selected as superior tree candidates. Obviously, we do not want to select a tree that has taken 200 years to reach 12 inches d.b.h. when another tree has done it in 50 to 60 years.

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RESEARCH NOTE NC-76

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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A Basal Stem Canker of Sugar Maple

ABSTRACT. — A basal stem canker of sugar maple is common on trees in lightly stocked stands and on trees on the north side of roads and other clearings in the Lake States. The cankers are usually elongate, usually encompass about one-fourth of the stem circumference, and face the south. Most cankers originated following logging of old-growth stands on stems that had been present as suppressed individuals with a d.b.h. of 1 to 1½ inches. Many of the cankers have failed to heal although more than 30 years old. In some cases a fungal-insect complex appears to have prevented canker closure.

OXFORD: 422.3:416.4:176.1 *Acer saccharum*

During a tour of second-growth northern hardwood stands in Wisconsin in 1964, I noticed a basal stem canker on sugar maples (fig. 1). The cankers occurred on trees along the north side of roads and clearings (fig. 2) or in lightly stocked stands — always on the south side of the trees. In fact, more than two-thirds of the cankers examined faced somewhere between south and southwest. The base of most cankers was within 3 feet of the ground.

Examination of 92 northern hardwood Continuous Forest Inventory sample plots in northern Wisconsin and the Upper Peninsula of Michigan revealed that 2 percent of the sugar maples bore such cankers. Pomerleau[1] reported similar cankers on sugar maple in Quebec.

Typically, the cankers are elongate, 3 to 16 times longer than wide; perfectly round ones are rare. Some of them encompass as much as three-fourths of the total stem circumference, although most affect only about one-fourth of the circumference.

Dissection of such cankers showed that the injury occurred at the interface of growth rings, indicating that the damage had taken place before, during, or just after the dormant period. Callus patterns on the canker faces that indicate past healing attempts vary from no callus layers present (uncommon) to multiple layers (common).

Generally, cankers found on small stems were younger than those found on larger stems. Apparently cankering begins when the trees are young. Dissections showed that cankered 6-inch trees were 1 to 1½ inches when cankering occurred.

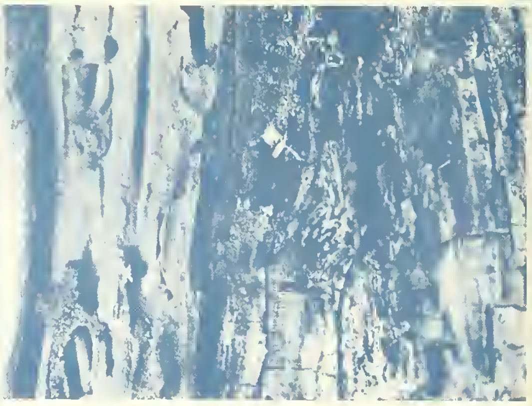
F-519221

Figure 1. — Canker of pole-sized sugar maple. Notice layers of decaying callus tissue.

[1] *Pomerleau, R. Observations sur quelques maladies non parasitaires des arbres dans le Quebec. Can. J. Res. 22: 171-189. 1944.*

F-519222

Figure 2. — Several cankered trees along the north side of a woods road.



F-519223

Figure 3. — Larvae of *Mycetochara bicolor* tunnelling along the edge of a canker.

Cankering is common in stands heavily cut within the past 50 years. Dissection of cankered trees showed that the exposed saplings began to canker after release by cutting and continued to do so over a period of several years.

Many frost cracks were found to have been initiated by cankering. Many cankers either fail to heal (even though more than 30 years old) or else they develop into frost cracks. Dead callus layers visible on such canker faces show that the wound healing process has not proceeded normally. Closer examination and dissection of these cankers disclose the presence of insect larvae and numerous fungal colonists. Fungus and insect activity or repeated frost injury to the cambial tissue may contribute to this failure to heal. The larvae of one insect, *Mycetochara bicolor* Couper, was often found tunnelling at the canker edge near the most recent callus layer (fig. 3). Tunnels of this insect appear to provide a favorable environment for the development of several fungi. Moreover, some fungi colonize the dead bark and exposed wood of the canker face and produce fruiting bodies on the canker face. More than 16 different fungi were found to sporulate on the cankers.

The virulent canker fungus, *Eutypella parasitica,* was found sporulating on about 10 percent of the more than 500 cankers examined for fungal fruiting. The canker causing organisms, *Nectria galligena* and *Hypoxylon mammatum,* were found sportulating on occasional cankers. *Diatrype stigma,* one of the most commonly observed fungi sporulating on the cankers, may be the same fungus reported by Pomerleau[1] as *D. macounii.* Pomerleau described *D. macounii* as contributing to canker development following stem sunscalding. When inoculated into healthy stems of sugar maple saplings, however, *D. stigma* was not pathogenic and no cankers were produced. *Diatrype stigma* seems to be primarily an early colonizer of recently killed bark and wood tissues.

In addition to the fungal sporulators on the cankers, algae, lichens, and slime molds were observed on the canker faces. When isolations for micro-organisms were made from the discolored wood beneath the canker faces, a typical microflora was found, consisting of filamentous fungi, bacteria, and occasional yeast organisms. As might be expected, some of the filamentous fungi proved to be those found sporulating on the canker faces. Other fungi were only isolated from the wood and were not found sporulating on the cankers while some of the canker face sporulators were never isolated from the wood.

Since many of the cankers resemble target-like, perennial Nectria cankers and *Nectria galligena* occasionally was found producing fruiting bodies on cankers, I decided to investigate the possibility that Nectria was a primary factor preventing canker closure. Two Nectria isolation media were developed. These media contained the antibiotics pyrrolnitrin and phytoactin to inhibit the growth of fast growing saprophytic fungi on the isolation plates.[2] Numerous isolations using these media showed that *Nectria galligena* is not commonly associated with these cankers.

The physiological basis for the initiation of this type of injury remains obscure. Pomerleau[1] felt that the injury may be caused by the springtime termination of the stem's resistance to cold. Severe spring frosts would then damage the unhardened tissues.

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1969

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[2] *I am grateful to Eli Lilly and Co., Indianapolis, for supplying a sample of pyrrolnitrin and P-L Biochemicals, Inc., Milwaukee, for supplying a sample of phytoactin.*

U. S. FOREST SERVICE

RESEARCH NOTE NC-77

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Interpreting Neutron Probe Readings In Frozen Soil

ABSTRACT. — Several factors associated with soil freezing complicate the interpretation of neutron probe readings in frozen soil. Temperature is unimportant, but the effect of vertical resolution must be considered. Because of the possibility of both gains and losses of water at the same depth during a period of measurement, interpreting changes in the water content of frozen soil is a subjective process.

OXFORD: 114.122 — 015:114.16

Soil freezing can affect the distribution of water in natural soil profiles in several ways: It may restrict or prevent infiltration and percolation, it may alter the direction of subsurface flow on sloping land, and it may cause upward movement to the freezing front. Rainfall or snowmelt on frozen soil may result in a water buildup in the upper few centimeters of the profile with no change at lower depths. The higher water content near the surface will affect neutron readings at lower depths if vertical resolution of the probe exceeds the sampling interval. The possibility of simultaneous gains from infiltration, losses from percolation, and upward migration further confuses the interpretation of neutron probe results in frozen soils.

Effect of Temperature and Frozen Soil

High temperatures can affect the shield count rate of some neutron probe instruments (van Bavel *et al.* 1963). However, I found no significant low-temperature effect on either shield or probe units of the one instrument tested (a Nuclear-Chicago Model P19 D/M gage with an 80 mc. Am-Be source)[1] and concluded that temperature *per se* would not affect neutron probe readings under the conditions that normally accompany soil freezing. The tests were run at temperatures ranging from 60° to –17° C. The abnormal condition created by the access tube must also be considered. By producing a horizontal temperature gradient, metal access tubes could cause water to move toward the tube from the surrounding soil. This possibility was investigated by Dickey *et al.* (1964) in a study of temperature and water gradients around steel access tubes, but they found no discernible temperature gradient and concluded that horizontal water movement does not occur.

Because the molecular density of water decreases when it changes to ice, I suspected that the change in state might affect neutron meter count. Readings taken in both water and ice (in a plastic container 52 cm. deep and 40 cm. in diameter) showed that freezing did indeed affect neutron meter count. The count in ice was 90 percent of the count in water.

[1] *Mention of trade name does not constitute endorsement of the product by the U.S.D.A. Forest Service.*

To test the effect of soil freezing, I buried three plastic containers (52 by 40 cm.) so that just the top 2 cm. remained above the ground. I then filled each with a different soil: silt loam, sand, and a mixture of the two, which had water contents of 15, 32, and 35 percent by volume, respectively. I covered the containers to exclude rain and minimize evaporation, installed access tubes in each, and took readings before and after the soils froze. There was no significant change with freezing in any of the soils. The expected decrease in count was either too small to be measured, or was masked by an increase resulting from thermal movement.

Effect of Vertical Resolution

The layer of influence or vertical resolution of the probe — defined by van Bavel *et al.* (1954) as the thickness of the layer of soil that significantly determines the counting rate — should be considered when interpreting any neutron meter data. Vertical resolution determines the shallowest depth at which the observed count is unaffected by the soil surface. It also determines the minimum sampling distance that can be used without having overlap in the measurements. Vertical resolution varies only a little among different neutron source types (Ziemer *et al.* 1967), but it varies appreciably with water content of the soil (van Bavel *et al.* 1954). I found it to be 60 cm. in a dry soil (15 percent water) and 35 cm. in a wet soil (35 percent water). Thus, in the dry soil the shallowest reading would have to be taken at a depth of at least 30 cm. to be unaffected by the soil surface; and the depth interval would have to be at least 60 cm. for the readings to be unaffected by the water content at the next depth.

The effect of vertical resolution has special significance in frozen soil. This is because water can accumulate on or close to the ground surface — from snow or ice buildup, or from restricted percolation. For example, I found that 30 cm. of snow (water equivalent = 5 cm.) increased neutron count at the 15-cm. depth in a dry soil (17 Pv) by an amount equivalent to 1.0 percent water content. An ice layer at the ground surface could have a greater effect. A wet surface layer in an otherwise dry soil profile is common in winter. From gravimetric sampling in a frozen sandy soil, I found 33 percent water in the top 7.5 cm. and only 14 percent water in the next 7.5 cm. The wet surface layer would affect neutron readings at more than one depth in this situation if the depth sampling interval were too short.

Downward Versus Upward Movement

The possibility of both downward (from percolation) and upward (with a thermal gradient) movement of water further complicates the interpretation of neutron probe readings in frozen soil. In one study I tried to eliminate percolation to get a better picture of upward movement. Two access tubes 3 m. apart were installed in each of two soils, one a sandy soil, the other a silt loam. After the ground began to freeze, the soil surface around one tube at each site was covered with a sheet of clear polyethylene, 2.3 m. square, to prevent infiltration.

The procedure was only partly successful. Both covered and uncovered plots showed soil water increases in the upper 30 cm. (fig. 1). Increases at the covered plots resulted from water running under the plastic because the edges were not buried. This was observed several times during the frost period, particularly later on when the frost was harder, thus restricting infiltration more. However, the greater increases on the uncovered plots in the first 40 days coupled with no decreases at lower depths indicated that the changes resulted largely from infiltration rather than upward movement. Data from three other years suggested the same thing (Sartz 1969).

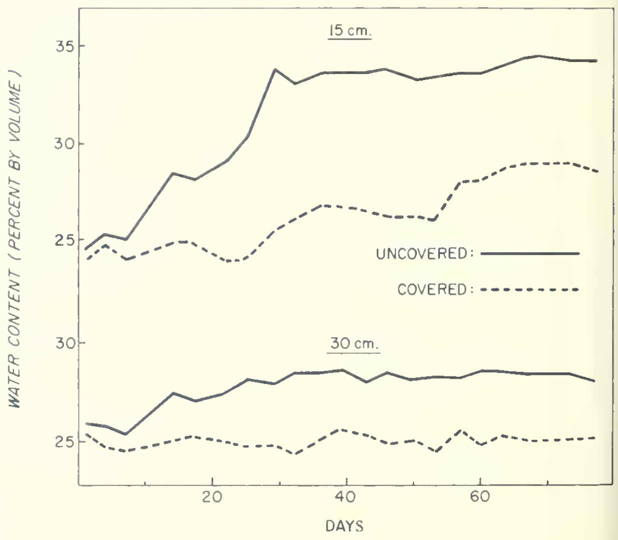

Figure 1. — Soil water changes at two depths on covered and uncovered plots in silt loam during soil freezing period, 1967-68.

However, in one instance I found what clearly appeared to be upward movement. Data from six tubes at two different sites indicated that water had moved from the 30-cm. zone to the 15-cm. zone. The change took place during a 2-week period in which frost penetrated from 2 cm. to 15 cm. (fig. 2). There was no rainfall or snowmelt during the period. The maximum change in soil water was 5 percent or 8 mm. in the 15-cm. layer. Some water may also have moved from the 45- to the 30-cm. zone, but this movement was less pronounced. The downward trend shown at the 45-cm. depth may have been simply a continuing percolation loss, and the upward trend at the 30-cm. depth may have been an infiltration gain, as indicated by the 15-cm. plotting (fig. 2). This example illustrates one of the difficulties in interpreting changes in the distribution of water in frozen soils.

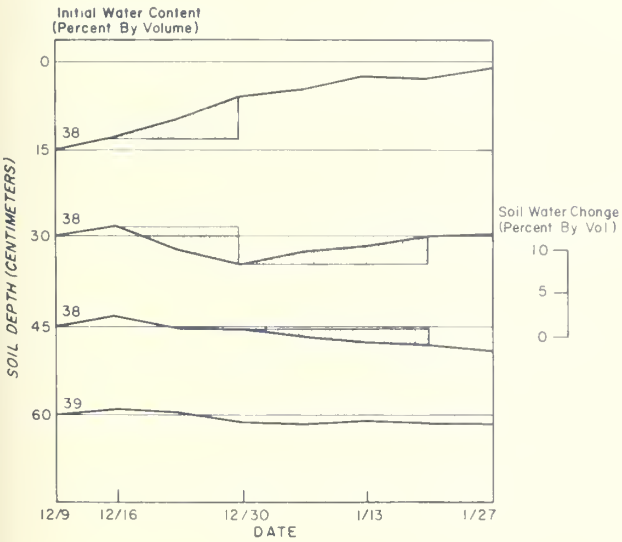

Figure 2. — Soil water changes at successive 15-cm. depths, silt loam, southeast slope — December 9, 1963, to January 27, 1964. Shading indicates probable translocation.

Even more puzzling are increases that cannot be explained by either infiltration or upward movement. Such increases occurred several times on both sloping and relatively level land. The most interesting example took place in a silt loam soil during a thaw in March 1964, when one of three plots on a southeast slope showed a 60-mm. gain in water during a 2-day period (fig. 3). The ground was bare of snow on March 2, and only 13 mm. of rain fell before the plots were remeasured on March 4. Although water content increased at all levels on one plot, only small changes were found on the other two, and these could have resulted from instrument error. The differences are surprising because cover and slope were the same, and the access tubes were only 3 m. apart. Although penetrometer measurements showed bonded frost between depths of 8 and 30 cm. on the site, resistance blocks and thermistors installed near each access tube did indicate faster thaw on Plot 3. However, this could have been either a cause or an effect of the greater water movement on the plot. Whatever the reason, the example shows that large differences in water can occur over small distances in frozen soils.

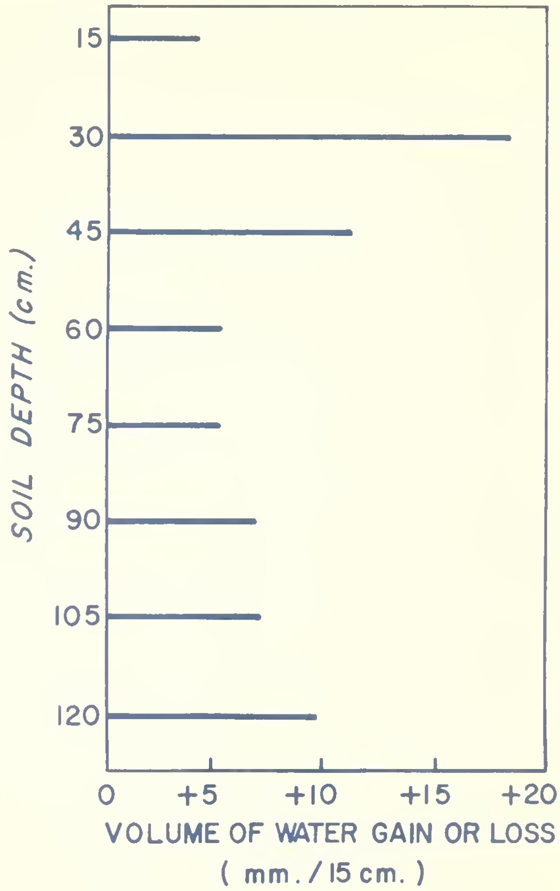

Figure 3. — Net change in soil water on silt loam Plot 3, southeast slope — March 2-4, 1964.

Where the water came from is a good question. I ruled out translocation from a water table as suggested by Benz *et al.* (1968) because of depth to the water table (at least 5 m.) and the short time involved. Upward movement from unsaturated soil below the zone measured also seemed unlikely. That left interflow as the only reasonable explanation.

Conclusions

What actually takes place when natural soil profiles freeze and thaw is still something of a mystery. Because of the possibility of both gains and losses at the same depth from infiltration, percolation or thermal movement, interpreting changes in the water content of frozen soils is at best a subjective process. Low temperature and soil freezing *per se* had no apparent effect on neutron probe readings, but variation in the depth and density of frozen soil within a sampling unit increased the normal experimental error in measuring the distribution of soil water. A better understanding of how and why water moves in frozen soil is needed before we can interpret neutron probe readings with confidence.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-78

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Water Storage and Related Physical Characteristics of Four Mineral Soils in North Central Minnesota

ABSTRACT. — Soil water storage in a 7.5 foot profile varied nearly 100 percent (7.9 to 15.5 inches) among four mineral soils ranging from a sand to sandy loam. Bulk density, size fractions, and four water retention values are tabulated for each horizon.

OXFORD: 114.1:114.124(776)

Bulk density, size fractions, water retention, and hence water storage were determined for four soil types on the Marcell Experimental Forest in central Itasca County (ca. 47° 32′N;93° 28′W). These data were used in water budget studies for determining absolute changes in soil water storage and to interpret streamflow from experimental watersheds. Because of limited soils information in this area, these data should also be useful for correlating newly identified soil series as well as other water budget studies on similar soils.

The four soil types, Menahga loamy sand, Menahga sand, Warba sandy loam, and a taxadjunct[1] to Chisholm sandy loam, developed in two different parent materials.[2] The two Menahga types developed in noncalcareous, yellowish brown, coarse-textured drift; the Warba and taxadjunct to Chisholm types developed in slightly calcareous, light olive brown, medium-textured drift. The latter material was deposited over the coarse-textured drift so that soils developed in the medium-textured drift cover about 75 percent of the experimental forest. Soils developed in similar parent materials occur throughout north-central Minnesota.

Procedure

Soil profiles were selected, using a recent soil survey of the Experimental Forest[2], so that a large range of soil textures would be encountered. Bulk density was determined from four samples using either the clod method or 68.7 cc. split ring cores, depending on rockiness and density of the horizon. Values based on clod samples have been reduced by 12 percent to correct for interclod spaces. Total porosity was calculated with a particle density of 2.65.

Soil water retention values were determined from two samples using the pressure extraction technique. These values were corrected for the greater than 2 mm. fraction when ground samples of 2 mm. and less were used. When clod samples were used, no correction was necessary. In this study, water storage capacity is considered to be the difference between water retention values at 15 atm. and at either 0.06 atm. for coarse-textured soils or 0.10 atm. for fine-textured soils.

Soil textures were determined by dry sieving, wet sieving, residual, and Bouyoucos hydrometer methods for the greater than 2 mm., 2–.05 mm. (sand), .05–.002 mm. (silt), and the less than .002 mm. (clay) fractions, respectively.

[1] *Soils handled as taxadjuncts are considered adjuncts to, but not parts of, a mapping unit name. The taxadjunct to Chisholm sandy loam is enough like the Chisholm soil in morphology, composition, and behavior that little or nothing would be gained by adding a new series. (Personal communication, U.S.D.A. Soil Conserv. Serv.)*

[2] *Paulson, Richard O. A soil survey of Marcell Experimental Forest. U.S.D.A. Soil Conserv. Serv. 34 p. 1968.*

Results and Discussion

The four soil types vary nearly 100 percent in water storage capacity. Periodic measurements of soil water to a depth of 10 feet show that the zone of significant water depletion and recharge extends to 7.5 feet under mature aspen stands (the dominate vegetation of the Marcell Experimental Forest and north-central Minnesota). Because of this, total water storage to a depth of 7.5 feet is used to compare the four soil types.

The Menahga loamy sand retains 7.9 inches while the Menahga sand retains 11.7 inches. The type names of the surface horizon appear to contradict the water storage values; however, these two profiles mark the textural extremes (coarse to fine) of the Menahga series. This contradiction can be explained by the distribution of two textural groups. First, the loamy sand contains 8 to 40 percent gravel (> 2 mm.) while the sand contains 0 to 6 percent. Second, the A2 horizon of the loamy sand contains 36 percent fine and very fine sand while the sand contains 54 percent. If the percentage of fine sand is high throughout the profile, it will yield higher water storage values than the type name (sand) would indicate; while the high percentage of gravel will yield lower water storage values than the type name (sandy loam) would indicate. The Warba sandy loam and taxadjunct to Chisholm retain 14.1[3] and 15.1 inches.

The data (tables 1-4) can be used to make gross estimates of water storage on similar soil series; however, because of the large difference occurring within one soil series (3.8 inches in Menahga) more accurate estimates are obtainable by using water storage values for horizons within a soil type.

Although absolute soil water storage values are not always necessary for a general water budget study, they are important for predicting and interpreting the hydrologic response of a watershed. For example, storm runoff is diminished by that part of the precipitation that satisfies the available soil water storage.

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[3] *Since the Warba type was only sampled to a depth of 6.0 feet, the 5- to 6-foot water retention values were extrapolated to 7.5 feet. Auger samples show similar material extending 8 to 15 feet throughout the Warba type.*

Table 1. — Menahga loamy sand[1]

Horizon	Depth	Bulk density	Total porosity	Water by volume (percent) retained at-- .06 atm.	.10 atm.	.33 atm.	3 atm.	15 atm.	Water storage (inches) per-- Horizon	Foot	Soil fractions (percent) > 2 mm.	< 2 mm. Sand	Silt	Clay
	Feet		Percent											
A2	0.00-0.25	1.27	52	20.8	-	8.1	4.1	2.8	0.54	2.16	7.9	83.8[3]	13.1	3.1
B2	.25-1.10	1.50	43	16.2	7.1	5.5	3.5	2.4	1.41	1.66	26.3	75.8	19.8	4.4
B3	1.10-1.50	1.70	36	14.4	-	4.9	2.7	1.9	.60	1.50	20.6	92.0	5.3	2.7
B3	1.50-2.50	1.74	34	12.4	-	4.6	2.9	1.9	1.26	1.26	22.6	89.4	7.8	2.8
C	2.50-3.50	1.72	35	12.4	-	4.6	3.0	2.3	1.21	1.21	20.0	91.6	6.3	2.6
C	3.50-4.50	1.66	37	8.6	-	3.5	2.2	1.4	.86	.86	40.3	92.6	4.4	3.0
C	4.50-5.50	1.56	41	9.5	-	4.3	3.2	2.3	.86	.86	7.3	94.3	2.4	3.3
IIC2[2]	5.50-5.75	1.72	35	13.3	11.8	9.0	6.9	7.0	.19	.76	5.2	90.0	2.8	7.2
IIIC3[2]	5.75-5.90	1.55	42	-	36.6	33.0	24.0	18.1	.33	2.22	.3	41.3	16.2	42.5
IVC4	5.90-6.50	1.56	41	4.0	-	2.1	1.4	1.1	.21	.35	5.2	97.9	.7	1.4
IVC4	6.50-7.50	1.51	43	5.0	-	1.7	1.2	1.1	.47	.47	2.5	99.3	.6	.1
IVC4	7.50-8.50	1.47	45	2.9	-	1.2	1.2	1.0	.23	.23	1.5	99.6	.0	.4
IVC4	8.50-9.50	1.49	44	3.2	-	1.3	1.1	1.0	.26	.26	2.2	99.6	.2	.2
IVC4	9.50-10.5	1.49	44	3.1	-	1.3	1.0	.6	.30	.30	1.6	99.8	.1	.1

1/ Menahga series: sandy, mixed, frigid; Typic Udipsamment; Entisol.
2/ Bulk density and water retention values in these horizons are based on clod samples.
3/ Division of sand for this horizon is: V.C. 11.7, C. 34.6, M. 17.8, F. 28.2, V.F. 7.7 percent.

Table 2. — Menahga sand[1]

Horizon	Depth	Bulk dens-ity	Total poros-ity	Water by volume (percent) retained at--					Water storage (inches) per--		Soil fractions (percent)			
				.06 atm.	.10 atm.	.33 atm.	3 atm.	15 atm.	Horizon	Foot	> 2 mm.	< 2 mm. Sand	Silt	Clay
	Feet		Percent											
A2	0.00-0.20	1.16	56	19.1	-	8.4	4.5	3.3	0.38	1.90	0	[3/]87.7	8.8	3.5
B2	.20-0.50	1.58	40	17.1	-	7.3	5.1	3.9	.48	1.60	0	92.8	4.8	2.4
B3	.50-1.50	1.51	42	11.5	-	2.9	2.3	1.9	1.15	1.15	0	98.6	.8	.6
C	1.50-2.50	1.58	40	14.4	-	3.8	1.6	1.3	1.57	1.57	0	97.2	1.4	1.4
C	2.50-3.50	1.58	40	14.7	-	3.2	2.1	1.3	1.60	1.60	0	97.1	1.9	1.0
C	3.50-4.50	1.60	40	15.0	-	2.7	2.6	1.6	1.61	1.61	0.2	96.2	2.6	1.2
C	4.50-5.50	1.61	39	-	15.8	8.2	6.3	3.8	1.44	1.44	1.0	85.9	9.2	4.9
C	5.50-6.50	1.70	36	-	18.4	9.6	7.5	5.0	1.60	1.60	5.7	84.8	10.2	5.0
IIC2[2/]	6.50-7.50	1.70	36	-	26.9	17.8	16.0	11.1	1.90	1.90	4.4	71.0	15.1	13.9
IIC2[2/]	7.50-8.50	1.72	35	-	25.2	23.2	17.0	12.6	1.51	1.51	8.2	61.0	24.4	15.1
IIC2[2/]	8.50-9.50	1.74	34	-	23.1	20.0	15.8	10.9	1.46	1.46	4.5	65.9	18.9	15.2
IIC2[2/]	9.50-10.0	1.60	40	-	32.5	27.2	22.2	14.6	1.71	2.42	2.8	37.9	38.6	28.5
IIIC3	10.00-10.5	1.50	43	4.4	3.7	1.5	1.3	1.2	.20	.40	4.2	97.3	1.7	1.0

1/ Menahga series: sandy, mixed, frigid; Typic Udipsamment; Entisol.
2/ Moisture retention values in these horizons are adjusted to a clod sample basis.
3/ Division of sand for this horizon is: V.C. 1.0, C. 10.5, M. 35.0, F. 47.6, V.F. 5.9 percent.

Table 3. — Warba sandy loam[1]

Horizon	Depth	Bulk dens-ity	Total poros-ity	Water by volume (percent) retained at--					Water storage (inches) per--		Soil fractions (percent)			
				.06 atm.	.10 atm.	.33 atm.	3 atm.	15 atm.	Horizon	Foot	> 2 mm.	< 2 mm. Sand	Silt	Clay
	Feet		Percent											
A2	0.00-0.35	1.09	59	-	19.4	8.9	6.4	5.3	0.59	1.69	12.4	[3/]67.7	27.6	4.7
A22	.35-1.10	1.42	46	-	21.0	10.3	6.3	5.0	1.44	1.92	9.8	69.6	23.2	7.2
B21t[2/]	1.10-1.50	1.59	40	-	25.8	23.6	21.4	5.7	.97	2.42	3.5	56.9	25.7	17.4
B22t[2/]	1.50-2.30	1.57	41	-	31.9	29.3	21.9	19.0	1.24	1.55	4.3	41.4	28.3	30.3
B3[2/]	2.30-3.50	1.54	42	-	37.3	32.7	21.4	19.3	2.59	2.16	2.6	43.8	32.6	23.6
C[2/]	3.50-5.00	1.58	40	-	35.3	25.8	23.3	19.8	2.79	1.86	3.1	43.5	29.3	27.2
C[2/]	5.00-6.00	1.58	40	-	35.8	27.9	25.2	20.9	1.79	1.79	4.8	42.3	29.4	28.3

1/ Warba series: fine-loamy, mixed, frigid; Typic Eutroboralf, Alfisol.
2/ Bulk density and water retention values in these horizons are based on clod samples.
3/ Division of sand for this horizon is: V.C. 14.6, C. 25.3, M. 18.3, F. 29.5, V.F. 12.3 percent.

Table 4. — Taxadjunct to Chisholm sandy loam[1]

Horizon	Depth	Bulk density	Total porosity	Water by volume (percent) retained at--					Water storage (inches) per--		Soil fractions (percent)			
				.06 atm.	.10 atm.	.33 atm.	3 atm.	15 atm.	Horizon	Foot	> 2 mm.	< 2 mm. Sand	Silt	Clay
	Feet		Percent											
A2	0.00-0.30	1.31	51	-	27.6	12.3	6.4	5.5	.79	2.63	5.3	[3] 66.6	24.9	8.5
B21irh	.30-0.50	1.36	49	-	21.4	10.4	5.6	3.6	.42	2.10	8.7	70.2	25.2	4.6
B22irh	.50-1.35	1.49	44	-	17.8	7.7	4.7	3.2	1.48	1.74	6.6	78.9	16.9	4.2
B3	1.35-1.80	1.58	40	-	11.4	4.4	2.6	1.8	.51	1.13	13.7	84.5	10.9	4.6
IIA'2t[2]	1.80-2.40	1.74	34	-	24.6	18.1	11.9	8.0	1.19	1.98	7.5	65.8	21.3	12.9
IIA'2t& IIB'2t[2]	2.40-4.00	1.65	38	-	30.2	29.7	22.1	11.9	3.52	2.20	3.8	45.8	24.7	29.5
IIB'2t[2]	4.00-5.00	1.58	40	-	35.8	27.5	24.2	18.6	2.07	2.07	3.4	48.7	24.5	26.8
IIB'3t[2]	5.00-7.25	1.57	41	-	37.1	29.2	20.5	18.1	5.13	2.28	3.6	45.9	24.7	29.5
IIC[2]	7.25-8.75	1.71	35	-	31.8	27.1	21.5	18.3	2.43	1.62	11.4	44.5	34.4	21.1
IIC[2]	8.75-10.50	1.71	35	-	33.1	24.8	21.0	19.1	2.94	1.68	8.3	45.2	39.2	15.6

1/ Taxadjunct to Chisholm series: fine-loamy, mixed, frigid, Typic Eutroboralf; Alfisol.
2/ Bulk density and water retention values in these horizons are based on clod samples.
3/ Division of sand for this horizon is: V.C. 14.3, C. 29.0, M. 20.0, F. 24.0, V.F. 12.7 percent.

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1969

U. S. FOREST SERVICE

RESEARCH NOTE NC-79

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Computer Calculation of Fire Danger

ABSTRACT. — This paper describes a computer program that calculates National Fire Danger Rating Indexes. Fuel moisture, buildup index, and drying factor are also available. The program is written in FORTRAN and is usable on even the smallest compiler.

OXFORD: 431.5:U681.3

Since its introduction in 1964 the National Fire Danger Rating System has been adopted by most Federal and State forest fire control agencies, and has become an integral part of the decision-making process in fire control planning. Modern high-speed computers are an efficient tool for manipulating and analyzing the vast amount of fire danger data generated from this system. Using the National Fire Danger Rating System requires working with as many as five tables and seven variables. Danger ratings are obtained from this tabular method on a day-to-day basis. However, when mass conversion of historical weather data to the present system is required, the computer is an essential tool. In such cases a computer solution will speed up the calculations and provide computational accuracy.

This paper describes a computer program that computes buildup index, fire-load index, and various spread indexes. The program closely follows the method detailed by Nelson.[1] An equation computation method was chosen instead of a table look-up scheme for this program.[2] Primarily, the decision was dictated by computer memory limitations. Utilizing a look-up method would necessitate larger core size because of the 1,218 storage locations needed for the four tables.

The results from the formulas differ slightly from the table values. However, the differences are not great, and there is reason to believe that the computed results are more accurate than the tabular results.[3]

The flow chart (fig. 1) and listing of the program are included so the program may be used on the smallest FORTRAN compiler. The program has been thoroughly tested and run on an IBM 360/30 and requires less than 4K of memory. It uses the lowest possible level of FORTRAN, thus ensuring success on any machine.

For input, the program requires dry-bulb and wet-bulb readings, a yes or no decision regarding snow on the ground, the preceding 24-hour precipitation, the current windspeed, yesterday's buildup index, and current herbaceous stage of vegetation. These are the same variables required by the tabular method.

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[1] *Nelson, Ralph M. The National Fire Danger Rating System: derivation of spread index for eastern and southern States. U.S.D.A. Forest Serv. Res. Pap. SE-13, 44 p., illus. (Southeast. Forest Exp. Sta., Asheville, N.C.). 1964.*

[2] *Barney, Richard J. Calculating the National Fire-Danger Rating Spread Index by computer. U.S.D.A. Forest Serv. Res. Note INT-19, 2 p. (Intermountain Forest, Range Exp. Sta., Ogden, Utah.) 1964.*

[3] *Memorandum from John J. Keetch dated December 28, 1962. On file at North Central Forest Exp. Sta., St. Paul, Minn.*

The program first tests for snow on the ground, a condition that results in spread index values of zero. If there is no snow, it calculates the fine fuel moisture and drying factor. Yesterday's buildup index is then adjusted for precipitation and the drying factor is added. Timber fuel moisture content is adjusted from the current buildup index. The fine fuel spread index and timber spread index are then calculated. The last step computes the fire-load rating, man-hour base.

The program calculates fine fuel spread, timber spread, buildup index recovery, and fire-load rating for each day. Additionally, fine fuel moisture, adjusted fuel moisture, and drying factor are also available, if desired.

The following formulas have been circulated in memoranda but have never been published. The formulas appear in the program and are reproduced here for greater emphasis and clarity.

Fine Fuel Moisture[4]

$FFM = Ae^{B}$ (dry-wet)

Where

A	B	Range of (dry-wet)
30.0	-.1859	< 4.5° F.
19.2	-.0859	< 12.5° F.
13.8	-.0579	< 27.5° F.
22.5	-.0774	> 27.5° F.

A and B are the piecewise regression coefficients used to determine FFM. The depression of the wet bulb is used to decide which set of A and B will be used. Herb stage is used to adjust the calculated fine fuel moisture by adding 5 percent for transition stage or 10 percent for green fuels.

Adjusted Fuel Moisture[5]

(50-Day Lag)

$$ADFM = .9FFM + 9.5e^{\frac{-BUI}{50.}}$$

Where — FFM is the current fine fuel moisture

BUI is today's buildup index recovery

e is the base of the natural logs

Adjusted fuel moisture is also equal to equivalent fuel moisture.

[4] *Memorandum from George M. Byram dated January 30, 1963. On file at North Central Forest Exp. Sta., St. Paul, Minn.*

[5] *Memorandum from David Bruce dated March 1, 1963. On file at North Central Forest Exp. Sta., St. Paul, Minn.*

Buildup Index[3]

$$BUI = -50 \left(\log_e \left(1-\left(-e^{\frac{BUO}{50.}}\right)\right)_e 1.175 \, (PRECIP - .1)\right)$$

Where — BUI is today's buildup recovery corrected for any precipitation in the past 24 hours

BUO is yesterday's buildup

PRECIP is the past 24 hours precipitation in inches and hundredths

LOG $_e$ is the natural log

is the base of natural logs

BUI must be adjusted by adding the drying factor *after* correction for any precipitation greater than 0.1 inch.

Fine Fuel Spread[5]

$$GRASS = A \, (WIND + B) \, (33. - FFM)^{1.65} - 3.$$

Timber Spread Index[5]

$$TIMBER = A \, (WIND + B) \, (33. - ADFM)^{1.65} - 3.$$

Where	A	B	Windspeed
	0.01312	6.0	< 14 m.p.h.
	0.009184	14.4	>14 m.p.h.

FFM = Fine fuel moisture

ADFM = Fuel moisture adjusted for 50-day timelag

WIND = Windspeed in m.p.h., 20 feet above open level ground

Fire Load Index[6]

(Man-Hour Base)

$$FLOAD = 10.^{(1.75(\log_{10} TIMBER) + .32\,(\log_{10} BUI) - 1.64)}$$

Where — TIMBER is the Timber Spread index

BUI is the buildup index recovery

Fire load index is not a feature of the National system, but has been suggested as an experimental feature for consideration.

[6] *Outline for discussion of fire load rating, prepared by John J. Keetch, undated. On file at North Central Forest Exp. Sta., St. Paul, Minn.*

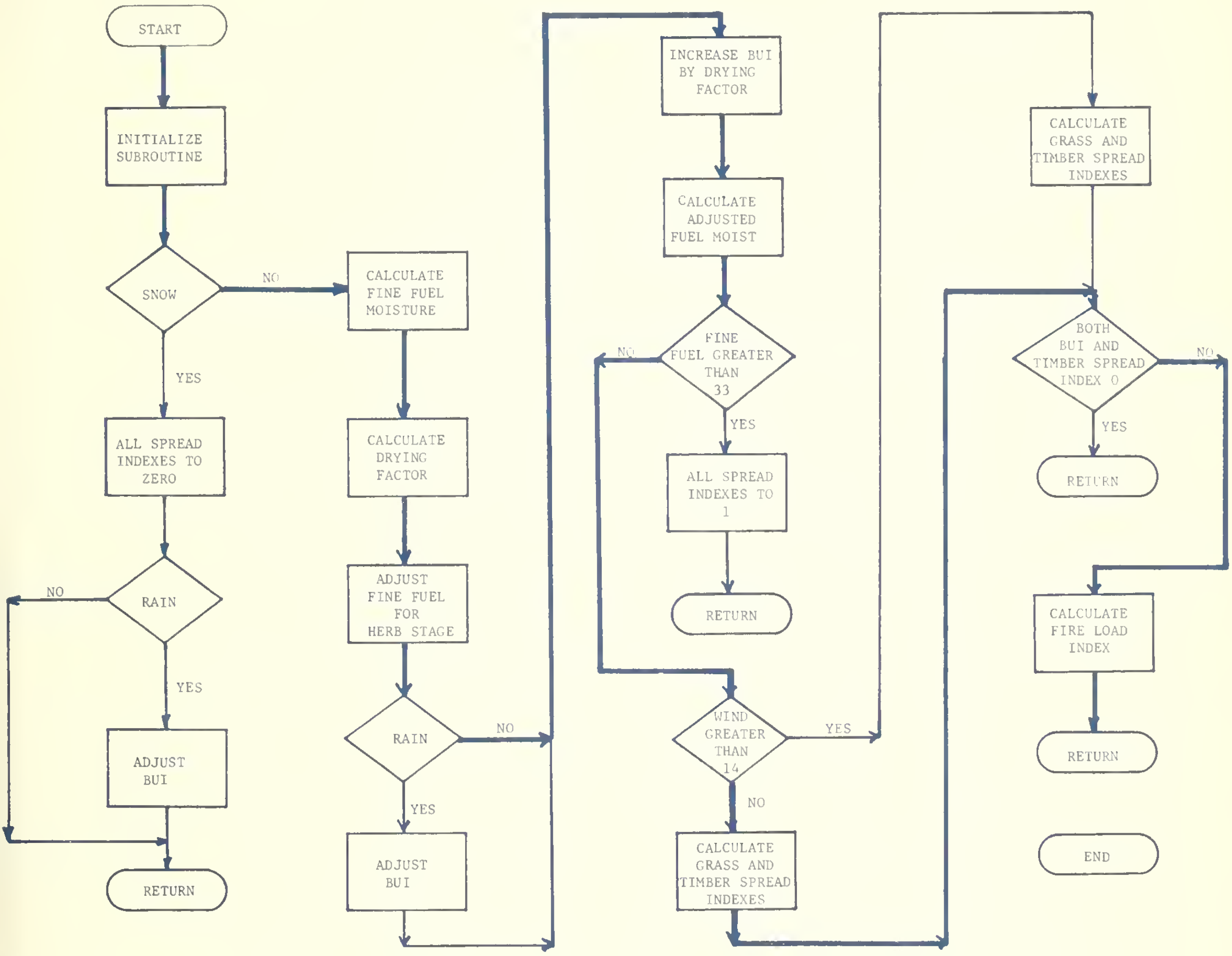

Figure 1. — Flow chart of subroutine to calculate National Fire Danger Rating Indexes.

Program

```
      SUBROUTINE DANGER (DRY,WET,ISNOW,PRECIP,WIND,BUO,IHERB,             DNGR 001
     /       DF,FFM,ADFM,GRASS,TIMBER,FLOAD)                              DNGR D02
C     RDUTINE FOR COMPUTING NATIONAL FIRE DANGER RATINGS AND FIPE LOAD INDEX
C     DATA NEEDED FOR THE CALCULATIONS ARE=
C     DRY,     DRY BULB TEMPERATURE
C     WET,     WET BULB TEMPERATURE
C     ISNOW,   SOME ROSITIVE NON ZERO NUMBER IF THERE IS SNOW ON THE GROUND
C     WIND,    THE CURRENT WIND SPEED IN MILES RER HOUR
C     BUO,     THE LAST VALUE OF THE BUILD UR INDEX
C     IHERB,   THE CURRENT HERB STATE OF THE DISTRICT 1=CURED,2=TPANSITION,3=GREEN
C     DATA RETURNED FROM THE SUBROUTINE ARE
C     DRYING FACTOR AS                          DF
C     FINE FUEL MOISTURE AS                     FFM
C     ADJUSTED (1D DAY LAG) FUEL MOISTURE AS    ADFM
C     GRASS SPREAD INOEX WILL BE RETURNED AS    GRASS
C     TIMBER SRREAO INDEX WILL BE RETUPNEO AS   TIMBEP
C     FIRE LOAD RATING (MAN-HOUR BASE) AS       FLOAO
C     BUILD UR INDEX WILL BE RETURNED AS        BUO
      OIMENSION  A(4),B(4),C(3),D(6)                                      DNGR DD3
      FFM= 99.                                                            DNGR DD4
      ADFM= 99.                                                           DNGR OD5
      DF=0.                                                               DNGR DD6
      FLOAD=0.                                                            DNGR OD7
C     THESE ARE THE TABLE VALUES USED IN COMRUTING THE OANGER RATINGS
      A(1) = -D.1B59DD                                                    DNGR 00B
      A(2) = -D.B59DD                                                     DNGR 009
      A(3) = -0.D59660                                                    DNGR D1D
      A(4) = -0.077373                                                    DNGR D11
      B(1)=30.D                                                           DNGR D12
      B(2)=19.2                                                           ONGR 013
      B(3)=13.B                                                           DNGR D14
      B(4)=22.5                                                           DNGR D15
      C(1) = 4.5                                                          DNGR D16
      C(2) = 12.5                                                         ONGR 017
      C(3) = 27.5                                                         DNGR 018
      0(1)=16.0                                                           ONGR 019
      D(2)=10.0                                                           DNGR 020
      D(3)= 7.D                                                           ONGR 021
      D(4)= 5.0                                                           ONGR 022
      D(5)= 4.D                                                           DNGR 023
      D(6)= 3.D                                                           ONGR 024
C     TEST TO SEE IF THERE IS SNOW ON THE GROUND

      IF(ISNOW) S,5,1                                                     DNGR 025
C     THERE IS SNOW ON THE GROUND AND THE TIMBER AND GRASS SRREAD INDEXES
C     MUST BE SET TO ZERO.  WITH A ZERO TIMBER SRREAD THE FIRE LOAD IS
C     ALSO ZERO.  BUILD UP WILL 8E ADJUSTED FOR PRECIRITATION.
    1 GRASS=0.                                                            DNGR 026
      TIMBER=0.                                                           DNGR 027
      IF ( PRECIP - .1 ) 4,4,2                                            DNGR 028
C     PRECIPITATION EXCEEOED  .1 INCHES AND WE REDUCE THE BUILD UR INDEX
    2 BUO=-50.*ALOG(1.-(1.-EXR (-BUO/5D.))*EXR (   -1.175*(PRECIR-.1)))  ONGR 029
      IF ( BUO ) 3,4,4                                                    DNGR 030
    3 BUO=0.                                                              DNGR 031
    4 RETURN                                                              ONGR D32
C     THERE IS NO SNOW ON THE GROUND AND WE WILL COMRUTE THE SPREAD INDEXES
C     AND FIRE LOAD
    5 DIF=DRY-WET                                                         DNGR D33
      DO 6 I=1,3                                                          DNGR 034
      IF( DIF-C(I) ) 7,7,6                                                DNGR 03S
    6 CONTINUE                                                            DNGR 036
      I=4                                                                 DNGR 037
    7 FFM=B(I)*EXP (A(I)*DIF)                                             DNGR 03B
C     WE WILL  NOW FIND THE DRYING FACTOR FOR THE DAY
      DO 8 I=1,6                                                          DNGR 039
      IF ( FFM - D(I) ) 8,8,9                                             DNGR 040
    8 CDNTINUE                                                            DNGR 041
      DF=7                                                                DNGR 042
      GO TO 1D                                                            DNCR 043
    9 DF=I-1                                                              DNGR 044
C     TEST TO SEE IF THE FINE FUEL MOISTURE IS ONE OR LESS
C     IF FINE FUEL MOISTURE IS ONE OR LESS WE SET IT TO ONE
   10 IF ( FFM-1. ) 11,12,12                                              ONGR 045
   11 FFM=1.                                                              ONGR 046
C     ADO S PERCENT FINE FUEL MOISTURE FOR EACH HERB STAGE GREATER THAN ONE
   12 FFM = FFM + ( IHERB-1 ) * S.                                        ONGR D47
C     WE MUST ADJUST THE BUI FOR RRECIPITATION 8EFORE ADDING THE ORYING FACTOR
      IF (PRECIR -.1) 1S,1S,13                                            ONGR 04B


C     PRECIPITATION EXCEEOED  0.10 INCHES      WE MUST REOUCE THE
C     BUILO UP INDEX (BUO) BY AN AMOUNT EQUAL TO THE RAIN FALL
   13 BUO=-SO.*ALOG(1.-(1.-EXP (-BUO/SO.))*EXP (-1.17S*(PRECIP-.1)))      DNGR 049
      IF ( BUO ) 14,1S,1S                                                 DNGR 0S0
   14 BUO=D.0                                                             DNGR 0S1
C     AFTER CORRECTION FOR RAIN, IF ANY, WE ARE READY TO ADO TODAY'S
C     ORYING FACTOR TO OBTAIN THE CURRENT BUILO UP INOEX
   1S BUO=BUO+OF                                                          ONGR 0S2
C     WE WILL AOJUST THE GRASS SPREAO INDEX FOR HEAVY FUEL LAGS
C     THE RESULT WILL BE THE TIMBER SPREAD INDEX
C     THE ADJUSTED FUEL MOISTURE, AOFM, ADJUSTED FOR HEAVY FUELS, WILL
C     NOW BE COMPUTED
      ADFM = .9*FFM +.S +9.S*EXP ( -BUO/SO.)                              ONGR 0S3
C     TEST TO SEE IF THE FUEL MOISTURES ARE GREATER THAN 30 PERCENT.
C     IF THEY ARE, SET THEIR INDEX VALUES TO 1.
      IF ( AOFM-30. ) 19,16,16                                            ONGR 0S4
   16 IF (  FFM-3D. ) 18,17,17                                            DNGR 0SS
C     FINE FUEL MOISTURE IS GREATER THAN 30 RERCENT, THUS WE SET THE GRASS
C     AND TIMBER SRREAO INOEXES TO ONE.
   17 GRASS = 1.                                                          ONGR 0S6
      TIMBER = 1.                                                         DNGR 0S7
      RETURN                                                              ONGR 0S8
   1B TIMBER = 1.                                                         DNGR 0S9
C     TEST TO SEE IF THE WIND SPEEO IS GREATER THAN 14 MPH
      IF ( WINO-14. ) 21,2S,2S                                            ONGR 060
   19 IF ( WIND-14. ) 20,24,24                                            DNGR 061
   20 TIMBER = .01312*(WIND+6.) * (33.-AOFM)**1.6S - 3.                   DNGR 062
   21 GRASS  = .01312*(WIND+6.) * (33.- FFM)**1.6S - 3.                   ONGR 063
      IF ( TIMBER-1. ) 22,22,28                                           DNGR 064
   22 TIMBER = 1.                                                         DNGR 06S
      IF ( GRASS-1. ) 23,28,28                                            ONGR 066
   23 GRASS = 1.                                                          ONGR 067
      GO TO 28                                                            DNGR 068
C     WIND SPEED IS GREATER THAN 14 MRH.  WE USE A DIFFERENT FORMULA.
   24 TIMBER = .00918*(WIND+14.) * (33.-ADFM)**1.6S - 3.                  DNGR 069
   2S GRASS  = .00918*(WIND+14.) * (33.- FFM)**1.65 - 3.                  DNGR 070
      IF ( GRASS-99. ) 28,28,26                                           DNGR 071


   26 GRASS = 99.                                                         DNGR 072
      IF ( TIMBER-99. ) 28,28,27                                          DNGR 073
   27 TIMBER = 99.                                                        DNGR 074
C     WE HAVE NOW COMRUTED THE GRASS AND TIMBER SPREAD INDEXES
C     OF THE NATIONAL FIRE DANGER RATING SYSTEM.  WE HAVE THE
C     8UILD UP INDEX AND NOW WE WILL COMPUTE THE FIRE LOAD RATING
   28 IF ( TIMBER ) 30,30,29                                              DNGR 07S
   29 IF ( 8UO ) 30,30,31                                                 DNGR 076
C     IT IS NECESSARY THAT NEITHER TIMBER SRREAD NOR 8UILD UP 8E ZERO
C     IF EITHER TIMBER SPREAD OR BUILD UP  IS ZERO, FIRE LOAD IS ZERO
   30 RETURN                                                              DNGR 077
C     80TH TIM8ER SPREAD AND 8UILD UP ARE GREATER THAN ZERO
   31 FLOAD=1.7S*ALOG10( TIMBER ) + .32*ALOG10( 8UO ) - 1.640             DNGR 078
C     ENSURE THAT FLOAD IS GREATER THAN ZERO, OTHERWISE SET IT TO ZERO.
      IF ( FLOAD ) 32,32,33                                               DNGR 079
   32 FLOAD = 0.                                                          DNGR 080
      RETURN                                                              DNGR 081
   33 FLOAD = 10. ** FLOAD                                                DNGR 082
      RETURN                                                              DNGR 083
      END                                                                 DNGR 084
```


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1969

U. S. FOREST SERVICE

RESEARCH NOTE NC-80

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Characteristics of Blister Rust Cankers on Eastern White Pine

ABSTRACT. — The growth, development, and sporulation of white pine blister rust cankers were studied on eastern white pine in Wisconsin and Minnesota. Three distinct canker types were identified on the basis of physical appearance, growth rate, and sporulation. Canker growth rate and sporulation decreased as tree size or age increased, and many cankers apparently became inactive. High mortality of branch cankers was associated with older trees, heavily stocked stands, and small branch diameter.

OXFORD: 172.8 *Cronartium ribicola:* **174.7** *Pinus strobus:* **(775) (776)**

The physical appearance, growth, and sporulation of white pine blister rust (*Cronartium ribicola* Fischer) cankers on eastern white pine (*Pinus strobus* L.) were studied from 1962 to 1967 in the high hazard blister rust zone of northern Wisconsin and Minnesota. These cankers exhibited substantial natural variation in both appearance and growth characteristics. Information on natural variation is of value not only because of general biological interest but also because it may aid in future evaluation of chemical treatments. It is now known that many cankers do not fit the standard "textbook" description. Failure to recognize this variation in canker appearance led to misinterpretation of results in some early tests, in which antibiotics were concluded to have controlled white pine blister rust.

METHODS

The study trees ranged in age from 8 to 31 years and in size from 2 to 10 inches d.b.h. They were all untreated control trees from other experiments conducted to evaluate the effectiveness of chemicals for white pine blister rust control. All trees had at least one apparently active bole canker that girdled less than 60 percent of the stem. Most bole cankers originated when the trees were seedlings or saplings, and 94 percent were less than 8 feet above the ground. The physical appearance of more than 15,000 cankers was recorded prior to chemical treatment. In addition, growth of 400 bole cankers and 81 branch cankers was measured annually over the 5-year period on control trees that were not treated with chemicals.

RESULTS AND DISCUSSION

Examination of blister rust cankers on eastern white pine showed the presence of three distinct types of bole cankers. The typical, or "textbook," canker is confined almost entirely to young trees and the smooth-barked portion of older trees. This is a relatively young canker with a yellow-green or orange-green margin that is usually rather puffy in appearance (this marginal color is enhanced by wetting and scrubbing the bark). Such cankers usually produce spores and grow the fastest. With increasing age of both host and canker, there is a gradual change in appearance, growth, and sporulation pattern. Margin coloration usually disappears entirely as the bark roughens on older wood. Canker growth slows down, particularly in the vertical direction, and portions of the canker margin apparently become inactive. Ridges of callus may develop along the lateral margins of the canker. As a result, tree mortality rate decreases with age and in some instances tree diameter growth may exceed the rate of girdling. Sporulation decreases as the canker and tree get older.

The second type, which made up 10 percent of all cankers observed, has no marginal coloration on smooth-barked trees, even when the canker and the tree are young. These cankers, which do not sporulate, develop on both branches and bole; a distinct margin is evident between the brown, necrotic face of the canker and the surrounding live, green bark. Their growth on the bole is usually more rapid laterally than vertically.

The third type of canker, confined primarily to pole-size and larger trees, has a callus ridge on both sides of the entry branch from which blister rust invaded the bole. The canker thus has the appearance of a deep, narrow groove in the bole, extending several inches to several feet in length. A small necrotic area is found around the entry branch and in most instances no other symptoms are visible—externally, these cankers appear to be naturally arrested. They have no marginal coloration and do not sporulate. Occasionally, canker activity develops beyond the callus ridge and normal blister rust symptoms (i.e., color and sporulation) appear on the opposite side of the bole. About 5 percent of all cankers observed were of this type.

The last two types of cankers are probably more abundant than these percentages indicate because the sample trees on which the percentages are based were selected to meet certain requirements for the chemical tests and are not representative of the genral population of infected trees.

Canker Growth

Bole cankers.— As tree size or age increased, average canker growth rate decreased, and many cankers apparently became inactive (table 1). Growth rate varied greatly among individual cankers within a diameter class and even in the same canker from year to year. Average canker growth was also greater on trees in the most northerly plot locations. As was pointed out earlier in the paper, most of the cankers included in this study were well-established infections. It should be recognized that the decreased canker growth rate with increased tree age is due at least in part to the nature of the sample trees — many older trees with fast-growing infections would have been more than 60 percent girdled, thus excluding them from the sample.

Table 1. — *Growth of blister rust bole cankers*[1]

D.b.h. class (inches)	Average d.b.h.[2]	5-year tree mortality	Cankers	Bole cankers		
				Average annual increase		Natural canker inactivation[3]
				Length	Girdling	
	Inches	Percent	Number	Inches	Percent	Percent
1.0- 4.0	2.9	26	123	4.2	12.6	1
4.1- 6.0	5.0	19	107	3.6	10.0	2
6.1- 8.0	6.9	4	144	2.9	6.8	6
8.1-10.0	8.5	0	26	2.8	6.6	9

1/Distance from a central point on the canker to the vertical and lateral margins was measured to determine growth rate.
2/At start of observation period.
3/No apparent sign of life.

Branch cankers. — Fatal bole infections usually develop from branch cankers. Only 9 percent of the branch cankers on 9- to 13-year-old trees died during the 5-year study period, but a much higher percentage died on 25- to 35-year-old trees due primarily to death of infected branches from shading (table 2). In the 25- to 35-year-old plantations, approximately 45 percent of the branch cankers died in relatively open stands and 70 percent in heavily stocked stands. Stocking level, therefore, is important in determining the amount of fatal bole infection that subsequently develops. Branch diameter, as well as degree of shading, was found to be related to canker mortality. Mortality varied from about 30 percent on branches over 1.6 inches in diameter to 70 percent on branches under 0.5 inch in diameter.

Table 2. — *Analysis of branch cankers during a 5-year period*

SEEDLINGS 8-13 YEARS OLD

Branch diameter class (inches)	Branch cankers	Average annual growth toward the bole	Cankers alive but still in branch at end of 5 years	Cankers that entered bole during 5 years	Cankers dead at end of 5 years
	Number	Inches	Percent	Percent	Percent
0-1.0	13	3.1	29	62	9
POLES 25-35 YEARS OLD					
0-0.5	28	1.9	16	14	70
0.6-1.0	29	2.3	4	40	56
1.1-1.6	17	2.3	5	39	56
1.7+	7	2.1	12	58	30

Canker Sporulation

Production of aecia by bole cankers varied with tree age, locality, and year. On nearly all plots bole canker sporulation and aecial production decreased with increasing tree and canker age. The Minnesota test area showed a consistently lower percentage of cankers producing aecia. This was probably due to parasitism of the rust by the fungus *Tuberculina maxima* Sacc., because this was the only test area where it was present to any extent.

The young, vigorous cankers began aecial production in early May, while the older cankers on roughbark trees began as late as mid-June and did not produce aecia at all in most years. Aecial pustules were numerous on young cankers and sparse on older ones. Occasionally pustules were produced under rough bark that were not visible on the surface.

Pycniospores were produced over several months, starting about the first of June and continuing into September and October. A much higher percentage of cankers produced pycnia than aecia, and sporulation extended over a greater portion of the canker margins. On some cankers the portions producing pycnia were outlined with map pins, and in many cases these areas did not produce aecia in following years.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-81

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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THE CURRENT STATUS OF PRESCRIBED BURNING IN THE LAKE STATES

ABSTRACT. — Describes the current usage of prescribed fire in the Lake States. Costs are summarized for each purpose and reasons for cost differences are discussed.
OXFORD: 436:156.2(774/776)

The use of prescribed burning is increasing in the Lake States. A survey was made in Minnesota, Wisconsin, and Michigan during the 1968 field season to determine what agencies are currently doing prescribed burning, their reasons for burning, and their costs.

The survey showed that approximately 13,800 acres were burned by prescription in the three States during 1968 (table 1). About 13,000 acres of the total were burned for wildlife habitat improvement, about 550 acres were burned for forest regeneration purposes, and 50 acres were burned for blueberry production. Approximately 7,500 acres (55 percent of the total area burned) were burned at the Crex Meadows Wildlife Area managed by the Wisconsin Department of Natural Resources.

Costs of prescribed burns ranged from $0.15 to $18.77 per acre. Generally, the wildlife habitat burns were largest and cost less per acre than the forest regeneration burns.

Cost-per-acre differences among the various agencies were not great, but tended to be lowest among the more experienced operators. The greatest cost differences were associated with the purposes for making the burns. For example, burning for seedbed preparation was more expensive than for improving wildlife habitat.

Conclusions

Even though prescribed burning is being used more frequently, it is not yet widely used by land-management agencies in the Lake States. The reasons for this are not clear, but probably lack of experience and training in the use and application of prescribed fire is the chief one. However, costs of prescribed burning are competitive with costs of other techniques available, and its use should increase in the future.

Methods of reducing costs per acre include burning under the least hazardous conditions possible commensurate with accomplishing the objective, improving the ignition and control techniques, and providing thorough training on how to execute the burns. Area ignition shows great promise as a means of reducing the manpower and length of time required to burn large areas, as well as reducing control problems.

Table 1.—*Summary of reported prescribed burns during the 1968 field season in the Lake States*

OPERATIONAL BURNS

Agency	Area burned	Purpose	Average cost per acre
	Acres		Dollars
Bureau of Sport Fisheries and Wildlife	1,364	Wildlife management	0.41
Michigan Department of Conservation	556	Wildlife management	3.02
Minnesota Department of Conservation	1,280	Wildlife management	1.48
	144	Seedbed preparation	8.48
	104	Planting site preparation	7.64
U.S.D.A. Forest Service	250	Planting site preparation	3.77
	50	Blueberry production	5.00
	45	Seedbed preparation	13.00
	270	Wildlife management	1.94
Wisconsin Department of Natural Resources	9,772	Wildlife management	.32
	34	Planting site preparation	4.81
	13,869		

EXPERIMENTAL BURNS

Agency	Area burned	Purpose
University of Minnesota	235	Natural area maintenance
U.S.D.A. Forest Service	350	Jack pine seedbed preparation
Minnesota Department of Conservation in coopera-tion with Univ. of Minn.	330	Ruffed grouse habitat
Minnesota Department of Conservation	21	Black spruce seedbed preparation
	936	

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1969

U. S. FOREST SERVICE

RESEARCH NOTE NC-82

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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EFFECT OF WATERSHED COVER ON OVERLAND FLOW FROM A MAJOR STORM IN SOUTHWESTERN WISCONSIN[1]

ABSTRACT. — A runoff study in the Driftless Area showed that both total flow and peak rate of flow from a 3-hour, 4-inch rain were strongly affected by the watershed cover. Peak flows ranged from 2.42 inches per hour for alfalfa meadow to 0.010 inch per hour for undisturbed forest. The timing of flow on open-land and forested watersheds was surprisingly similar. OXFORD: 116.21:116.25(775)

Flash floods from thunderstorms are a common occurrence in southwestern Wisconsin's rugged Driftless Area. Because of the deep soils and porous bedrock, rainfall that infiltrates the soil does not normally contribute to flood flows. Floods result only when restricted infiltration produces overland flow. Because soil cover largely determines how fast the soil takes up water (or yields overland flow), land use has a strong influence on flash floods in this area.

Early work by Bates and Zeasman (1930) and a later study by Hays, McCall, and Bell (1949) showed that relatively undisturbed forest land in the Driftless Area yielded little overland flow. Flood source studies now being conducted on the Coulee Experimental Forest near La Crosse have strengthened this general observation (Curtis 1966) and are also providing new information for other watershed conditions. A high-intensity storm that hit the experimental forest in June 1968 gave us an excellent chance to compare flows from six different cover conditions: undisturbed, logged, and grazed forest, alfalfa meadow, old field, and "goat prairie."

The Study Watersheds

Undisturbed forest. — As used here, "undisturbed" means *relatively* undisturbed. The forest cover is pole-to-sawtimber-size oak-hickory, typical of the high-graded farm woods in the area. One of two watersheds classed as undisturbed had been selectively logged (logger's choice) in 1960, and both had been pastured for many years until 1960.

Logged forest. — The logged watershed was clear cut in the fall of 1966 as part of a timber management study. Two-thirds of the watershed was logged with a minimum of disturbance to the soil.

Grazed forest. — The grazed watershed has a forest cover in poor condition and some patches of prairie. It is also traversed by a tractor road, which contributes to overland flow. The area has been used as pasture for many years, and because of the condition of the forest cover and the amount of exposed soil it is an extreme example of grazed forest.

[1] *This research was done in cooperation with the Wisconsin Department of Natural Resources.*

Alfalfa meadow. — These watersheds were in third-year alfalfa that had not yet been cut at the time of the storm.

Old field. — The medium-density cover on this area consists of Kentucky bluegrass, wild carrot, goldenrod, and other herbaceous plants. This area had been cropped and pastured for many years until 1960.

Goat prairie. — The term "goat prairie" is a local name given to the steep, rocky, south-facing, natural prairie slopes that are a distinctive part of the Driftless Area landscape. The goat prairie studied has a thin cover of big bluestem, other native grasses and forbs, and Kentucky bluegrass. It is on a steep (50 percent) slope that had been grazed for many years until 1960.

The forested watersheds are single ridge-to-valley topographic units with sharp divides. Size ranges from 20 to 60 acres, and the average slope is about 40 percent. The meadow and old-field watersheds are segments of ridgetop fields that lie above forested slopes. The segments are bounded by natural divides on the sides and top but are terraced at the bottom to cut off downslope runoff and channel it to the flume. Size ranges from 1.5 to 2.0 acres and slope averages about 15 percent. The goat-prairie watershed is a long, narrow strip of slope 1.3 acres in area bounded by a ridge at the top and a terrace at the bottom. The artificial terraces might affect rate, but not volume, of flow. Thus, the open-land watersheds might better be described as natural runoff plots. However, in this area of intermixed forest, field, and prairie, they are as close as we can come to actual watersheds in a single open-land use.

Flow from all areas was measured with H-type flumes equipped with water-level recorders. The runoff measured was entirely overland flow. None of the watersheds produces either base or seepage flow, even during heavy rainfall periods.

The Storm

The rain fell between 12:10 a.m. and 5:10 a.m. on June 21, 1968. Total rainfall was 4 inches, of which 3.8 inches fell in the first 2 hours and 15 minutes. Maximum amounts that fell in various time intervals during the storm and their probable recurrence according to the Rainfall Frequency Atlas of the United States (U.S. Department of Commerce, Weather Bureau 1961) are as follows:

Time interval	*Rainfall amount*	*Rainfall frequency*
(minutes)	(inches)	(years)
15	0.90	......
30	1.45	5
60	1.85	5
120	3.00	50
180	4.00	100

Total storm rainfall was surprisingly uniform on the experimental forest. The amounts caught by two recording gages 2 miles apart differed by only 0.04 of an inch, and the two charts showed identical intensity patterns.

Watershed Response

Both total and peak flows from study watersheds were strongly affected by land use (fig. 1). The peak flow of 2.4 inches per hour from meadow was 1.8 times the peak from old field, 5 times the peak from grazed forest, and 32 times the peak from logged forest. Total flow followed a similar pattern. The small flow from goat prairie upsets the view held by some that these steep, sparsely vegetated slopes are high runoff producers. Although the flow from old field was high compared with the flow from any of the forest conditions, it would be low compared with flows from tilled cropland. Runoff from meadow is generally much lower than from tilled land. Thus, simply idling cropland with no further treatment reduces runoff substantially.

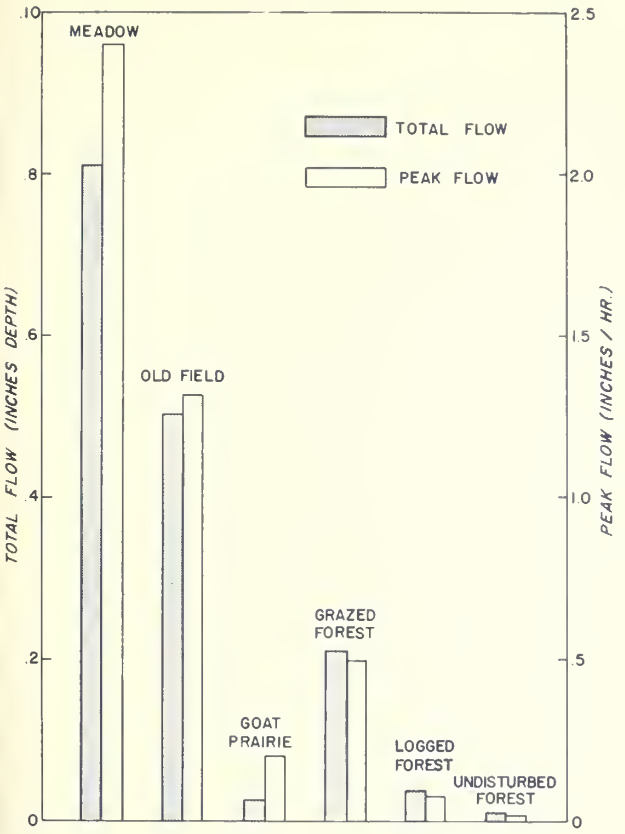

Figure 1.— Total and peak flows for watersheds in different cover conditions.

Although grazed forest runoff was high compared to logged forest, undisturbed forest, and goat prairie runoff, it was low compared to meadow runoff. Because the grazed forest watershed studied probably represents an extreme condition for grazed forest land, it appears that forest-land pastures are not an important source of flood runoff.

Considering the differences in size and topographic makeup between the open-land and forested watersheds, timing of flow was surprisingly similar on both types. Runoff began on all the open-land watersheds 60 minutes after it began to rain, and on the forested watersheds just a few minutes later. However, flows on the alfalfa meadow, old field, and grazed forest watersheds showed much greater fluctuation with short bursts of high-intensity rain than flows on the other watersheds. This difference in watershed response is shown by the hydrographs for a meadow and an undisturbed forest watershed (fig. 2). All

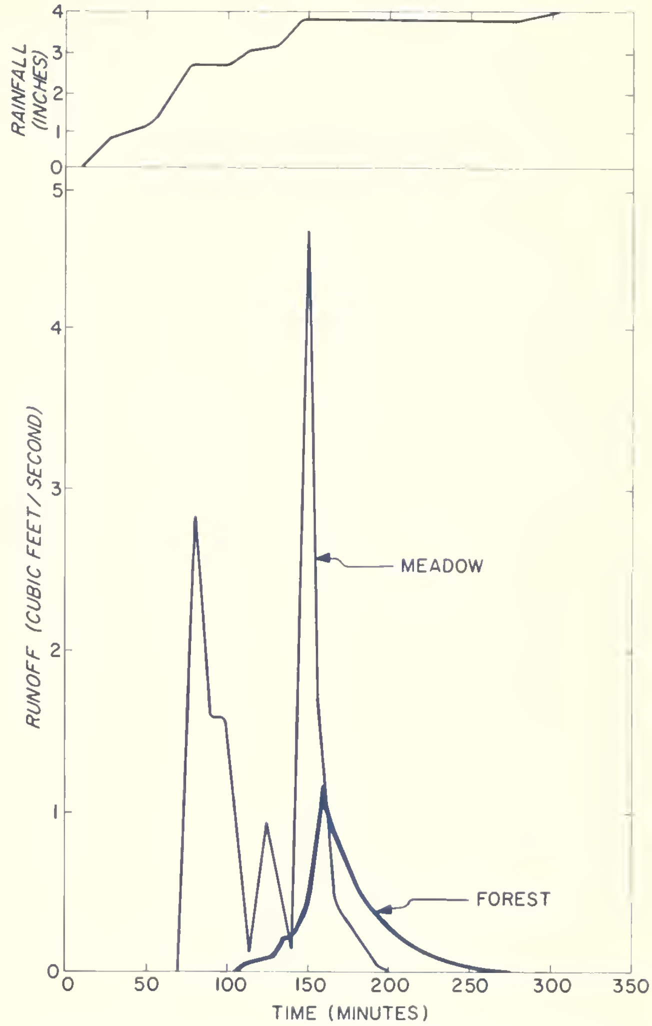

Figure 2. — Mass rainfall curve and hydrographs for a meadow and an undisturbed forest watershed. Note that hydrograph plots are in cubic feet per second. Meadow watershed area is 2 acres, forest watershed area is 61 acres.

watersheds except one (undisturbed forest) had two distinct flow peaks; the timing of these peaks was about the same on all watersheds. The second peak was higher except on the grazed forest watershed and on one of the undisturbed forest watersheds. The cause of this difference in watershed response to the storm is not known, but is probably related to some inherent watershed characteristic.

Although the flows cited here may not be strictly comparable because of differences in the size, shape, soils, and topography of the watersheds, the data do show the relative contribution of some common land uses to rainstorm floods in the Driftless Area.

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1969

U. S. FOREST SERVICE

RESEARCH NOTE NC-83

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

THE GERMINATION OF SEVERAL TREE SPECIES IN PLASTIC GREENHOUSES

ABSTRACT. — The technique of growing tree seedlings in plastic greenhouses is being evaluated for red pine, jack pine, white spruce, and yellow birch at the Chittenden Nursery in northern Lower Michigan. Both a long growing season and a normal-length growing season in plastic greenhouses were compared with standard outdoor nursery beds (control). First-year results showed that germination and survival of red pine and jack pine were significantly higher in the greenhouses than in the control. Also, for red pine, the long growing season was superior to the other greenhouse treatments and the control. Results with white spruce and yellow birch were variable and differences between greenhouse treatments and the control were not statistically significant.
OXFORD: 232.329.1:U678.5:181.525

Researchers in northern Europe have found that plastic greenhouses substantially increase germination and growth of forest-tree seedlings. Nursery managers in Finland have been able to reduce production time for pine and fir by 1 year with this method[1,2]. As the first step in evaluating this technique for growing red pine, jack pine, yellow birch, and white spruce at the Chittenden Nursery in northern Lower Michigan, we compared first-year germination and survival of seedlings grown under the following conditions: (1) a long growing season under plastic, (2) a normal-length growing season (with and without supplemental heat) under plastic, and (3) standard outdoor nursery beds.

The greenhouses measured 16 x 20 x 8 feet, and had a door with a transom vent near the top at each end (fig. 1). The area within each greenhouse was divided into four seedbeds of equal size, and each species was randomly assigned to one of the beds. The greenhouse frameworks were erected in the fall but were not covered with plastic until spring. Seed was broadcast sown in the fall on ordinary nursery soil with a small fertilizer-seed spreader at a rate that produces about 35 seedlings per square foot under standard nursery conditions.

F-519458

Figure 1. — View of greenhouses with vents open. Irrigation line in foreground was used for watering greenhouse and control seedbeds.

[1] *Bergman, F., and Leskinen, U. Plant production under plastic. Skogen. 50:216-291. 1963.*

[2] *Bergman, F., and Leskinen, U. Production de plants forestiers sous plastique en Suede. Pepinieristes Hort. Maraichers 46: 1929-1935. 1964.*

The following treatments in a randomized block design with two replications were initiated the next spring: (1) long season — greenhouses were covered March 1 with ultraviolet-resistant polyethylene and heated with an electric heater to maintain a minimum temperature of 45° F.; (2) normal season (heated) — greenhouses were covered with polyethylene when germination began (about May 1), and heated as above; (3) normal season (unheated) — same as above except no artificial heat was used; (4) control — standard outdoor nursery beds.

About 1 foot of snow was on the ground when the greenhouses were covered for the long-season treatments on March 1, but it melted completely after about a week. All species began germinating in this treatment by March 29. All species were germinating in the remaining seedbeds by May 1, and the normal-season greenhouses were then covered. On clear summer days the vents in the greenhouses were opened to reduce heat buildup. Nevertheless, air temperature in the greenhouses exceeded 100° F. several times during the summer. Soil temperature in the greenhouses ½-inch beneath the surface averaged 5 to 10 degrees higher than outside. In late September the plastic covers and electric heaters were removed.

Live seedlings were counted on randomly selected plots in all treatments and replications 2, 4, and 6 weeks after germination began, and again in the fall when the plastic was removed. Initial germination was highest in the long-season treatment, and this treatment maintained the greatest number of seedlings throughout the growing season. Seedling germination differences between the heated and unheated normal-season greenhouse treatments were insignificant. By the end of the season the greenhouse treatments had produced a greater number of seedlings per square foot than the control for all species (table 1). However, the differences were statistically significant (at the .05 level) only for jack pine and red pine. Also, the long-season treatment resulted in a significantly greater number (.05 level) of red pine seedlings than any of the other treatments. Mortality did not appear to be affected by treatment except in the case of yellow birch, where more seedlings died in the greenhouses than in the control.

The results of this study showed that plastic greenhouses can be used to obtain greater first-year germination and survival for jack pine and red pine than standard outdoor nursery beds. The technique could be especially useful for growing stock from high-value seed, such as hybrid or superior-tree seed.

Table 1.— *Average number of live seedlings per square foot by treatment, September 20, 1968*

Species	Greenhouse treatment			Control
	Long season	Normal season (heated)	Normal season (unheated)	
Red pine	32.4	12.3	14.4	4.5
Jack pine	43.7	30.8	26.0	13.2
White spruce	39.9	24.2	18.5	13.7
Yellow birch	37.1	31.2	28.2	9.2

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U. S. FOREST SERVICE

RESEARCH NOTE NC-84

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

SURVIVAL AND GROWTH OF EASTERN REDCEDAR SEED SOURCES IN SOUTHWEST MISSOURI

ABSTRACT. — After five growing seasons on a southwest Missouri outplanting site, trees from a West Virginia eastern redcedar source had better survival, form, vigor, and height growth than trees from eight other sources tested. The local Missouri source, handicapped at planting by an unfavorable top:root ratio, is now growing vigorously.
OXFORD: 232.311.21:174.7 *Juniperus virginiana:* **232.324:232.43(778)**

Eastern redcedar (*Juniperus virginiana* L.) shows much geographic variation in growth rate, form, foliage color, and other traits. In 1961 a study was begun to evaluate trees from several redcedar sources outplanted in six northern and central states for the purpose of finding superior sources for planting in these areas. Early results of the planting in southwest Missouri show that there are differences in tree survival, height growth, and form among the sources.

Methods

Seed collected from 16 sources within the natural range of the species was sown in the fall of 1961 in the George White Nursery in Licking, Missouri.[1] In the spring of 1962 seeds in only 8 of the 16 seed lots germinated. All sources were held in the nursery for another year in the hope of delayed germination, but no additional seeds germinated in the second year. In the spring of 1964 the 2-0 stock from the 8 sources (table 1) was planted on the Ava Ranger District of the Mark Twain National Forest (Taney County). Unfortunately, all of the 2-0 stock was somewhat larger than desired, with top:root ratios ranging from 3.3 to 5.7. Seedlings grown from local seed (Christian County, Missouri) were exceptionally large (fig. 1) because of low density in the nursery bed resulting from poor seed germination. Nursery-run 1-0 seedlings from a Nebraska source were also included in the test plantings. The plantings were laid out in a randomized complete block design with 12 replicates of 15-tree plots. Prior to herbiciding, the planting site supported an oak-hickory stand with a black oak site index of 60.

The seedlings were measured at the end of the first, second, and fifth growing seasons after outplanting. Form and vigor of the seedlings were classified as good, fair, or poor:

Form

Good — a single straight stem
Fair — some crook in the main stem
Poor — one or more forks

[1] *The cooperation of the Missouri Conservation Department in growing the planting stock for this study is appreciated.*

Table 1.—*Characteristics of trees from nine redcedar seed sources 5 years after planting*

Seed source number and origin	Mean survival	Mean height growth	Good form	Good vigor
	Percent	Feet	Percent	Percent
10 Mason Co., northwestern W. Virginia	[1] 80 ± 9	[1] 4.7 ± 0.2	62	72
20 Seward Co., southeastern Nebraska	78 ± 3	3.1 ± 0.2	31	21
9 Buffalo Co., western Wisconsin	65 ± 5	3.1 ± 0.3	25	25
12 Ellis Co., central Kansas	59 ± 5	2.6 ± 0.2	23	1
14 Trego Co., central Kansas	49 ± 7	2.4 ± 0.2	18	14
13 Riley Co., northeastern Kansas	49 ± 5	3.2 ± 0.3	34	5
16 Madison Co., east central Kentucky	41 ± 4	3.3 ± 0.2	30	37
8 Christian Co., southwestern Missouri	37 ± 5	4.1 ± 0.2	41	26
11 Montgomery Co., west central Arkansas	32 ± 7	4.2 ± 0.3	47	59

1/ The ± figures indicate standard error of the mean.

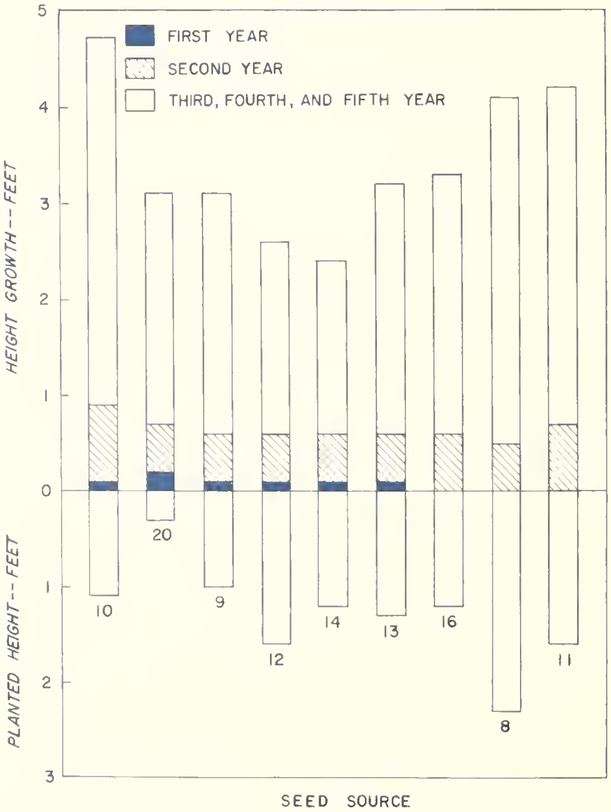

Figure 1.— Height after planting and at end of first, second, and fifth growing seasons.

Vigor

Good — all foliage on tree having a normal, healthy appearance

Fair — one-half or less of foliage dead

Poor — more than one-half of foliage dead

Results

After 5 years, trees from the West Virginia source had the best survival, greatest height growth, and best form (fewest trees with forks) (table 1). Survival of the 1-0 seedlings from the Nebraska source was also good, but almost 50 percent of the trees had poor form. The variation in mean height growth within sources was small and uniform among all sources (± 0.2 to 0.3 ft.). Within-source variation in mean survival was also similar among sources (± 3 to 9 percent).

The seedling-survival patterns of the nine seed sources after the first, second, and fifth growing seasons suggest that the true potential of the Kentucky, Missouri, and Arkansas stock is not indicated by the poor survival after 5 years. In these sources there was high seedling mortality (50 to 60 percent) during the first growing season, followed by a small loss the second year. During the next 3 years, however, there was little or no mortality, suggesting that the great initial mortality was caused by imbalance of top and root.

The height-growth patterns of seedlings of the Kentucky, Missouri, and Arkansas sources also indicate that the roots of these seedlings were too small in relation to the size of the tops (fig. 1). There was no height growth during the first growing season; in fact, many seedlings died back. During the second year, however, these seedlings grew as well as seedlings from the other sources.

The poor survival and growth of seedlings from the two central Kansas sources (12 and 14) was probably a result of the seedlings not being suited to the planting site, rather than because of excessive seedling size. Survival and height growth of seedlings during the first year were as good as those of the West Virginia seedlings. However, mortality was high during the next 4 years, especially in the Trego County, Kansas, source, and growth of the surviving trees was slow.

As might be expected, there was a relationship between the vigor of the trees after 5 years, as expressed by the amount of living foliage, and the height growth. Seedlings from the two sources from central Kansas had the poorest height growth, and also the largest percentage of dying trees. In contrast, the two sources with the fastest growing seedlings — West Virginia and Arkansas — had the greatest percentage of trees in the good vigor category (table 1).

Needle blight fungi (*Cercospora* spp. and *Piricanda* spp.) were found on the dead foliage of the seedlings.[2] It appears that seedlings of the two central Kansas sources were more susceptible to these needle blights than seedlings of the other sources. There was little difference among sources in foliage color or crown shape. The living foliage on all sources was a normal green and most of the trees had a roughly conical shape.

Better survival and growth would probably have resulted if seedlings had been intermediate in size between the small Nebraska 1-0 stock and the large 2-0 stock of the other sources. The 1-0 stock had an average stem diameter at the root collar of 0.07 inches and height of 0.3 feet. In contrast, the Missouri 2-0 stock, which grew at low density because of poor germination, had a root collar diameter of 0.4 inches and a height of 2.3 feet. First-year survival of this large stock with

[2] *Identification of the needle blight fungi was made by Dr. Merton Brown, University of Missouri Pathology Department.*

poor balance between top and root was less than 50 percent. Stoeckeler and Slabaugh[3] recommend that redcedar nursery stock be transplanted after 1 year to produce a more fibrous root system and a top:root ratio of from 2.0 to 3.5. The use of 1-1 transplants or 1-0 seedlings grown at a lower density in the nursery bed would probably increase first-year survival on many of the droughty planting sites in the Missouri Ozarks.

Observations and measurements will be continued to give long-term evaluation of the sources. Growth and survival in the last three growing seasons, during which the impact of planting-stock quality should have been declining, indicate that seedlings from the Arkansas, Missouri, and West Virginia sources will continue to grow vigorously. Until these sources have been more fully evaluated, however, seedlings grown from local seed should be used for planting in the Ozark region.

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1969

[3] *Stoeckeler, J H., and Slabaugh, P E. Conifer nursery practice in the prairie-plains. U.S. Dep. Agr. Handb. 279, 93 p. 1965.*

U. S. FOREST SERVICE
RESEARCH NOTE NC-85

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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RELATION OF SNOWPACK ACCUMULATION TO RED PINE STOCKING

ABSTRACT. — A snow accumulation study was conducted in a 33-year-old red pine plantation thinned to different stocking levels. Snowpack water content increased an average of 2 percent for each 10 square feet of basal area reduction, within the range of 60 to 180 square feet of basal area. Reducing plantation stocking from 180 to 60 square feet of basal area per acre would result in 1.4 to 1.9 inches of additional water in a winter when 6 to 8 inches of precipitation were received.
OXFORD: 111.784:228.1:174.7 *Pinus resinosa* **(774)**

Two-thirds (420,000 acres) of the forest plantations in northern Lower Michigan are either red pine (*Pinus resinosa* Ait.) or mixed red and jack pines (*Pinus banksiana* Lamb.) (Stone and Chase 1962). Many plantations are now reaching the size and stocking level where they must be thinned periodically. Present economic guidelines for thinning red pine are based on expected returns from timber (Lundgren 1965). Possible changes in value of other forest resources following thinning are usually not considered, primarily because of the lack of quantitative information about the effect of stocking level on these resources. This paper describes the results of a study designed to determine the relation between red pine density and snow accumulation, and provides some of the information necessary to incorporate the effects of thinning on water yields into management guidelines.

Methods

The study was conducted from 1967 to 1969 in a 33-year-old red pine stand, located 20 miles west of Cadillac in the northwest corner of the Lower Pen. sula of Michigan. The stand is on Kalkaska and Rubicon soils with a site index potential of 70. In 1960 portions of the stand were thinned to stocking levels of 30, 60, 90, 120, and 150 square feet of basal area per acre. Additional thinning was done in 1966 to maintain the plots at their designated stocking levels. Two plots with initial stocking of 166 and 176 square feet were left unthinned. Nineteen plots were selected for snowpack measurements (fig. 1). All plots were 0.4 acre in size and were 132 feet (about 3 tree heights) across.

Some plots were thinned from below, some from above, and some by a combination of both. Others were thinned by removing every second or third row (rows were oriented north-south). However, the effects of the different thinning methods on snowpack water content were not detectable with the sampling intensity used, and in any event, appeared smaller than the effects of reduced stocking.

Snow measurements were made along a 50-foot line that crossed several tree rows near the center of each plot. Ten snow samples were taken at 5-foot intervals along the line using a Mt. Rose snow tube and scales. The 10 samples were emptied into a pail and the accumulated sample was weighed and recorded.

The winter snow accumulation period usually has at least one period of rain or snowmelt. Melt rates and snowpack water loss would be expected to be greatest in the lower density plots (Eschner and Satterlund 1963, Goodell 1959, Kittredge 1948). Because these are the same plots that have the greatest snowpack accumulation, the accelerated water loss could partially or even entirely obscure the accumulation differences. Consequently, sampling dates were

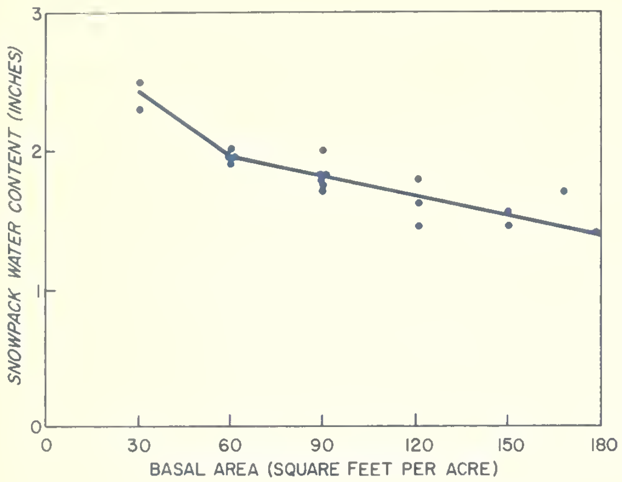

Figure 1.—Snowpack water content at different basal areas for one 32-day storm period of 2.4 inches total precipitation. Each point represents the mean water content of one plot.

selected so that periods of snowpack accumulation could be separated from periods of water loss due to midwinter snowmelt or rain. Snowpack measurements were usually made several days after every snow accumulation period (after the intercepted snow had left the crowns, but before any snowmelt water loss had occurred) and after every period of snowmelt that produced water loss from the snowpack. Thus, it was possible to separate the effect of stand density on snowpack accumulation without the confounding effect of intermittent melting. Snow accumulation periods that did not have pre- and post-snowfall measurements according to the above criteria, or that contained substantial amounts of rain or snowpack water loss, were rejected from the analysis.

Results

Eight snow accumulation periods ranging from 3 to 33 days, were selected for analysis from the three winters of record. In each period there was an obvious trend toward greater snowpack water content with lower residual stocking. A typical trend for one snowpack accumulation period is illustrated in figure 1.

Plots thinned to 30 square feet of basal area had snowpack water contents consistently higher than less heavily thinned plots. These low stocking level plots appeared as holes in the canopy, and may have accumulated more snow than they would have if the same stocking level was maintained over a large area. In fact, there was no significant difference ($p = .05$) between the snow water content caught in the 30-square-foot plots during snow accumulation periods and that caught in the nearest precipitation station located in a forest opening 4 miles south. Therefore, the snow water content in the 30-square-foot plots (mean of two plots) was used as the total precipitation for the accumulation periods analyzed.

Snowpack water content decreased at higher stocking levels for all eight accumulation periods (fig. 2).

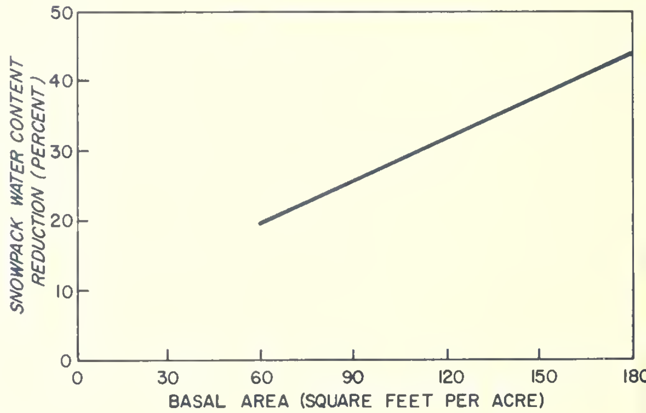

Figure 2.—Reduction in snowpack water content at different basal areas as a percentage of total precipitation. Based on mean of eight accumulation periods.

The smallest snowpack water content, which occurred at the 180-square-foot[1] stocking level, ranged from 34 to 69 percent and averaged about 44 percent of the precipitation.

[1] *No plots were actually thinned to 180 square feet of basal area. Data for this level were obtained by extrapolating the trend lines past 176 to 180 square feet.*

The difference in snowpack water content between plots of different stocking levels increased as snowfall increased (fig. 3). The upper curve shows the difference between 0 and 180 square feet of basal area for different size storms. The lower curve provides a more useful comparison for the forest manager. It shows the difference in snowpack water content resulting from maintaining plantations at 180 square feet rather than 60 square feet. For example, the snowpack contained 0.5 inch less water in a 180-square-foot plot than in a 60-square-foot plot after 2 inches total precipitation, with an average difference for all storms of about 25 percent.

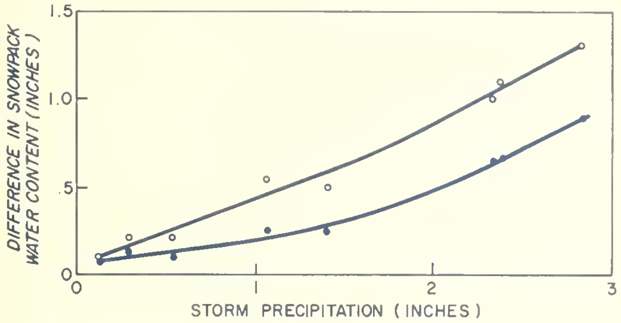

Figure 3.—Difference in snowpack water content for selected stocking-level alternatives over a range of precipitation. The upper curve shows reduction in snowpack water content from managing at 180 square feet of basal area as compared with clear cutting; the lower curve shows reduction from managing at 180 square feet as compared with 60 square feet.

Using the above data, it is possible to estimate the increase in snowpack water content for a given reduction in stocking level. Assuming that the effect of stocking on snow accumulation is linear over the range in stocking levels of 60 to 180 square feet of basal area, and that an average of 24 percent more snow is accumulated at 60 square feet than at 180 square feet, there would be a 2-percent increase in the snowpack water content for each reduction of 10 square feet of basal area between 180 and 60. The effect of basal area reduction for different accumulated snowpack water contents up to 8 inches is shown in figure 4.

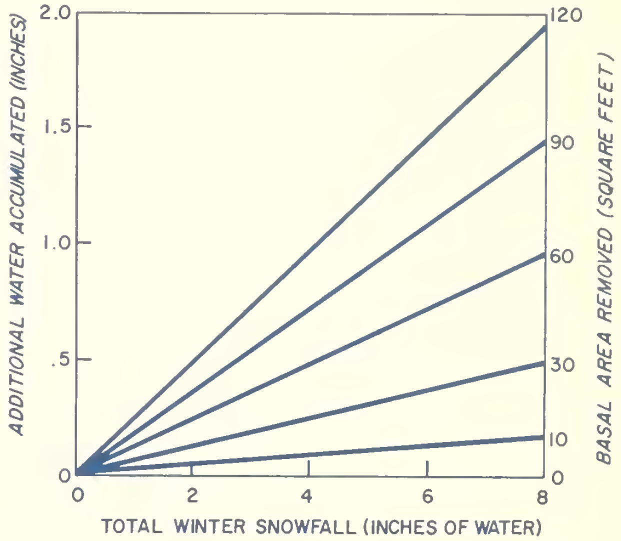

Figure 4. — Additional snowpack water accumulated for given levels of basal area reduction and given total winter snowfall. Relationshps are for a 33-year-old red pine stand with initial stocking of 180 basal area and site index 70.

Total annual precipitation in the study area averages 32 inches (U.S. Weather Bureau 1956). Eight inches, or about 25 percent, comes from December to March, mostly in the form of snow. In this area of highly permeable sands, most snowmelt infiltrates the soil to recharge the ground-water supply, with little contributing to direct surface runoff. It has been demonstrated that the amount of ground-water recharge is closely related to the water content of the snowpack under these conditions (Urie 1966). Therefore, it is reasonable to expect that the additional snowpack gained through reduced stocking will result in a proportional increase in ground-water recharge.

The "snowpack water content" data (figs. 1, 2, and 3) also include any snowpack evaporative loss that occurred during the same time periods. Snow accumulation during these periods was apparently typical over the major portion of the winter, and thus should adequately represent the net winter snow accumulation. However, the data do not cover the 2- to 4-week spring snowmelt period, when higher temperatures might have increased evaporative loss (Geiger 1965, Kittredge 1948, West 1962). Because evaporation rates would be expected to be greatest in the plots with low stocking (Kittredge 1948, West 1962) less water would be available for soil moisture recharge. The magnitude of such reduction is not known at present. Also, the differences in snowpack water content could be expected to vary with climate and stand conditions. Factors such as temperature, site, stand age, initial stand density, and previous thinnings might affect the magnitude of the snowpack differences. Therefore, the values in figure 4 should be treated as approximations of the potential water increase at this time.

It should be noted that this study dealt only with snowfall. Because only about 60 percent of the annual ground-water recharge in the study area originates from the December through March snowfall season,[2] during which some of the precipitation is rain, the effect of stand density on the quantity of rain reaching the ground is also important to the water yield picture. Although no local data are available, several interception studies throughout the world have shown that rainfall interception by conifers is at least as great as snowfall interception (Kittredge 1948, Geiger 1965, Rowe and Hendrix 1951). Also, the effect of conifer stocking on rainfall interception (Kittredge 1948) is similar in direction to the snowfall trend presented here.

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[2] *Unpublished data from Dean H. Urie, U.S.D.A. Forest Service, North Central Forest Experiment Station, Cadillac, Mich.*

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RESEARCH NOTE NC-86

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Lake States Pulpwood Production Plummets 413,000 Cords, 1968

ABSTRACT. — This twenty-third annual report shows that the 1968 Lake States pulpwood output dropped to about 3½ million cords from about 4 million cords in 1967. Michigan's roundwood harvest dropped 198,000 cords in 1968, while the Wisconsin and Minnesota harvests each fell more than 125,000 cords. Pulpwood receipts fell ½ million cords below the 1967 level in Wisconsin, but remained steady in Minnesota and Michigan.
OXFORD: 861.0(77):792

Lake States pulpwood production in 1968 declined to 3,552,000 cords, 10 percent below 1967, and 17 percent below the peak year 1966 (table 1). The major cause of the lower harvest was a substantial cutback in pulpwood inventory at several Wisconsin mills. The mills reduced inventories in 1968 to cut overhead costs and prevent wood quality deterioration in the woodyards.

Year-end pulpwood inventories at Wisconsin mills were more than 10 percent of the U.S. total in every year between 1958 and 1967 (table 2). Between 1960 and 1965 the total year-end inventory for mills in the State declined more than 300,000 cords. However, at the close of 1967 Wisconsin mills had rebuilt their inventories to 995,000 cords, a 58-percent rise in 2 years and the highest carryover since 1958.

Pulpwood producers in all three States were jolted by the 1968 inventory adjustments, because Wisconsin is a large net importer of pulpwood from Michigan and Minnesota. Michigan's roundwood harvest dropped 198,000 cords in 1968, while Wisconsin and Minnesota harvests each fell more than 125,000 cords.

Part of the decline in roundwood cut was due to substitution of residues for roundwood. Roundwood (including chips from roundwood) constituted 93 percent of the 1968 Lake States pulpwood output; mill residues, such as chips, slabs, and veneer cores, made up the remaining 7 percent. In 1967 only 5 percent of the pulpwood output came from residues. The residue proportion of the pulpwood output will probably continue to increase as more sawmills and veneer mills install debarkers and chippers.

Aspen, the major pulpwood species in the Lake States, accounted for about half of the total decline of 457,000 cords in the region's 1968 roundwood harvest. Most of the decrease in aspen cut occurred in Wisconsin and Michigan. These States also accounted for most of the 105,000-cord drop in miscellaneous hardwoods cut. Spruce pulpwood output fell 99,000 cords in 1968, with three-fifths of the decrease in Minnesota.

During 1968 Lake States pulpmills received 4 million cords of pulpwood, 467,000 cords less than in 1967. Receipts were down ½ million cords in Wisconsin, unchanged in Michigan, and up 35,000 cords in Minnesota. The Lake States supplied 88 percent of the pulpwood, western States 6 percent, and Canada 6 percent (table 3).

In reducing pulpwood inventories, Wisconsin mills procured 205,000 cords less in Michigan, 133,000 cords less in Minnesota, and 129,000 cords less locally in 1968 than in 1967. By contrast, Michigan and Minnesota pulpmills procured more local wood than in 1967.

Table 1.–Production and imports of pulpwood, Lake States, 1968

Species and destination	Production by States[1]				Imports			Total receipts
	Minnesota	Wisconsin	Michigan	Regional total	Other U.S.[2]	Canada	Total imports	
Aspen								
Minnesota	554,866	9,238	--	564,104	--	11,810	11,810	575,914
Wisconsin	27,482	616,638	215,580	859,700	--	125	125	859,825
Michigan	32	3,257	323,615	326,904	--	982	982	327,886
Exported[3]	444	--	1,111	1,555	--	--	--	--
Total	582,824	629,133	540,306	1,752,263	--	12,917	12,917	1,763,625
Balsam fir								
Minnesota	33,020	--	--	33,020	--	104	104	33,124
Wisconsin	10,092	50,865	39,466	100,423	--	11	11	100,434
Michigan	--	--	20,282	20,282	--	14,428	14,428	34,710
Exported[3]	63	--	1,804	1,867	--	--	--	--
Total	43,175	50,865	61,552	155,592	--	14,543	14,543	168,268
Birch								
Minnesota	145	--	--	145	--	--	--	145
Wisconsin	223	56,760	2,035	59,018	--	--	--	59,018
Michigan	--	--	10,651	10,651	--	--	--	10,651
Exported[3]	200	--	--	200	--	--	--	--
Total	568	56,760	12,686	70,014	--	--	--	69,814
Hemlock								
Minnesota	--	--	--	--	--	--	--	--
Wisconsin	--	43,876	42,346	86,222	--	--	--	86,222
Michigan	--	--	3,096	3,096	--	--	--	3,096
Total	--	43,876	45,442	89,318	--	--	--	89,318
Pine								
Minnesota	157,473	--	--	157,473	--	48,223	48,223	205,696
Wisconsin	43,642	199,335	72,038	315,015	82,468	7,626	90,094	405,109
Michigan	--	--	133,178	133,178	--	--	--	133,178
Exported[3]	1,552	--	--	1,552	--	--	--	--
Total	202,667	199,335	205,216	607,218	82,468	55,849	138,317	743,983
Spruce								
Minnesota	89,070	--	--	89,070	350	2,950	3,300	92,370
Wisconsin	50,614	10,826	22,016	83,456	223	116,582	116,805	200,261
Michigan	--	--	14,879	14,879	--	45,988	45,988	60,867
Exported[3]	17,451	--	2,127	19,578	--	--	--	--
Total	157,135	10,826	39,022	206,983	573	165,520	166,093	353,498
Tamarack								
Minnesota	12	--	--	12	--	--	--	12
Wisconsin	25,687	4,652	2,240	32,579	--	--	--	32,579
Michigan	--	--	--	--	--	--	--	--
Total	25,699	4,652	2,240	32,591	--	--	--	32,591
Misc. hardwoods								
Minnesota	21,348	--	--	21,348	--	5,820	5,820	27,168
Wisconsin	1,160	180,779	23,049	204,988	--	--	--	204,988
Michigan	--	--	147,300	147,300	50	--	50	147,350
Exported[3]	--	4,133	1,111	5,244	--	--	--	--
Total	22,508	184,912	171,460	378,880	50	5,820	5,870	379,506
Total roundwood								
Minnesota	855,934	9,238	--	865,172	350	68,907	69,257	934,429
Wisconsin	158,900	1,163,731	418,770	1,741,401	82,691	124,344	207,035	1,948,436
Michigan	32	3,257	653,001	656,290	50	61,398	61,448	717,738
Exported[3]	19,710	4,133	6,153	29,996	--	--	--	--
Total	1,034,576	1,180,359	1,077,924	3,292,859	83,091	254,649	337,740	3,600,603
Residues softwood								
Minnesota	12,777	--	--	12,777	--	--	--	12,777
Wisconsin	2,422	13,649	3,126	19,197	140,678	--	140,678	159,875
Michigan	--	--	--	--	--	--	--	--
Exported[3]	1,203	2,701	2,838	6,742	--	--	--	--
Total	16,402	16,350	5,964	38,716	140,678	--	140,678	172,652
Residues hardwood								
Minnesota	31,086	13,201	--	44,287	1,140	--	1,140	45,427
Wisconsin	4,473	81,060	32,340	117,873	--	--	--	117,873
Michigan	--	834	48,733	49,567	6,574	--	6,574	56,141
Exported[3]	--	5,736	2,643	8,379	--	--	--	--
Total	35,559	100,831	83,716	220,106	7,714	--	7,714	219,441
All wood material								
Minnesota	899,797	22,439	--	922,236	1,490	68,907	70,397	992,633
Wisconsin	165,795	1,258,440	454,236	1,878,471	223,369	124,344	347,713	2,226,184
Michigan	32	4,091	701,734	705,857	6,624	61,398	68,022	773,879
Exported[3]	20,913	12,570	11,634	45,117	--	--	--	--
Total	1,086,537	1,297,540	1,167,604	3,551,681	231,483	254,649	486,132	3,992,696

[1]Vertical columns of figures under box heading "Production by States" present the amount of pulpwood cut in each State.
[2]Mostly western States.
[3]Pulpwood shipped to mills outside of region.

Table 2. — Year-end pulpwood inventories at Wisconsin and United States mills, 1958 to 1967

Year	Inventory: Wisconsin	Inventory: United States	Wisconsin percent of total
	Thousand cords	Thousand cords	
1958	1,038	5,942	17.5
1959	931	5,173	18.0
1960	947	5,984	15.8
1961	837	5,515	15.2
1962	762	5,266	14.5
1963	780	4,732	16.5
1964	743	4,843	15.3
1965	628	5,923	10.6
1966	757	6,529	11.6
1967	995	6,825	14.6
Average	842	5,673	14.8

Source: U.S. Department of Commerce 1959-1969, Pulp, Paper, and Board, Current Industrial Reports, Series M26A-13.

Lake States pulpwood imports from other States (primarily western States) remained high, but Canadian wood imports fell 13 percent from 1967. Regional imports (12 percent of the total wood received) have been shifting from Canada to western States in recent years as shown below:

Year	From other (primarily western) States (thousand cords)	From Canada (thousand cords)
1960	82	347
1961	44	303
1962	108	205
1963	153	309
1964	135	270
1965	137	297
1966	190	330
1967	239	293
1968	231	255

If this trend continues, imports from western States will exceed those from Canada in a year or two. Almost two-thirds of the pulpwood from other States was mill residues in 1968; all of the Canadian imports were roundwood.

Table 3. — Geographic origin and destination of pulpwood received by Lake States mills, 1968

Species	Percent of pulpwood originating from: Minn.	Wis.	Mich.	Canada	Other U.S.	Percent of pulpwood received by mills in: Minn.	Wis.	Mich.
Aspen	33	36	30	1	--	33	49	18
Balsam fir	26	30	35	9	--	20	60	20
Birch	1	81	18	--	--	*	85	15
Hemlock	--	49	51	--	--	--	97	3
Pine	27	27	28	7	11	28	54	18
Spruce	40	3	10	47	*	26	57	17
Tamarack	79	14	7	--	--	*	100	--
Misc. hardwoods	6	48	45	1	--	7	54	39
Residues	13	28	21	--	38	15	71	14
All wood material	27	32	29	6	6	25	56	19
Previous year (1967)	27	32	30	6	5	22	61	17

*Less than 1/2 of 1 percent.

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RESEARCH NOTE NC-87

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Germination of Yellow and Paper Birch Seeds After 8 Years Storage

ABSTRACT. — Seeds of yellow and paper birch were stored successfully in closed containers at 36° to 40° F. for 8 years, but viability varied greatly among individual lots.

OXFORD: 232.315.2:181.524:181.525:176.1 *Betula alleghaniensis* **Britt.: 176.1** *B. papyrifera* **Marsh.**

In 1964 I tested the germination of yellow birch (*Betula alleghaniensis* Britt.) and paper birch (*B. papyrifera* Marsh.) seeds after 4 years of storage.[1] At that time, germination percentages for 12 seed lots of each species averaged 60.6 for yellow birch and 78.4 for paper birch. These seeds were collected in the fall of 1960, dried at room temperature for a week or more, and stored in tightly closed bottles at 36° to 40° F. None of the seed lots decreased and most increased in viability during the first 4 years of storage. in testing these same seed lots after 8 years of storage, I found that some germinated almost as well as they did 4 years ago, others declined drastically, and a few lost all viability.

Test conditions in 1968 after 8 years storage were identical to those in 1964: 100 unstratified seeds of each lot were placed on moist perlite in petri dishes and maintained in a greenhouse at about 70° F. for 30 days at a day length extended with fluorescent and incandescent light to 20 hours.

For comparison the results of the previously published tests[1] are listed with the recent results (table 1). The average germination of the yellow birch seed lots increased from 39.3 percent in 1961 to 60.6 percent in 1964, but decreased to 26.4 percent in 1968. Germination of two seed lots changed little between 4 and 8 years of storage, four lots decreased to about one-half of their previous germination, five lots declined drastically, and one lot lost all viability.

The paper birch seed lots increased from an average of 36.6 percent germination in 1961 to 78.4 percent in 1964, and declined to 31.5 percent in 1968. Germination of one seed lot in 1968 was almost as good as 4 years earlier, three lots decreased somewhat, three lots decreased to about one-third of their previous germination, four lots declined drastically, and one lot was inviable.

Table 1.—Germination percentage after 30 days; yellow and paper birch seed collected in 1960

Tree number	Yellow birch Jan. 1961	Yellow birch Nov. 1964	Yellow birch Dec. 1968	Tree number	Paper birch Jan. 1961	Paper birch Nov. 1964	Paper birch Dec. 1968
1899-1	21	33	31	1802-S[1/]	58	79	72
1899-2	5	16	8	1802-N[1/]	--	83	71
1899-3	15	46	12	1903-1	1	86	31
1899-4	10	55	8	1903-2	53	87	7
1899-5	84	87	82	1903-3	46	81	18
1900-1	70	81	68	1903-4	57	85	17
1900-2	81	98	3	1903-5	31	42	2
1900-3	61	72	5	1903-6	29	69	0
1900-4	49	85	65	1904	6	78	27
1900-5	24	26	2	1905	48	99	52
1900-6	21	63	0	1946-G[2/]	--	76	52
1900-7	21	65	33	1946-T[2/]	--	76	29
Average	39.3	60.6	26.4	Average	36.6	78.4	31.5

1/ Seed from two separate stems of same tree.

2/ Lot G collected from ground, Lot T from tree itself.

[1] *Clausen, K. E. Yellow and paper birch seeds germinate well after 4 years' storage. U.S.D.A. Forest Serv. Res. Note LS-69, 2 p. Lake States Forest Exp. Sta., St. Paul, Minn. 1965.*

After 8 years of storage only five seed lots each of yellow and paper birch had a satisfactory germination percentage of 30 percent or higher. The viability of the yellow birch seed lots after 4 years of storage seems to have had little effect on their viability after 8 years of storage. Of the lots that remained essentially unchanged, one originally had a low germination percentage and the other a high percentage. Similarly, of the lots that declined in viability between 4 and 8 years storage, some had relatively poor germination at 4 years, others had very good germination. Even the seed lot that lost all viability during the last 4 years of storage had better than average germination in 1964. As with yellow birch, the viability of the paper birch seed lots after 4 years of storage was unrelated to viability after 8 years of storage; the lot with no viability after 8 years had 69 percent germination after 4 years.

Because moisture content of seed is known to affect its storage life,[2] the moisture content of all 24 seed lots was determined. The yellow birch lots ranged from 2.0 to 8.3 and averaged 5.0 percent moisture, while the paper birch lots ranged from 2.8 to 10.7 and averaged 7.4 percent. How well a seed lot of either species maintained its viability was not consistently related to its moisture content.

As a follow-up on the unexpected increase in the viability of these seed lots during the first 4 years of storage,[1] four lots each of yellow and paper birch seed collected in the fall of 1964 were stored with the first lots under identical conditions in the same cooler. These seed lots were tested for germination as described above during December 1964 and again in December 1968. The yellow birch lots all lost viability during the 4 years of storage, and on the average germination was only about half as good as when fresh (table 2). One lot of paper birch had slightly better germination after 4 years, while the other three lots had poorer germination. Thus, the common pattern was a decrease rather than an increase in viability during storage. Apparently storage life of yellow and paper birch seed varies with the year of collection and the individual trees involved.

Table 2.—Germination percentage after 30 days; yellow and paper birch seed collected in 1964

Tree number	Yellow birch		Tree number	Paper birch	
	Dec. 1964	Dec. 1968		Dec. 1964	Dec. 1968
3290-3	43	16	3225-1	82	44
3290-4	29	19	3225-2	83	86
3290-5	55	24	3225-3	59	44
3290-6	70	37	3225-4	73	14
Average	49.2	24.0	Average	74.2	47.0

Although some lots of yellow and paper birch seed maintained their full viability during 8 years of storage in tightly closed containers at 36° to 40° F., most lots had poorer germination after 8 years than they did after 4 years of storage. The decline was often drastic, and one lot of each species lost all viability during this period. Lots with good germination at 4 years did not necessarily maintain their viability any better than lots with poor germination. While it is possible to store seed of yellow and paper birch successfully for 8 years, individual seed lots vary so much in their storage life that they should always be tested for germination before they are used.

[2] *U.S.D.A. Forest Service. Woody-plant seed manual. U.S. Dep. Agr. Misc. Public. 654, 416 p., illus. 1948.*

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U. S. FOREST SERVICE

RESEARCH NOTE NC-88

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

The Sprouting Potential of Dormant Buds on the Bole of Pole-Size Sugar Maple

ABSTRACT. — A study of epicormic sprouting in pole-size sugar maples showed that all visible dormant buds on the bole were capable of producing epicormic shoots. The buds were induced to break dormancy by applying four methods of crown removal known to stimulate sprouting. The amount of crown removed determined the year that the buds broke dormancy; this may be accounted for by the location of growth regulators at the time of treatment. Few buds broke dormancy on untreated trees, indicating that the crown exerts a major influence on the formation of epicormic shoots.

OXFORD: 164.4:181.63:228.11:176.1 *Acer saccharum*

Epicormic shoots tend to occur in varying numbers on the main stem of sugar maple trees. These shoots develop from dormant buds located at the base of branches and at terminal bud scars. The buds become visible on 2-year-old growth and are easily identified by their size and external appearance (Church and Godman 1966). Most dormant buds remain latent and persist without appreciable differentiation, apparently being sustained through a specialized vascular connection with the pith. The more frequent occurrence of epicormic shoots near the base of the live crown, however, raises the question of whether all dormant buds are capable of development, especially those on the lower bole where quality is most important.

THE STUDY

Development of epicormic shoots can be stimulated by a rapid loss of the live crown, which apparently creates the physiological and environmental conditions favorable for dormant bud break. Several intensities of crown removal were tested on 75 sugar maple trees in a 25-year-old stand on the Argonne Experimental Forest in northern Wisconsin to determine the number and location of dormant buds on the main stem capable of shoot development. All study trees were in the codominant crown class, 4 to 6 inches in diameter, and 40 to 50 feet in height. The trees were clear of live branches for approximately half their height, suggesting that stand density was relatively uniform.

Fifteen trees were randomly assigned to each of five crown-removal classes: (1) all leaves removed, (2) leaves and 1-year-old twigs at the end of each branch removed, (3) leaves and the entire branches of the main stem removed, (4) main stem severed at the base of the live crown, and (5) no treatment. To evaluate the possible influence of different moisture conditions within the tree at different times during the day, five trees in each crown-removal class were treated in midmorning, five in midafternoon, and five in the evening.

All treatments were made between June 10 (about three weeks after full leaf development) and June 25. Prior to treatment, 90 percent of the study trees had epicormic shoots along the main stem, and about half of these were current-year shoots. Epicormic shoots present at the time of crown removal were given the same treatment as the main crown.

The number of buds breaking dormancy were counted and their position on the main stem with reference to the original base of the live crown recorded just prior to leaf fall at the end of the first growing season and at the beginning and end of the second growing season.

RESULTS AND DISCUSSION

The existing epicormic shoots that were treated failed to reflush and apparently died before new buds capable of vegetative development had developed at their base. Treatment comparison was therefore limited to the dormancy break of established buds on the main stem. Because the time-of-day treatments had no significant influence on new shoot formation, the 15 trees in each crown-removal class were analyzed as a single treatment.

All trees receiving crown-removal treatments and most untreated trees produced one or more epicormic shoots during the two growing seasons (table 1). Fewer sprouts were produced during the first year, and these came chiefly from dormant buds located in the upper part of the live crown (table 2). First-year sprouting below the live crown increased only slightly following removal of leaves and removal of leaves plus 1-year-old twigs. The severe crown-removal treatments, however, resulted in a significant increase in first-year sprouts.

One explanation for the low incidence of first-year sprouting might be the timing of the movement of growth hormones that regulate bud dormancy. Doorenbos (1953) and Hatcher (1959), working with crabapple trees, have shown that these hormones, which are produced in the growing tips of the branches, move progressively to the lower internodes and basal portion of the stem shortly after physiological activity begins in the spring. Since the crown-removal treatments were not applied in our study until well after growth activity had started, it would seem logical that the dormant bud-inhibiting auxins had already begun to diffuse from the growing terminals. Epicormic sprouting increased below the live crown as additional amounts of the woody portion of the crown were removed, presumably because the amount of regulating hormone was reduced in proportion to the amount of stem and crown that was severed. Because the vegetative buds are the principal source of the hormones, this effect would not be present during the second year.

In all crown removal treatments, all visible dormant buds on the stem produced shoots by the end of the second growing season. Close examination of the stem did not reveal any living buds that remained dormant. It is expected that additional dormant buds will form at the base of the new epicormic shoots, and following the normal pattern of dormant bud development in sugar maple, will become visible on the 2-year-old growth.

The mean number of shoots per tree was not significantly different among crown-removal treatments over the 2-year period (table 2).

Table 1.—Percent of surviving trees developing epicormic shoots in successive growing seasons by position on stem and crown-removal treatment

Crown-removal treatment	First growing season				Second growing season			
	Surviving trees	Below crown	Live crown	Total stem	Surviving trees	Below crown	Live crown	Total stem
	Number	Percent	Percent	Percent	Number	Percent	Percent	Percent
Untreated	15	0	53	53	15	73	87	87
Leaves	15	13	33	40	15	93	100	100
Twigs	15	13	80	80	13	100	100	100
Branches	15	53	100	100	14	100	100	100
Top	14	93	--	--	11	83	--	--

Table 2.—Average number of new epicormic shoots per surviving tree in successive growing seasons by position on stem and crown-removal treatment

Crown-removal treatment	First growing season			Second growing season			Total epicormic shoots		
	Below crown	Live crown	Total stem	Below crown	Live crown	Total stem	Below crown	Live crown	Total stem
Check	0.0	1.1	1.1	3.1	1.2	4.3	3.1	2.3	5.4
Leaves	.1	1.1	1.3	21.7	14.0	35.7	21.8	15.1	36.9
Twigs	.1	5.1	5.3	18.5	15.4	33.8	18.6	20.5	39.1
Branches	2.3	15.7	18.0	25.5	3.8	29.3	27.8	19.5	47.3
Top	8.9	--	--	10.6	--	--	19.5	--	--

However, the number of shoots was consistently greater on treated trees than on untreated trees. The maximum number of shoots observed within the live crown on any one tree was 30, and on the lower stem the maximum number was 67. The highest incidence of shoots occurred near the base of the live crown.

The decline in number of epicormic shoots within the live crown surviving at the end of the second growing season appeared to be related to a loss in overall vigor and impending mortality of the tree. Although new, vigorous epicormic shoots were abundant on the upper stem at the beginning of the second growing season, this foliage alone was not capable of supporting tree functions; all decapitated and branch-pruned trees, and half of the twig-pruned trees were dead by the beginning of the third growing season.

The pole-size sugar maples studied had one to three dormant buds per foot of stem, both above and below the base of the live crown. Although some dormant buds apparently aborted, especially on the lower bole, no stem sections were consistently free of living buds.

The fact that significantly fewer epicormic shoots formed on the untreated trees indicates that the crown (probably the growing terminals) is a major factor in the control of epicormic shoot development on the bole. This observation agrees with other reports that sugar maple trees with well-developed crowns, particularly the dominant trees in the stand, develop fewer epicormic shoots than trees with poorly developed crowns (Conover and Ralston 1959). Cultural treatments that provide adequate light and growing space to develop and maintain a vigorous crown should thus offer the most promise for preventing epicormic sprouting in this high-value species.

SUMMARY

The study showed that all visible dormant buds on pole-size sugar maple are capable of producing epicormic shoots and can be induced to break dormancy by methods that either defoliate the tree or remove the growing terminals. Four intensities of crown removal (leaves, leaves and first-year twigs, all branches, and entire live crown) were equally effective. However, all the trees that had all branches or the entire crown removed died, whereas most of those that had just leaves and first-year twigs removed survived. The year of shoot development varied with the method of crown removal, probably through the movement of hormones from the growing terminals to the lower portions of the stem.

These results are interpreted silviculturally to mean that the growing terminals of the crown are a major factor influencing epicormic sprout formation. Cultural treatments resulting in vigorous growth of the growing terminals would probably control or limit the formation of new branches, particularly those on the lower bole that can cause a major reduction in log quality.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-89

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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE--U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Direct Reading Frost Gage Is Reliable, Inexpensive

ABSTRACT. — A tube-type gage is economical, easy to make, and is a reliable indicator of frost depth. Gage readings were within ± 5 centimeters of indicated true frost depth 95 percent of the time. OXFORD: 111.744.2:U53.08

In our search for a better way of measuring soil frost depth, we tested two kinds of direct-reading, tube-type gages during the winter of 1968-69. The gages were a modified Gandahl gage (hereafter called MGT gage) [1] developed at the U. S. Army Cold Regions Research and Engineering Laboratory and a similar gage developed at the Fernow Experimental Forest. [2]

The MGT gage consists of an inner polyethylene tube, 5/8 inch inside diameter by 3/4 inch outside diameter, and an outer polyethylene tube, 1 inch inside diameter by 1-1/4 inch outside diameter. The bottoms of both tubes are either heat sealed or closed with a commercially available plug. The inner tube is filled with 0.01 percent solution of fluorescein and then with medium-size clean sand. The fluorescein dye solution produces a sharp color differentiation between the frozen and liquid phase. The sand adds rigidity to the polyethylene tube, decreases expansion upon freezing of the solution, and prevents thermal overturn. The top is sealed in the same manner as the bottom. A wire loop is embedded in the top of the inner tube so that it can be pulled out of the ground when the gage is installed. Materials to fabricate a complete 2-meter gage cost approximately $2.00.

The gage is installed in a 3.28-centimeter (1-1/4-inch) hole. The outer tube should extend above the ground to a height greater than expected snow depth. Even in areas of shallow snow, it should extend about 1 meter (3.3 feet) above the ground for convenience in reading the gage. The outer tube is capped with a commercially available snap-on or slip-on cap. Upon installation, the ground surface level is marked on the inner tube to indicate a zero-depth reading. The inner tube can be pulled from inside the outer tube by a dowel with a hook on one end. The frost depth is read from a calibrated adhesive tape applied to the inner tube or by a calibrated stick.

The Fernow gage is similar except that the outer housing is made from copper tubing and a Kool-aid solution is used for color differentiation upon freezing. The gage is approximately 75 centimeters (2-1/2 feet) long and 1.25 centimeters (1/2 inch) in diameter.

Gages were installed on both a flat Plainfield sand site and a southeast sloping Fayette silt loam site. Readings were made over a 4-month period with snow being removed several times to allow for deeper frost penetration. Gage readings were compared with penetrometer readings, which give an accurate measure of bonded frost depth. [3]

[1] *Brown, Jerry, and Richard, Warren. A modified freeze-thaw depth indicator. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. Tech. Note. 1968.*

[2] *Patric, James H., and Fridley, Burley D. A device for measuring soil frost. U.S.D.A. Forest Serv. Res. Note NE-94. Northeast. Forest Exp. Sta., Upper Darby, Pa.*

[3] *Sartz, Richard S. A test of three indirect methods of measuring depth of frost. Soil Sci. 104: 273- 278. 1966.*

Both the MGT gages and the Fernow gages performed well. However, the Fernow gages varied considerably during the critical measurement periods of fast freezing and thawing, apparently because of heat conduction (fig. 1). Color differentiation between the frozen and unfrozen phases was usually sharp and clear for both gage types. However, during periods of rapid freezing and thawing the color separation lines in the MGT gages were sometimes diffused and mixed.

The MGT gages read within ±5 centimeters of the penetrometer readings 95 percent of the time. Average mean difference for all plots was ± 2.3 centimeters, with an average standard deviation of 1.96 centimeters. The Fernow gages read within ± 5 centimeters of the penetrometer readings only 65 percent of the time. Average mean difference for all plots was ±4.8 centimeters with an average standard deviation of 3.56 centimeters. The larger variance in the Fernow gage readings resulted when they were exposed to the weather and when the frost depth was shallow (fig. 1). However, when covered with snow or when the frost was deep, they performed as well as the MGT gages.

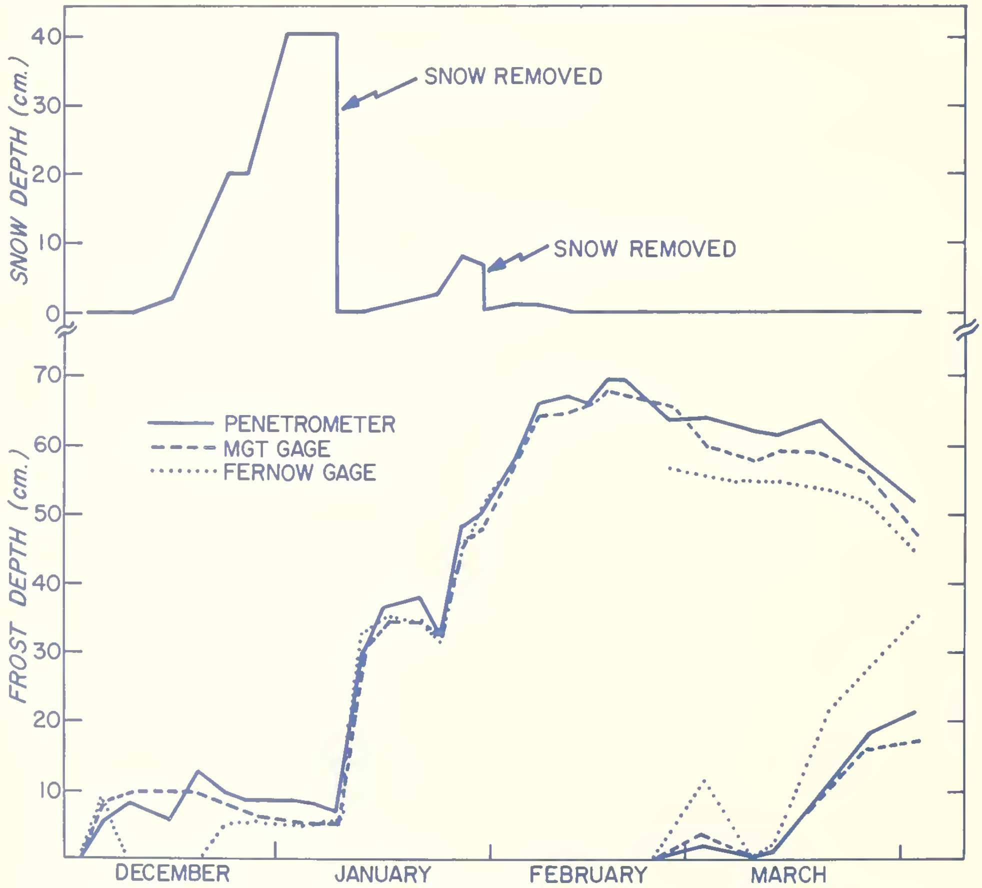

Figure 1.—Frost depth on Fayette silt loam site as measured by the penetrometer, MGT gage, and Fernow gage. Fernow gage measured frost only to a depth of 60 cm. Lines in lower right corner of graph show thawing from the surface down.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-90

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Variation in Density of Sugar Maple Sapwood and Heartwood

ABSTRACT. — Provides data on the variation in density and the proportion of sugar maple sapwood and heartwood by height in the tree.

OXFORD: 812.31:165.53:176.1 *Acer Saccharum*

The density of wood under normal conditions is a good indicator of strength and fiber yield. The within-stem variation in density (both vertically and radially) has been studied extensively for softwoods. However, much less information is available for hardwoods. Apparently, data on density variation was needed primarily for pulpwood and construction lumber, products that have traditionally been softwood. The increased use of hardwoods for these products is creating a need for density information for hardwoods.

It has been commonly believed that density decreases with increasing height. This view is well documented for certain softwoods although contradictory data are available (Anderson 1965, Paul 1963). Much less is known about hardwoods (Hamilton 1961, Paul 1934), although Barefoot (1963) found that the density of yellow poplar was higher at the base of the tree than it was at 17 feet above ground.

We studied (1) the variation in density of sugar maple sapwood and heartwood by height, (2) the percent of sapwood at various heights, and (3) the variation in combined heartwood and sapwood density by height.

METHODS

Ninety trees averaging 18 inches d.b.h. and 190 years old were selected for study in Upper Michigan. The trees were felled and bucked into 8-foot lengths to a top diameter of 6 inches or to the point of breakup into the crown. Two-inch thick discs were cut from the butt of each log and sent to the U.S. Forest Products Laboratory at Madison, Wisconsin, for measurement of basic density (based on volume green and weight ovendry) of both the sapwood and the heartwood.

RESULTS

Our findings show that the average density of sugar maple sapwood and heartwood decreases rapidly between the stump (1 foot) and 16 feet, and begins to level off between 16 and 32 feet. Sapwood density is 1.8 pounds per cubic foot greater at 0 feet than at 16 feet, while the density at 16 feet is only 0.1 pounds per cubic foot greater than at 32 feet. For heartwood, the density, is 2.6 pounds per cubic foot greater at 0 feet than at 16 feet, and only 0.4 greater at 16 feet than at 32 feet. Average density of the heartwood is greater than that of the sapwood, the difference ranging from 2.9 pounds per cubic foot at 0 feet to only 1.8 pounds per cubic foot at 32 feet.

The combined density was evaluated by weighting the densities of the sapwood and heartwood by the relative proportion of each, for each tree and height. Sapwood width and disc diameter were used to compute the percentage of sapwood at each height. The average percentages are listed below:

Height (from 1-foot stump) (Feet)	*Sapwood (Percent)*
0	84
8	76
16	76
24	76
32	68

On the average, the combined heartwood and sapwood density is 1.7 pounds per cubic foot greater at 0 feet than at 16 feet, with little difference in density between 16 and 32 feet (fig. 1).

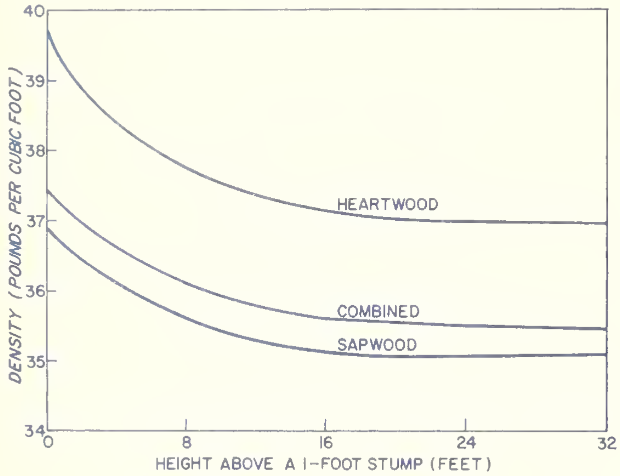

Figure 1.—Density of sugar maple sapwood and heartwood and combined sapwood-heartwood by height level.

Sapwood density decreases 5 percent from 0 to 16 feet, while the heartwood density decreases 7 percent.

The results of this study tend to support the view, developed from certain softwoods, that density decreases up the stem. However, this decrease appears, for Upper Michigan sugar maple, to be limited to the first 16 feet.

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RESEARCH NOTE NC-91

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Weights and Centers of Gravity For Quaking Aspen Trees and Boles

ABSTRACT. — This paper discusses the results of field tests to determine experimentally the weights and locate the centers of gravity for aspen trees and boles.

OXFORD: 526.1:539:U531.2:176.1 *Populus tremuloides*

Most of the attempts to mechanize logging up to the early 1960's concentrated on improving single work functions, such as skidding and loading. These efforts have significantly improved logging productivity and are expected to continue into the future. Since the early 1960's much of the research effort has been directed toward development of multifunctional logging equipment, with special emphasis on the log-making phases of the harvesting operation. At minimum, multifunctional harvesting machines both cut and handle material. Before machines of this type can be designed for maximum economy and efficiency, accurate information is needed concerning the variables that affect the machine's operation.

Such information is available for cutting methods, but few data are available on the forces and moments required to handle entire trees or their boles. To obtain the required values for the forces and moments that must be considered, it is first necessary to know the weight and center of gravity for the tree and its bole. This paper presents estimates of both for quaking aspen (*Populus tremuloides* Michx.).

In the summer of 1966, a cooperative study was initiated by the Forest Engineering Laboratory of the North Central Forest Experiment Station, U.S.D.A. Forest Service, and Michigan Technological University to determine weights and locate centers of gravity of quaking aspen trees of various diameters and heights. The sample trees were selected from two stands in Houghton County, Michigan. Each stand supported 3 to 5 cords of aspen pulpwood per acre. One stand was pure aspen on a dry, upland site; the other consisted of aspen mixed with spruce and pine on a swampy site. Data were obtained from 97 aspen trees ranging from 5 to 17 inches in d.b.h. and from 28 to 77 feet in height.

In this paper, the tree is defined as the entire tree above the stump. The bole is defined as the portion of the stem above the stump, delimbed and topped at a 3-inch diameter outside bark. The center of gravity is the distance in feet from the butt to the point of balance of the bole or tree.

FIELD PROCEDURES

The d.b.h. of each sample tree was measured to the nearest 0.1 inch and an 8 mm. increment core was taken at the d.b.h. for determining percent moisture content. The tree was then felled in the direction causing the least damage and loss of limbs. To determine taper, diameter outside bark of the felled tree was measured at the stump, at 2 and 4 feet from the butt, and at 8-foot intervals thereafter to the top diameter of 3 inches. The length and top diameter of any residual portion of the bole above the last 8-foot section were also measured. The total overall length of the tree above the stump was also recorded. All lengths were measured to the nearest 0.1 foot.

As soon as possible after felling (usually within 4 hours) the tree was picked up by a tractor-mounted, knuckle-boom loader. A specially de-

MAINTAINED IN COOPERATION WITH THE UNIVERSITY OF MINNESOTA

signed weight transducer [1] was placed between the boom and a chain sling suspending the tree (fig. 1). The sling connections included a swivel and a uniball joint to allow the tree to hang freely. A point on the tree vertically below the apex of the sling was marked as its center of gravity. The tree was then limbed and topped to a 3-inch diameter outside bark, the resulting bole was suspended and weighed, and its center of gravity was also marked in the same way.

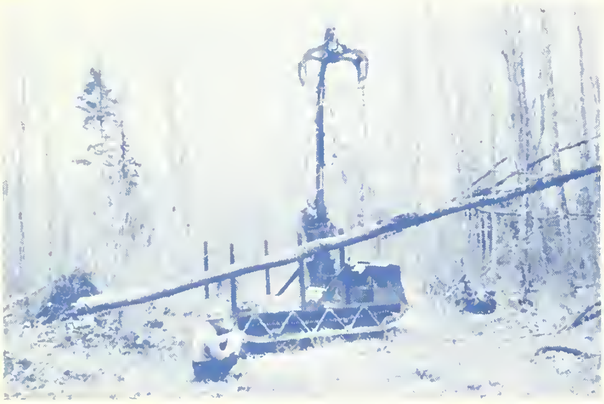

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Figure 1.—Method of suspending full tree and tree-length bole to obtain weight and locate center of gravity.

ANALYTICAL PROCEDURES

The cubic-foot volume for each bole was calculated from the taper measurements, using the formula for the volume of a truncated cone for each section of the bole. Because the taper measurements were taken outside the bark, calculated volumes of the boles include both wood and bark. The green weight in pounds per cubic foot for each bole was determined by dividing its weight in pounds by its calculated volume in cubic feet. In addition, the moisture content on a wet-weight basis, basic density, and weight (green basis) per cubic foot were calculated for each sample tree from an 8-mm. increment core taken at d.b.h. [2] The ranges and means of measured variables for the 97 quaking aspen trees sampled are presented in table 1.

RESULTS AND DISCUSSION

Because the objective of the study was to predict the weight and locate the center of gravity for trees and boles, d.b.h., tree height, and bole length were the significant independent variables. Notation for these variables follows:

Y_1 = Weight of the tree in pounds.
Y_2 = Weight of the bole in pounds.
Y_3 = Center of gravity of the tree in feet from butt.
Y_4 = Center of gravity of the bole in feet from butt.
X_1 = D.b.h. of tree in inches.
X_2 = Tree height in feet.
X_3 = Bole length in feet.

Several mathematical models were developed to analyze the data. Some of the models that were tried included additional terms, which did not significantly improve the predictions. The

Table 1.—Range, mean, and standard deviation of variables for 79 aspen trees, Houghton County, Michigan

No.	Variable	Range	Mean	Standard deviation
1.	D.b.h.	5.30 to 17.40 in.		
2.	Tree height	28.30 to 77.00 ft.		
3.	Tree-length bole	17.50 to 59.00 ft.		
4.	Green weight, tree	80.00 to 3,080.00 lbs.		
5.	Green weight, tree-length bole	50.00 to 2,600.00 lbs.		
6.	Tree center of gravity	10.25 to 28.42 ft. from butt		
7.	Tree-length bole center of gravity	7.58 to 24.25 ft. from butt		
8.	Tree length bole volume	1.87 to 51.61 cu. ft.		
9.	Moisture content of wood (based on wet weight)	35.60 to 61.10 %	48.60 %	± 4.97%
10.	Weight per cu. ft. of wood and bark	26.73 to 60.95 lbs.	49.32 lbs.	± 5.45 lbs.
11.	Basic density	19.13 to 31.82 lbs.	25.43 lbs.	± 1.91 lbs.
12.	Calculated weight (green basis) per cu. ft.	41.25 to 66.64 lbs.	49.87 lbs.	± 5.70 lbs.

[1] *Arola, Rodger A. A dual-range strain gage weighing transducer employing automatic switching. U.S.D.A. Forest Serv. Res. Note NC-44, 4 p. N. Cent. Forest Exp. Sta., St. Paul, Minn. 1968.*

[2] *Keen, R. E. Weights and centres of gravity involved in handling pulpwood trees. Pulp and Pap. Res. Inst. Can. Tech. Rep. 340, 93 p. 1963.*

remaining discussion deals only with those models that proved satisfactory in predicting weights and centers of gravity for quaking aspen trees and boles. The models and prediction equations for each dependent variable follow:

Tree Weight:

$$\frac{Y_1}{X_1^2 X_2} = k_1 + \frac{k_2}{X_1 X_2} + \frac{k_3}{X_1^2 X_2}$$
(Regression model)

Values of coefficients were:

$k_1 = .117, k_2 = 58.63, k_3 = -287.4$

The regression model can be rewritten as the prediction equation:

$Y_1 = -287.4 + 58.63\ (DBH) + .117\ (DBH)^2\ (Tree\ height)$

$S.E._{est.} = .0226\ (DBH)^2\ (Tree\ height).$

Bole weight:

$$\frac{Y_2}{X_1^2 X_3} = k_1 + \frac{k_2}{X_1 X_2} + \frac{k_3}{X_1^2 X_3}$$
(Regression model)

Values of coefficients were:

$k_1 = .152, k_2 = 20.04, k_3 = -103.6$

The regression model can be rewritten as the prediction equation:

$Y_2 = -103.6 + 20.04\ (DBH) + .152\ (DBH)^2\ (Bole\ length)$

$S.E._{est.} = .02126\ (DBH)^2\ (Bole\ length).$

Tree center of gravity:

$$\frac{Y_3}{X_2} = k_1 + k_2 X_2$$
(Regression model)

Values of coefficients were:

$k_1 = .430, k_2 = -.001$

The regression model can be rewritten as the prediction equation:

$Y_3 = .430\ (Tree\ height) - .001\ (Tree\ height)^2$

$S.E._{est.} = .0284\ (Tree\ height).$

Bole center of gravity:

$$\frac{Y_4}{X_3} = k_1 + k_2 X_3$$
(Regression model)

Values of coefficients were:

$k_1 = .438, k_2 = -.001$

The regression model can be rewritten as the prediction equation:

$Y_4 = .438\ (Bole\ length) - .001\ (Bole\ length)^2$

$S.E._{est_1} = .02602\ (Bole\ length).$

The regression model was set up in terms of ratios to facilitate the statistical analysis of the data and to simplify calculation from the final form of the equation.

Tree and bole weights are presented in table 2. In each case a 95 percent upper tolerance weight is given for each d.b.h. and height class.[3] The centers of gravity for trees and boles are presented in figures 2 and 3. A 95 percent upper tolerance limit is also presented for the centers of gravity. This upper tolerance limit allows reasonable assurance (probability $\gamma = .90$) that not more than 5 percent of the trees from the population represented will exceed this limit; or alternatively, that at least 95 percent will be below it.

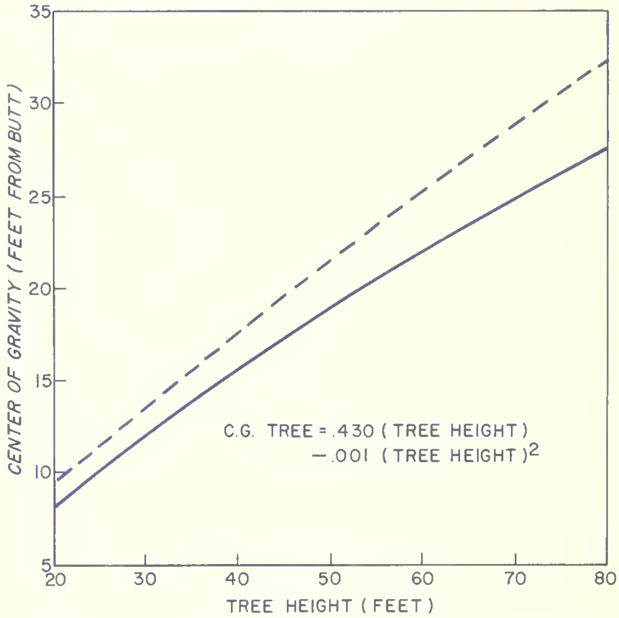

Figure 2.—Center of gravity for quaking aspen tree heights. The solid line is the mean value for center of gravity; the dashed line is the upper tolerance limit (95% level).

Upper tolerance limits for weights and centers of gravity are important for tree-harvesting machine design. The design cannot be based on the mean weight, because theoretically half of the trees will exceed the mean. Likewise, because most harvesting equipment will handle the tree or bole from a position below the center of gravity, an upper tolerance limit for center of gravity would insure against underdesign of the machine.

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3 *Owen, D. B. Factors for one sided tolerance limits and for variables sampling plans. Sandia Corp. Monogr. p. 9, 10, 164-189, 399-402. 1963.*

Table 2.—Aspen tree and bole weights

(In Pounds)

MEAN WEIGHT[1/]

D.b.h. (inches)	Bole length or tree height (feet) 30	40		50		60	70
	Bole	Tree	Bole	Tree	Bole	Tree	Tree
6	181	232	--	--	--	--	--
7	261	352	335	410	410	--	--
8	349	481	447	556	544	631	--
9	447	619	571	714	694	809	904
10	554	767	706	884	859	1,001	1,118
11	--	--	855	1,066	1,039	1,207	1,349
12	--	--	1,015	--	1,234	1,427	1,596
13	--	--	1,187	--	1,445	1,662	1,859
14	--	--	1,372	--	1,671	1,910	2,139
15	--	--	--	--	1,912	2,172	2,435
16	--	--	--	--	--	2,448	2,748
17	--	--	--	--	--	--	3,077
18	--	--	--	--	--	--	3,422
UPPER TOLERANCE LIMIT WEIGHT AT 95 PERCENT LEVEL[2/]							
6	227	299	--	--	--	--	--
7	321	439	414	514	510	--	--
8	429	595	549	692	673	793	--
9	549	765	700	887	856	1,015	1,146
10	680	947	867	1,098	1,060	1,256	1,418
11	--	--	1,049	1,325	1,282	1,517	1,713
12	--	--	1,246	--	1,525	1,796	2,031
13	--	--	1,459	--	1,787	2,096	2,372
14	--	--	1,687	--	2,069	2,415	2,736
15	--	--	--	--	2,370	2,754	3,123
16	--	--	--	--	--	3,113	3,535
17	--	--	--	--	--	--	3,969
18	--	--	--	--	--	--	4,427

1/ Mean bole weight was determined from equation $Y_2 = -103.6 + 20.04 \text{ (d.b.h.)} + .152 \text{ (d.b.h.)}^2 \text{ (bole length)}$. Mean tree weight was determined from equation $Y_1 = -287.4 + 58.63 \text{ (d.b.h.)} + .117 \text{ (d.b.h.)}^2 \text{ (tree height)}$.

2/ 95 percent of trees or boles in a given class should be below this weight.

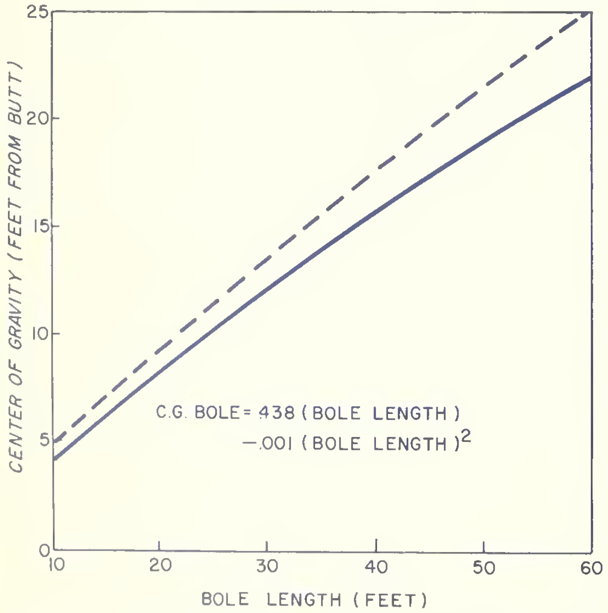

Figure 3.—Center of gravity for quaking aspen bole lengths. The solid line is the mean value for center of gravity; the dashed line is the upper tolerance limit (95% level).

A 14-tree sample was taken from a third site to test the prediction equations. Only one tree and one bole had weights exceeding the upper tolerance limits as presented in this report. The 14-tree test run employed equipment and instrumentation different from those used in the previous runs, thus indicating the results are valid.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-92

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Effect of Cutting Angle and Depth of Cut on the Occurrence of Chipped Grain on Sycamore

ABSTRACT.— **Sycamore specimens were planed with various combinations of depths of cut and rake angles. Depths of cut up to 1/16 inch had no significant effect on the occurrence of chipped grain in sycamore but rake angle did.**

OXFORD: 823.1:823.8:176.1 *Platanus occidentalis*

Guidelines for depth of cut and rake angle have been established for planing hardwood lumber. It has generally been accepted in practice, but not shown for all combinations of rake angles and depths of cut, that the thinner the depth of cut the higher the quality of the resulting surface. Davis, [1] when planing hardwood with a depth of cut as shallow as 1/32 inch and a rake angle of 30 degrees, showed that the greatest increase of defect-free specimens occurred when depth of cut was reduced from 1/16 inch to 1/32 inch. However, an interaction between smaller rake angles and shallow depths of cut, and the effect of various combinations of rake angles and depths of cut upon the occurrence of chipped grain have not been established. So we undertook a study to determine how shallow depths of cut (1/16 to 1/64 inch) in various combinations with four rake angles (25, 20, 15, and 10 degrees) would affect the occurrence of chipped grain within rough and finish milled sycamore specimens.

1 *Davis, E. M. Machining and related characteristics of United States hardwoods. U. S. Dep. Agr. Tech. Bull. 1267, 68 p., illus. 1962.*

The results indicate that when cutting with rake angles less than 30 degrees and thin depths of cut, rake angle does not interact with depth of cut.

METHOD OF STUDY

Nine cutting combinations (table 1) were replicated nine times and analyzed as a split-plot design where cutting angle was the major treatment and the rough and finish milling depth-of-cut combinations were the minor treatments. No combination of cutting depths exceeded 3/32 inch, the amount commonly finish planed to produce a satisfactory surface.

The specimens (1- by 4- by 25-inches) were cut from sycamore lumber kiln-dried and maintained at an average moisture content of 7 percent. They were planed on one side to provide

Table 1.—Depth-of-cut combinations used in study

(In 64ths of an inch)

Combination	Planing operations		
	Rough	First finish	Second finish
1	4	2	-
2	4	1	1
3	3	3	-
4	3	2	1
5	3	1	1
6	2	2	2
7	2	2	1
8	2	1	1
9	1	1	1

Note: Combined rough and finish cuts tested do not exceed 3/32 inch.

a flat surface and nearly uniform thickness so the rough milling cut would be relatively accurate.

After each pass through the molding machine against any predominent slope of grain at the prescribed cutting depth and rake angle, and at a rate of 16 knife marks per inch, the number of 1-inch square sections where chipped grain occurred was recorded as a percent of the total surface machined.

RESULTS AND DISCUSSION

Results show that:

1. Depth of cut up to 1/16 inch does not significantly influence the occurrence of chipped grain using the rake angles studied.

2. Rake angle does significantly influence the occurrence of chipped grain at depths of cut up to 1/16 inch, and the rake angle does not interact with depths of cut up to 1/16 inch.

Twenty percent of the specimens planed with a cutting depth of 1/32 inch were defect-free regardless of rake angle. In Davis' study the corresponding figuure was 22 percent. Hence, evaluating machine combinations of depth of cut and rake angle quantitatively by subdividing specimens and repeating the treatment is a refinement for measuring the occurrence of chipped grain compared with previous surface quality evaluation methods.

Chipped grain occurred most frequently with a 25-degree-rake-angle knives — the knives commonly furnished with finish planers to plane both hardwoods and softwoods (fig. 1). Hardwoods should generally be planed with knives of a rake angle of 20 degrees or less to reduce chipped grain. Although smaller rake angles produce less chipped grain, they usually require more power and the edges more frequent sharpening. Hence, to determine optimum rake angles, other factors beyond the scope of this study need to be considered.

Since depth of cut up to 1/16 inch (fig. 2) does not influence the occurrence of chipped grain in sycamore and results from other species may be similar, mill managers and machine operators should consider making more passes through planing machinery at shallower depths of cut and closer sawmill adjustment to reduce initial depths of cut and hence overall waste.

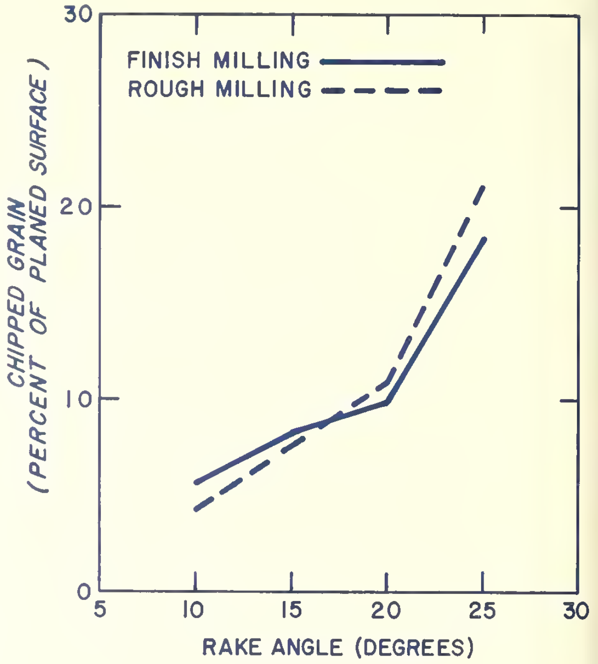

Figure 1.—The relation of chipped grain to rake angle by rough and finish planing.

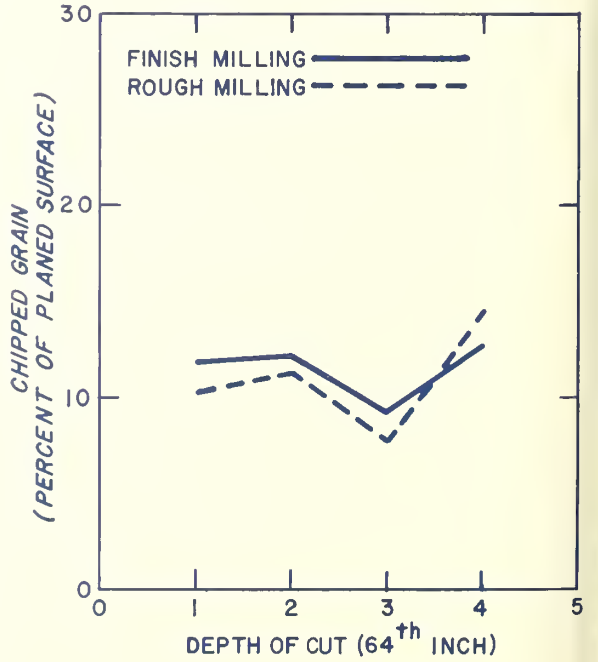

Figure 2.—The relation of chipped grain to a depth of cut, by rough and finish planing.

Cuts deeper than 1/16 inch were not included in the formal study because they exceed the amount commonly prescribed to produce a satisfactory finish-planed surface. Supplemental data however, show chipped grain increased as depth of cut increased beyond 1/16 inch (fig. 3). The greatest apparent increase was in the severity of the defect below the surface (fig. 4). Such a defect would cause a part to be rejected or would require subsequent processing. Consequently, the severity of the defect and not frequency of occurrence may limit the acceptability of a part. This suggests that the depth of the defect should also be measured in future studies to evaluate surface quality.

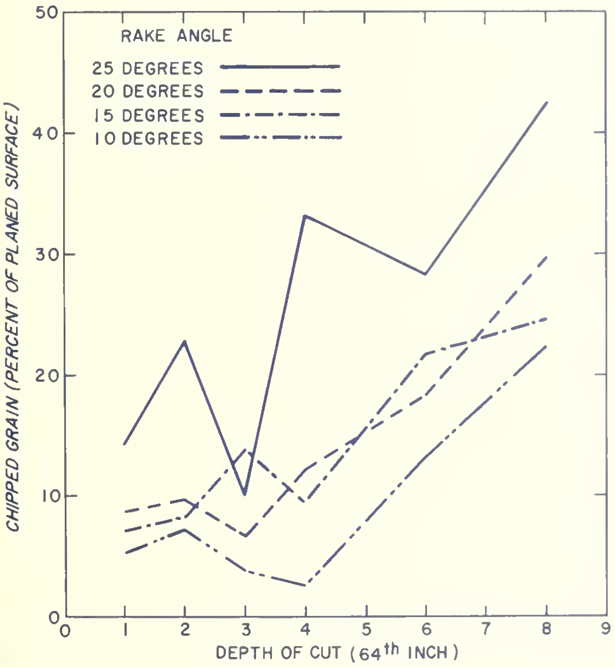

Figure 3.—The relation of chipped grain to depth of cut by rake angle (finish planing only).

When planing with the grain, many combinations of cutting angles and depths of cut will produce a satisfactory surface. When planing against the grain, however, chipped grain is a common defect that requires further processing. We do not presume from these results that all machining defects can be prevented, but chipped grain can be reduced and raw material can be saved by determining the best machining methods.

F-519550

Figure 4.—The occurrence of severe chipped grain when planing with a 25-degree rake angle and a depth of cut of 1/8 inch. This material would be rejected or would require substantial subsequent processing.

Because of the allowable variation of thickness within hardwood lumber,[2] initial depths of cut are variable. The depth of the planing cuts may range from almost zero to the machine setting (often 1/8 inch or more) when face jointing. Since the first pass on the thickness planer is often set to remove a nominal 1/16 inch from 4/4-inch lumber (plane to a thicknees of 15/16 inch), the actual depth of cut can range from almost zero to 3/16 inch due to the variability in thickness allowed in rough hardwood lumber. Large initial depths of cut in rough

[2] *National Hardwood Lumber Association. Rules for the measurement and inspection of hardwood and cypress lumber. 116 p., illus. 1967.*

F-519551

Figure 5.—The occurrence of chipped grain when planing with a 25-degree rake angle and a depth of cut of 1/16 inch. The severity (distance of the defect extending below the surface) of chipped grain becomes negligible at more shallow depths of cut.

F-519552

Figure 6.—Surface produced by rough milling at a depth of cut of 1/64th inch. Although saw marks remain, any chipped grain which occurred was hardly discernible; hence, subsequent processing would be minimal. The sanding process could be incorporated to remove final traces of saw marks and thus conserve raw material.

milling cause many defects that must be removed by finish planing. Further, many wood machining defects remaining after finish planing result from deep cuts when rough planing. Chipped grain can be reduced if the initial depths of cut are reduced (fig. 4, 5, 6).

Except for ripping and crosscutting the lumber, dimension part processing consists primarily of reducing thickness and removing surface milling defects from previous processing. Thus, rough planing removes rough sawing marks, finish planing removes rough planing defects, and sanding removes finish planing defects. The development of improved sawing equipment and techniques to produce thinner and more precisely dimensioned lumber should be encouraged to take full advantage of the benefits of shallow cutting. It follows that correct wood-seasoning practices must also be carried out to minimize deviations from flatness that could also affect depth of cut. Thus, initial rough milling depths of cut could be reduced, chipped grain would be reduced, and subsequent processing could be reduced.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-93

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Relation of Light to Epicormic Sprouting in Sugar Maple

ABSTRACT. — A test of the influence of light intensity on dormant buds of young sugar maple trees showed that exposure to light is not essential for epicormic sprouting.
OXFORD: 181.63:181.21:176.1 *Acer saccharum*

Epicormic sprouts reduce the quality of sugar maple (*Acer saccharum* Marsh.) saw logs, so it is important to know how sprouting is influenced by stand treatment. Two conditions seem to stimulate sprouting: rapid loss of the live crown (Wahlenberg 1950) and sudden or excessive exposure (Blum 1963, Kramer and Kozlowski 1960).

It has been assumed that heavy thinning causes epicormic sprouting by letting too much light into the stand. However, variation in light intensity itself, except at low levels, is not known to influence breaking of dormancy (Vegis 1964). In other words, it does not seem likely that dormant buds sprout solely as a result of increased light intensity on the bud.

To test the relation between light and epicormic sprouting in sugar maple, a study was conducted on the Upper Peninsula Experimental Forest from May to August. The results show that direct light on dormant buds is not necessary for epicormic sprouting.

METHODS

Twelve codominant sugar maple trees about 5 inches d.b.h. were selected for study in the spring; these trees were in an even-aged stand of second-growth northern hardwoods. All dormant buds in a 5-foot study zone below the base of the live crown were counted, and existing epicormic sprouts removed. On May 4, about 2 weeks before budbreak, the following treatments were made: (1) thinning — all trees for a radius of 20 feet around four sample trees were removed, (2) "decapitation"—tops of four sample trees were cut off at the base of the live crown, and (3) no treatment — four sample trees were used as controls. On two of the four trees in each treatment, the 5-foot study zone below the live crown was covered with 8-inch diameter galvanized stovepipe painted black on the inside surface (fig. 1). The galvanized outer surface reflected sunlight, reducing the

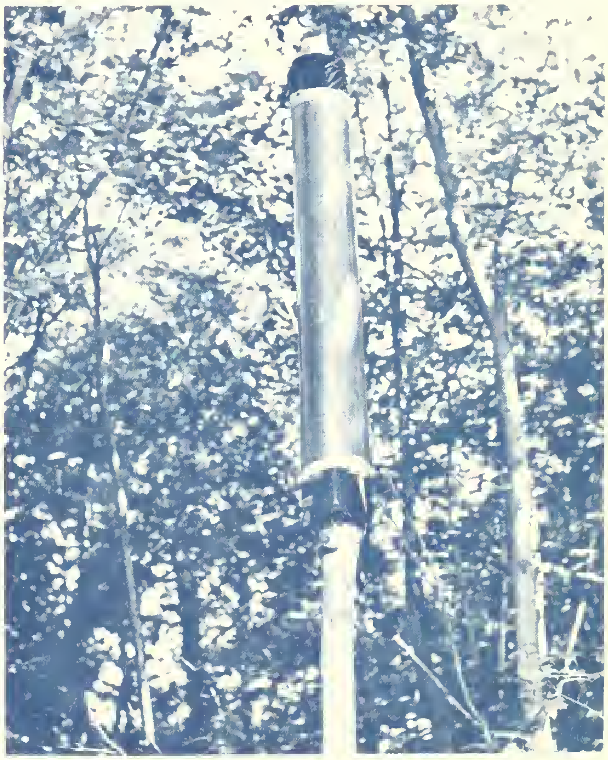

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Figure 1. — "Decapitated" tree with galvanized stovepipe covering a 5-foot section of the stem.

possibility of abnormally high temperatures at the tree surface. Black polyethylene was taped around the top and bottom openings of the stovepipe to exclude light; small holes in the polyethylene allowed some air circulation. The stovepipes were removed briefly three times in June and July while the buds were examined.

RESULTS

Thirty-five percent of all buds covered with stovepipe broke dormancy, thus indicating that light on the stem is not necessary for epicormic sprout production. (One bud even sprouted under the black polyethylene that was wrapped tightly against the bark.) However, light may have stimulated some sprout production, because 49 percent of all uncovered buds broke dormancy, although this difference is not statistically significant. Epicormic shoots from covered buds that broke dormancy were colorless, showing that little light penetrated the stovepipe covering.

Decapitation of the crown definitely stimulated epicormic sprouting; 88 percent of all buds (both covered and uncovered) on decapitated trees broke dormancy (table 1). Only four buds did not break dormancy on decapitated trees, and two of these swelled briefly but returned to a dormant state. Similar bud swelling has been observed by Church[1] and Church and Godman (1966).

Thinning had no significant effect on epicormic sprouting during the study period. Twenty-six percent of all buds on thinned trees broke dormancy, compared with 22 percent on untreated trees.

While this study does show that light on the bud is not essential for dormant bud break, it should not be inferred that thinning has no influence on epicormic sprouting. The physiological mechanisms controlling epicormic sprouting are complex and not yet fully understood. Many environmental factors, such as temperature and moisture, may have an effect on dormant bud break. In any event, sprouting appears to be primarily controlled by the crown, as evidenced by the response to the decapitation treatment.

Table 1. — *Dormant bud break on covered and uncovered trees by treatment*

Light condition	Number of buds	Buds that broke dormancy: Number	Buds that broke dormancy: Percent
DECAPITATED			
Covered	13	13	100
Uncovered	20	16	80
THINNED			
Covered	22	2	9
Uncovered	31	12	39
UNTREATED			
Covered	13	2	15
Uncovered	14	4	29

[1] *Church, T. W., Jr. An analysis of factors affecting epicormic sprouting in northern hardwoods. Problem analysis on file at N. Cent. Forest Exp. Sta., St. Paul, Minn.*

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U. S. FOREST SERVICE

RESEARCH NOTE NC-94

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Picloram in Spaced Stem Injections to Control Lake States Hardwoods[1]

**ABSTRACT. — Picloram (4 amino-3, 5, 6-trichloropicolinic acid), manufactured under the name of Tordon, controls most pole-size and smaller hardwoods in the Lake States by stem injections spaced up to 6 inches apart.
OXFORD: 414.26:176.1**

Most pole-size hardwoods in the Lake States can be killed by stem injections of picloram spaced up to 6 inches apart.[2] Treatments are equally effective during both dormant and growing seasons. The oral toxicity of picloram to mammals is in the range of ordinary table salt (Lynn 1965). Field use of salt and ester formulations has not resulted in any known damage to wild fish or bird populations (Kenaga 1969).

METHODS

Beginning in March 1963, Tordon 22K,[3] the first picloram herbicide available, was tested for effectiveness in spaced stem injections. Tordon 22K contains 2 pounds acid equivalent per liquid gallon of picloram as the potassium salt, but is not currently available in commercial quantities. Another picloram herbicide, Tordon 101 Mixture, was tested beginning in October 1963. This formulation, which is available commercially, contains 0.54 pounds of picloram plus 2 pounds of 2,4-D per liquid gallon, both as triisopropanolamine salts.

The injection treatments were tested at three times of the year: (1) the peak of the growing season, immediately after full leaf development (mid-June in southern Michigan), (2) the late growing season (September or early October, before first frost), and (3) the dormant season (early March).

The stem injections were made in slots cut with a 2-inch chisel to a depth of ½ inch or more, at spacings of 2, 4, and 6 inches (edge to edge). Injections generally were made 3 to 4 feet above the ground, although some were at 5 to 6 feet.

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[1] *John L. Arend (formerly Silviculturist for the Station, now retired) tested the herbicides and compiled the basic data.*

[2] *Picloram (4 amino-3,5,6-trichloropicolnic acid) is marketed in various formulations as Tordon, registered trademark of the Dow Chemical Company, Midland, Michigan.*

[3] *Mention of trade names does not constitute endorsement by the USDA Forest Service.*

A range of herbicide volumes for each spacing was used to determine the minimum effective dosage. Undiluted volume per injection ranged from 1/4 ml. to 2 mls. for Tordon 22K and from 1/2 ml. to 8 mls. for Tordon 101 Mixture. The herbicides were applied with an automatic 2 ml. pipette. A water dilution consisting of 1/4 ml. Tordon 22K and 3/4 ml. water was also tested to see if the larger volume would be more effective in covering the 2-inch wide injections. Tordon 101 Mixture, which has a much higher viscosity than Tordon 22K, was also diluted 50 percent by volume with water for winter applications. Each combination of herbicide dosage, spacing, and season was tested on a minimum of five randomly selected sample trees.

The first treatments in March and June 1963 were tried on both northern red oak (*Quercus rubra* L.) and white oak (*Quercus alba* L.). Trees were mostly pole size, although a few were small sawtimber size. Because initial results showed northern red oak more difficult to kill than white oak, later treatments were confined primarily to northern red oak. In addition, stem injection treatments were also tried on other hardwoods to compare their resistance to that of northern red oak. These species included hickory (*Carya* spp.), red maple (*Acer rubrum* L.), American beech (*Fagus grandifolia* Ehrh.) eastern hophornbeam (*Ostrya virginiana* (Mill.) K. Koch), white ash (*Fraxinus americana* L.), boxelder (*Acer negundo* L.), sugar maple (*Acer saccharum* Marsh.), black cherry (*Prunus serotina* Ehrh.), American elm (*Ulmus americana* L.), bigtooth aspen (*Populus grandidentata* Michx.), and serviceberry (*Amelanchier* spp.).

Treatments comparing species resistance were tried on 10 to 100 trees of each species ranging from pole size to 26 inches d.b.h. In these trials, trees were selected that would be difficult to kill, such as members of sprout clumps and forked trees, to test the effectiveness of the prescription rates that were effective on red oak. Only white ash and sugar maple showed a greater resistance to picloram than northern red oak.

RESULTS AND DISCUSSION

Tordon 22K

One-fourth ml. of undiluted Tordon 22K per injection at 2-inch spacing was adequate to kill northern red oak and white oak during all seasons (table 1). However, 1/4 ml. at 4-inch spacing killed only 80 percent of the trees and at 6-inch spacing only 40 percent. In contrast, the water dilution containing 1/4 ml. Tordon 22K killed all the trees at all three spacings.

When a single stem in a hardwood sprout clump was injected with Tordon 22K, one or more of the untreated stems often died during the third growing season. This did not occur with stem injections using Tordon 101 Mixture. Newton and Holt (1967) found stem-injected Tordon 22K to be effective in killing Douglas-fir, but in dense stands the adjacent untreated trees also died — apparently because of root grafts with the treated trees.

Table 1. — *Effects of undiluted Tordon 22K applied by spaced stem injections to northern red oak and white oak*

Spacing between injections (Inches)	Volume per injection	Average volume per tree	Trees treated	Range in d.b.h.	Trees killed by Aug. 1965
	Mls.	Mls.	Number	Inches	Percent
MARCH 1963					
2	1/4	1.5	10	6-10	100
	1/2	2.7	10	5-9	100
	1	5.1	10	5-11	100
4	1/4	1.0	10	5-10	40
	1/2	1.6	10	5-9	80
	1	3.7	10	4-11	100
	2	7.3	10	4-11	100
6	1/4	0.7	10	5-10	30
	1/2	1.4	10	5-10	80
	1	3.1	10	6-10	100
	2	4.8	10	5-8	80
JUNE 1963					
2	1/4	1.4	15	5-10	100
	1/2	3.1	15	4-16	100
	1	6.7	15	5-12	100
4	1/4	1.0	10	5-10	80
	1/2	2.1	15	5-12	90
	1	4.4	15	4-13	100
	2	11.8	5	9-12	100
6	1/4	0.7	10	5-10	30
	1/2	1.4	15	5-10	80
	1	3.0	15	5-10	100
	2	7.9	5	6-14	100
OCTOBER 1963					
2	1/4	1.7	5	8-10	100
	1/2	4.1	5	6-14	100
	1	8.0	5	8-11	100
4	1/2	2.4	5	7-12	80
	1	4.1	5	6-10	100
	2	8.1	5	6-11	100
6	1/2	1.4	5	5-9	80
	1	3.3	5	7-10	100
	2	7.3	5	8-12	100

Tordon 101 Mixture

This formulation was effective on oak and other pole-size hardwoods with about twice as much volume per injection as with Tordon 22K (table 2).

Table 2. — *Effects of Tordon 101 mixture applied by spaced stem injections to northern red oak*

Spacing between injections (Inches)	Volume per injection	Average volume per tree	Trees treated	Range in d.b.h.	Trees killed by Sept. 1967
	Mls.	Mls.	Number	Inches	Percent
OCTOBER 1963[1/]					
2	0.5	3.6	5	6-11	60
	1.0	7.7	5	9-10	100
	2.0	14.7	5	7-14	100
2	1.0	4.5	5	6-11	60
	2.0	10.1	5	9-10	100
	4.0	18.4	5	7-10	100
4	2.0	7.8	5	7-14	80
	4.0	14.7	5	10-15	100
	8.0	39.4	5	6-11	100
JUNE 1964[1/]					
2	0.5	3.2	5	6-12	100
	1.0	6.9	5	7-10	100
	2.0	16.9	5	8-18	100
4	1.0	5.3	5	9-12	40
	2.0	10.6	5	6-12	100
	4.0	18.6	5	7-12	100
6	2.0	7.0	5	7-11	80
	4.0	15.6	5	8-11	100
	8.0	31.7	5	6-18	100
MARCH 1966[2/]					
2	0.5	2.9	10	6-9	80
	1.0	5.6	5	6-8	100
	2.0	14.8	7	7-11	100
4	1.0	5.0	5	7-12	80
	2.0	8.9	10	6-11	100
	4.0	17.2	10	6-10	100
6	2.0	7.2	5	6-12	80
	4.0	14.9	10	7-11	100
	8.0	29.8	10	5-14	100

1/ Undiluted quantities for the October and June treatments.
2/ Diluted 50 percent by volume with water for the March treatments.

However, large-crowned sugar maples were not killed by stem injections spaced 2 and 4 inches apart if made during the dormant season. The ground vegetation around the base of these treated maples often was killed for a radius of several feet, indicating that some herbicide was washed down the stems by rain possibly after copious sap flow during the dormant season.

Tordon 101 Mixture, which tends to be thick and syrupy in cold temperatures, flowed freely when diluted 50 percent by volume with water. Kill of red oaks following March injections with the diluted solution was roughly equal to that following June and October injections with the undiluted Tordon 101 Mixture (table 2). Thus the diluted injections, containing only half as much Tordon 101 Mixture, were about as effective as the undiluted injections. It appears that the cost of controlling hardwoods with this herbicide can be greatly reduced by diluting it properly.

Stem Damage from Sapwood Injections

Stems of oaks killed by spaced stem injections of picloram showed similar but more extensive damage than caused by 2,4,5-T amine (Arend 1967). No important tangential damage to the xylem was observed between injection points. A slightly wider portion of the sapwood was killed on each side of the injection than with 2,4,5-T; however, the area narrowed more quickly above the injection. In addition, phloem translocation of picloram apparently exceeds that of 2,4,5-T amine.

The stems of several sugar maple trees, both killed and unkilled from injections of Tordon 101 Mixture spaced 2 and 4 inches apart, were examined 2 years after the treatments. The sapwood, cambium and phloem were dead for at least 2 feet directly above and below the 2-inch wide injections in both the living and dead trees. This limited stem damage resulted in the death of trees with small, suppressed crowns, but only an occasional branch or small portion of the crown died on trees with large, vigorous crowns. The damage to the sapwood of maples was shallow — rarely exceeding 1 inch in depth — suggesting more limited radial translocation of the injected herbicide than in oak.

The limited radial damage in the sapwood may help explain why sugar maples continue to live for years after they have been treated with complete chemical frill girdles. The outer sapwood is killed only to about the depth of the injections.

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1970

PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife — if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

U. S. FOREST SERVICE

RESEARCH NOTE NC-95

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Spacing, Thinning, and Pruning Practices for Young Cottonwood Plantations

ABSTRACT. — The 5-year growth of cottonwood trees planted at five spacing levels is summarized. Wide spacing resulted in better diameter and height growth, but less total wood production per acre than close spacing. Early thinning of closely spaced trees did not maintain diameter growth equal to that of trees with initial wide spacing.

OXFORD: 238:232.43:242:245.1:176.1 *Populus deltoides*

Eastern cottonwood (*Populus deltoides* L.) can be grown on alluvial soils at exceptionally short rotations for various wood products or for stabilization of river and stream front sites. Successful plantations require intensive practices for planting and culture.[1,2] Because more information is needed on intensive management of cottonwood, the effects of spacing, thinning and pruning practices were compared in young plantations. Results after 5 years show that: (1) initial spacing strongly affects subsequent growth, (2) early thinning cannot overcome the effects of narrow initial spacing, (3) method of thinning affects growth, and (4) early pruning is required for clear bole length.

METHODS

In the spring of 1963 three plantings of cottonwood of about 5 acres each were established on alluvial secondary bottoms in southern Illinois. Sites were nearly flat and soil types were mostly Belknap, Sharon, and Cuba. Some small strips of Bonnie soil were also present. Planting sites received complete site preparation and plantations were established with seedlings and given intensive care including cultivation, fertilization, and spraying for insects.[2]

Five initial spacings were tested on 1-acre plots in three different areas: 25, 50, 100, 200, and 400 square feet per tree, essentially equivalent to 5- by 5-, 7- by 7-, 10- by 10-, 14- by 14-, and 20- by 20-foot spacings (table 1). Each spacing plot was divided into three parts to test the effect of thinning, and these parts were split to compare two pruning treatments. One part was mechanically thinned, one part was free-thinned, and one part was left untreated. In mechanical thinnings alternate rows were removed; one direction in the first thinning and at right angles in the second thinning. Each thinning removed half the trees present. Free thinnings also removed half the trees but "leave" trees were selected on the basis of quality rather than spacing. Although the pruning treatment will ultimately remove all branches to a height of 25 feet or more, only dead branches were pruned in the first 5 years. The original objective in thinning was to maintain about equal diameter growth in all spacing treatments. The two wide-spaced plots were not thinned because diameter growth had not yet slowed down.

Trees were pruned at all spacings at the end of the fourth and fifth years.

RESULTS

After 5 years, survival in the unthinned plots and subplots was 95 percent for the two wide spacings, 86 percent for the 10-foot spacing, and 77 percent for the two narrow spacings. A few trees were replanted in the two wide-spaced plots. Stocking was uniform and in accordance with the treatments (table 1).

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[1] *McKnight, J. S. and Biesterfeldt, R. C. Commercial cottonwood planting in the southern United States. J. Forest. 66(9): 670-675. 1969.*

[2] *Minckler, L. S., and Woerheide, John D. One way to establish cottonwood plantations — a case history. South. Lumberman 211(2632): 177-178, illus. 1965.*

Table 1. — *Number of live cottonwood trees per acre at the end of the fifth year (mean of three replications)*

Original spacing (feet)	Number originally planted	Number of thinnings 1/	Thinning treatment: Mechanical	Free	None
5 by 5	1,742	2/ 2	341	350	1,319
7 by 7	871	2/ 2	162	161	660
10 by 10	436	3/ 1	189	189	378
14 by 14	218	0	209	210	210
20 by 20	109	0	105	106	106

1/ Half the trees removed at each thinning.
2/ End of third and fourth years.
3/ End of fourth year.

Plantation Development

Through the second year, mean tree diameter of unthinned stands was not affected by spacing. From the third through the fifth year, however, there were increasing differences in diameter related to spacing up to 14 feet. At the end of the fifth year, trees in the 14- and 20-foot spacings had similar mean tree diameters (table 2).

Table 2. — *Height, diameter, and basal area of trees in cottonwood plantations 5 years after planting (mean of three replications)*

Original spacing (feet)	Number of thinnings	Thinning treatment: Mechanical	Free	None
		MEAN HEIGHT		
		Ft.	Ft.	Ft.
5 by 5	2	33	33	29
7 by 7	2	33	36	37
10 by 10	1	34	36	36
14 by 14	0	41	38	39
20 by 20	0	38	36	35
		MEAN D.b.h.		
		In.	In.	In.
5 by 5	2	3.7	3.9	2.9
7 by 7	2	4.1	4.7	4.1
10 by 10	1	4.6	5.0	4.8
14 by 14	0	6.1	5.5	5.6
20 by 20	0	6.3	5.7	5.7
		BASAL AREA PER ACRE		
		Sq.ft.	Sq.ft.	Sq.ft.
5 by 5	2	28	31	69
7 by 7	2	16	20	64
10 by 10	1	23	26	50
14 by 14	0	43	36	38
20 by 20	0	24	20	20

Annual height growth averaged over 7 feet and did not vary greatly from year to year. Trees spaced 5- by 5-feet apart began to slow down in height growth at the end of 3 years but height growth remained rather uniform at all other spacings. In unthinned, wide-spaced plantations, the average tree was 38 feet tall and 5.8 inches d.b.h. at the end of 5 years (fig. 1). In the 5-foot spacings the average tree was 32 feet tall and 3.5 inches d.b.h. (fig. 2). Average heights and diameters of trees in the other spacings ranged between these sizes (table 2).

F-519641

Figure 1. — Cottonwood plantation spaced 20 by 20 feet at start of the sixth growing season. Dead limbs have been pruned from trees in the center foreground.

F-519642

Figure 2. — Cottonwood plantation spaced 5 by 5 feet at start of sixth growing season.

At 5 years, basal area of unthinned stands ranged from 69 square feet per acre for 5-foot spacing to 20 square feet for 20-foot spacing (table 2). Total basal area of the stand was related to number of trees per acre (table 1) but obviously not in a linear fashion. For example, the unthinned 5 by 5 plantations had 12 times as many trees but only 3½ times as much basal area as the 20 by 20 stands.

The differences among treatments became sharply apparent during the fifth year. Mean height growth in the fifth year was two to three times as much for 20 by 20 plantations as it was for 5 by 5 plantations, whether thinned or not. Other spacings were intermediate. Tree diameter growth in the fifth year for unthinned stands was closely related to original spacing; trees in the 20 by 20 plots grew more than three times as much as those in the 5 by 5 stands (table 3). During the fifth year the differences in basal area growth of unthinned stands were diminishing, but original spacing still influenced growth. The stands spaced 5 by 5, 7 by 7, and 10 by 10 grew 16 to 17 square feet per acre, the 14 by 14 stands grew nearly 14 square feet, and the 20 by 20 plots grew about 8 square feet.

Table 3. — *Mean diameter growth of cottonwood trees during the fifth year*
(Inches d.b.h.)

Original spacing (feet)	Number of thinnings	Thinning treatment: Mechanical	Free	None
5 by 5	2	0.65	0.97	0.39
7 by 7	2	.62	1.31	.56
10 by 10	1	.86	1.18	.87
14 by 14	0	1.19	1.16	1.10
20 by 20	0	1.39	1.33	1.26

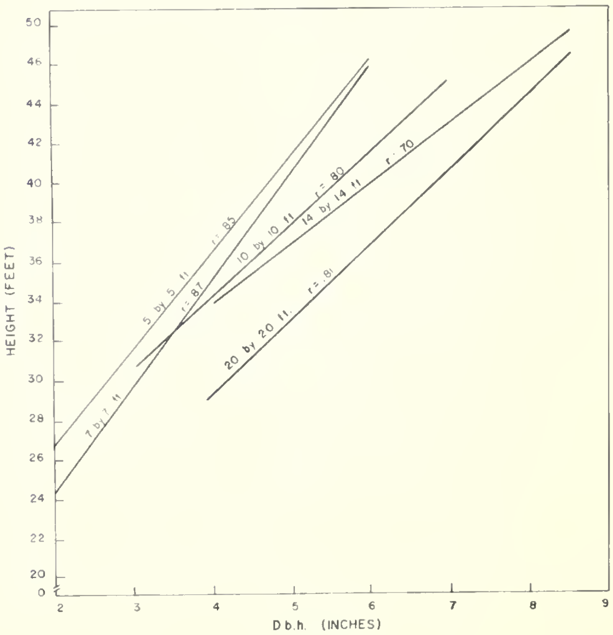
Effect of Thinning

After 5 years, mean tree diameter in heavily thinned plantations was only about 60 to 70 percent that of trees in plantations with original wide spacing (table 2). However, diameter growth in free-thinned plots during the fifth year was about equal to that of originally wide-spaced plots and much greater than for mechanically thinned plots (table 3). Mechanical thinning did not increase total diameter or fifth-year diameter growth except in the 5 by 5 spacings.

Height-Diameter Relation Affected by Spacing

Even though stand density did not greatly affect mean height, it did change the relationship between height and diameter (fig. 3). The wider the spacing the greater the d.b.h. in relation to height. For example, 38-foot trees in 5 by 5 plots were less than 4.5 inches d.b.h., whereas in 20 by 20 plots they were more than 6.0 inches d.b.h.

Figure 3. — Regression of height over d.b.h. at age 5 for unthinned stands of different spacings.



Pruning Dead Branches

Clear length for pruned trees ranged from 17 feet for 5 by 5 spacing to about 5 feet for 20 by 20 spacing. The clear bole length for thinned plantations was about 2 or 3 feet less than for unthinned. Unpruned plantations had only about 2 feet of clear length, and this did not vary among spacings.

Pruning time per tree averaged 3.7 man-minutes the fourth year and 2.1 man-minutes the fifth year. There was little difference in pruning time per tree among spacings or between thinned and unthinned plots. Wider spaced trees had fewer but larger limbs to prune.

CONCLUSIONS

Appropriate planting methods, intensive early care, and suitable sites are essential for establishment of successful cottonwood plantations. If these are not provided, it is useless to plant cottonwood. The spacing, thinning, and pruning practices that should be used depend on the objectives of management. Spacing also affects costs of establishment and subsequent care, especially where machinery is used.

Early results of this study strongly suggest that wide spacings will be best for large products or combinations of logs, veneer bolts and pulpwood. For example, the plantations spaced 14 by 14 feet produced more than 200 trees per acre in 5 years with a mean d.b.h. of about 6 inches. In another 2 or 3 years at least 100 of these could be removed in pulpwood thinning, leaving the remainder of logs or bolts. For the maximum production of wood fiber from small trees on a 5- or 6-year rotation, spacing can be as close as 5 by 5 feet. It seems apparent that trees of 6 to 8 inches d.b.h. for pulpwood could be produced in 7 or 8 years with an initial growing space of 60 to 80 square feet per tree.

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1970

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U. S. FOREST SERVICE

RESEARCH NOTE NC-96

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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Antibiotic Treatment of Blister Rust Cankers in Eastern White Pine

ABSTRACT. — Cycloheximide (Acti-dione)[1] and Phytoactin antibiotics, applied as basal stem treatments, aerial spray treatments, and complete foliar drenches were not effective in controlling blister rust cankers in eastern white pine. Cycloheximide was effective in suppressing canker activity and growth if directly applied to scarified cankers.
OXFORD: 443.3—172.8 *Cronartium ribicola* **— 414.19:174.7** *Pinus strobus* **—416.4+443—414.19**

This note presents the final evaluation of the antibiotics cycloheximide (Acti-dione) and Phytoactin when applied as basal stem treatments, aerial sprays, and ground foliar drenches for control of blister rust cankers on eastern white pine. The tests were established in Wisconsin and Minnesota during 1962. Preliminary evaluations were reported in Plant Disease Reporter 50(4): 224-228, 1966.

[1] *Mention of trade names does not constitute endorsement by the USDA Forest Service.*

METHODS

In the basal stem treatments, Phytoactin in three formulations (L 341, 439, 440), cycloheximide and cycloheximide semicarbazone were basally applied to 812 plantation trees 25 years old, averaging 35 feet tall and 6 inches d.b.h. Treatments were made during June, August, and October 1962 at different antibiotic concentrations (100-300 p.p.m.) in No. 1 or No. 2 fuel oil, with and without Triton B1956. There were three replications of four to five trees for each seasonal application. Approximately 1 quart of solution was applied to the nonscarified bottom 6 feet of each trunk and the first 18 inches of each branch in that area. Data were recorded from directly treated cankers as well as from those above the treated area (transport).[2]

[2] *Transport cankers are those that would be above the treated area on the tree and hence would not receive direct applications of chemotherapeutants. Thus the chemical would have to be translocated to these cankers by the tree's vascular system.*

An additional antibiotic direct canker treatment test, including scarification, was established during October 1963. Cycloheximide (200 p.p.m.) and three formulations of Phytoactin (L 440, 414, 415) were directly sprayed or painted on scarified and nonscarified cankers on 165 plantation trees. These trees were 9 years old, averaging 12 feet high and 3 inches d.b.h. The antibiotics were applied in No. 2 fuel oil, lanolin paste, and slurry paste.

For the aerial applications, cycloheximide semicarbazone (100-200 p.p.m.) and Phytoactin L318 and 444 (200 p.p.m.) were applied by helicopter to plantation trees 25 years old, averaging 35 feet tall and 5 inches d.b.h. Seven 4-acre blocks were treated and 50 test trees with active bole cankers were selected in each block. The materials were applied in No. 1 fuel oil as a 20-percent oil-water emulsion or in water with rhodamine dye at 10 gallons per acre.

Three formulations of Phytoactin (L 318, 319, 346), cycloheximide semicarbazone, and streptimidone (100-800 p.p.m.) were applied by pressurized sprayers during August 1962 as complete drenches to plantation trees 8 years old, averaging 10 feet tall and 2 inches d.b.h. Twelve 10-tree plots were treated. The antibiotics were applied in water or 20-percent oil-water emulsion at the average rate of 1.5 quarts of spray solution per tree.

RESULTS AND DISCUSSION

Five years after treatment cycloheximide and Phytoactin applied as basal stem treatments, aerial spray treatments, and complete foliar drenches, had not controlled blister rust cankers in eastern white pine. Phytoactin had little or no effect on canker development with any of the application methods tested. Cycloheximide suppressed canker growth and activity when it was applied directly to cankers as a basal stem treatment, especially to scarified cankers. However, it had little effect on cankers above the treated area.

Results also showed that although a few individual cankers were apparently inactivated by the basal stem treatment with cycloheximide, other cankers in the same treatment were still alive and active. The most effective treatments, as determined by canker measurement and activity scale, were also the most phytotoxic to the trees.

There were no significant statistical differences among treatments including untreated check trees according to the F-test in the analysis of variance. Therefore, treatments were not effective enough to warrant their use as a control method.

Thorough canker scarification before direct treatment with cycloheximide — at least 4 inches in all directions beyond the visible canker margin — showed the most promise for complete canker inactivation.

It is evident that there is either a wide variation in blister rust cankers and their reaction to antibiotic treatments, or else a great difference in the amount of antibiotic absorbed by the tree. All our tests indicated clearly that the most effective treatments killed the host tissue occupied by the blister rust fungus, thus isolating or suppressing the canker rather than selectively killing the rust mycelium itself.

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U. S. FOREST SERVICE

RESEARCH NOTE NC-97

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Is Cull Overestimated in Northern Hardwood Stands?

ABSTRACT. — To determine whether overestimated cull could partly explain differences between bid offers and appraised values of northern hardwood timber, cull volume estimated by the accepted method was compared with actual cull volume measured from flitch photographs and log-scaled cull volume.
OXFORD: 525.5(774):176.1 *Acer saccharum*

Bid offers for northern hardwood timber are often much higher than appraised values. Possible explanations are underestimated tree volume or quality, and overestimated cull volume. This paper deals only with the possibility of overestimated cull.[1]

The Zillgitt and Gevorkiantz method (1946) is currently used to estimate cull in northern hardwood stands.[2] This method relates defects such as dead limbs, conks, cracks, crook, and sweep to cull volume percentage. The defect types are grouped according to severity. This severity classification and the number of 16-foot logs per tree determines cull percentage.

[1] *Includes sound (crook and sweep) and unsound cull volume.*

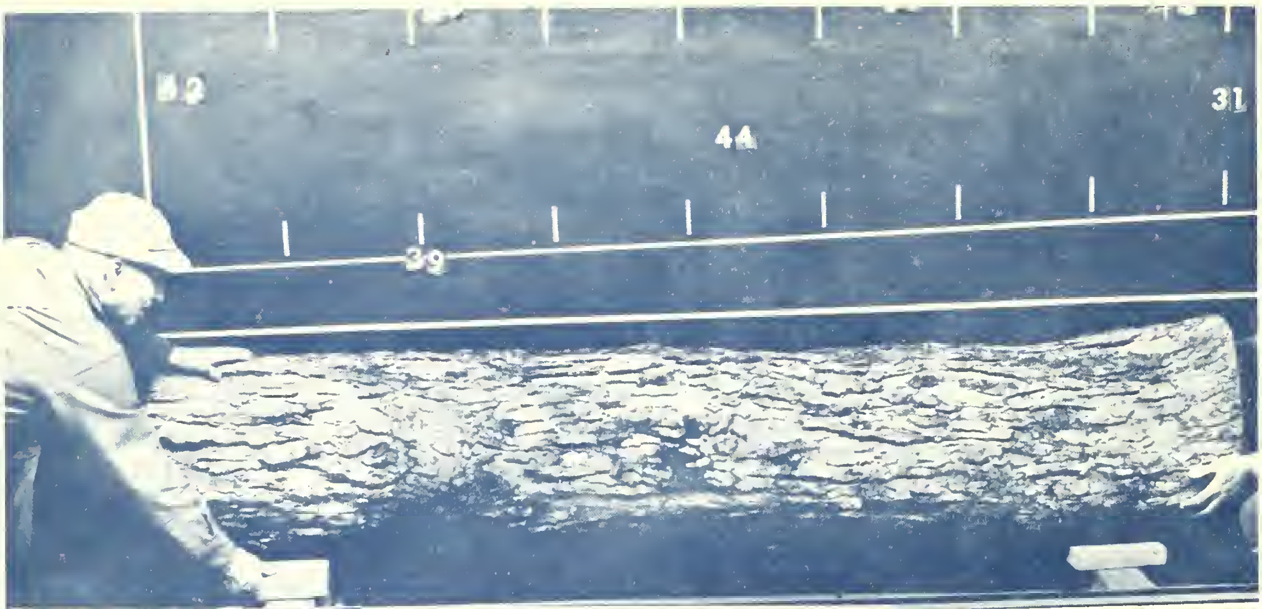
[2] *Actually, Zillgitt's (1946) four-class system is used, but the six-class system referenced above is identical except for more detail.*

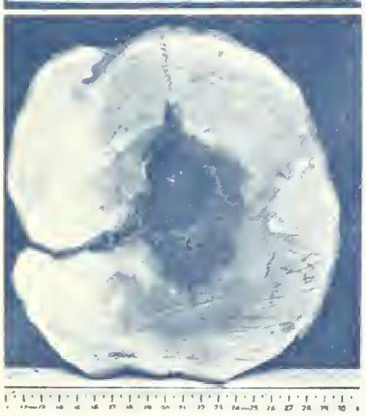
We used the Zillgitt and Gevorkiantz method to calculate average cull percentage for sugar maple (*Acer saccharum* Marsh.) trees, and then compared this value with cull volume measured (1) from flitch photographs and (2) from log-scaled volume, using log exterior and end photographs. The Zillgitt and Gevorkiantz method overestimated cull by about four times in our sample trees.

METHODS

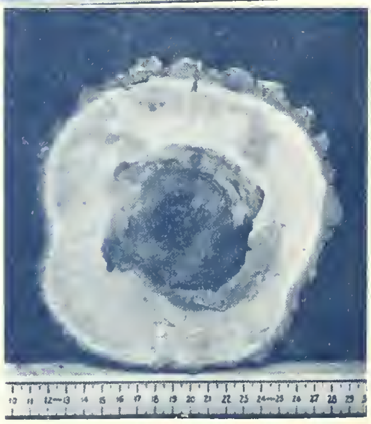
Sample trees were cut in old-growth sugar maple stands in Upper Michigan. These trees were selected by d.b.h. and the number of clear faces within the butt one-quarter of the merchantable stem.[3] Trees were separated into three d.b.h. classes, and three quality classes within each d.b.h. class. The d.b.h. classes were 11 to 15 inches, 16 to 20 inches, and 21 to 26 inches; the quality classes were 0 to 1 clear faces, 2 clear faces, and 3 to 4 clear faces. There were 10 trees in each d.b.h.-quality class combination, for a total of 90 trees. Tree age ranged from 92 to 289 years, averaging 192; d.b.h. averaged 18 inches.

[3] *The merchantable height was restricted by a 6-inch d.i.b. minimum top or separation of the stem into two or more distinct branches.*





F-501569, 519639, 519638
Figure 1. — Log exteriors and ends were photographed. Numbers above log identify defects by type, size, and location.



The trees were felled and bucked, all surface abnormalities (defects) found on each log identified and measured, and log exteriors and ends photographed (fig. 1). The logs were then sawed through-and-through into 1-inch-thick flitches, unsound cull areas outlined, and flitches photographed (fig. 2).

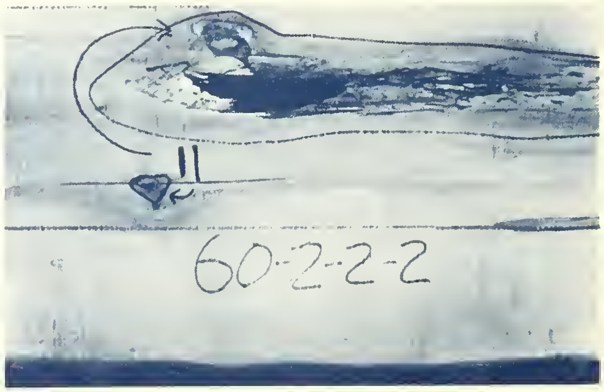


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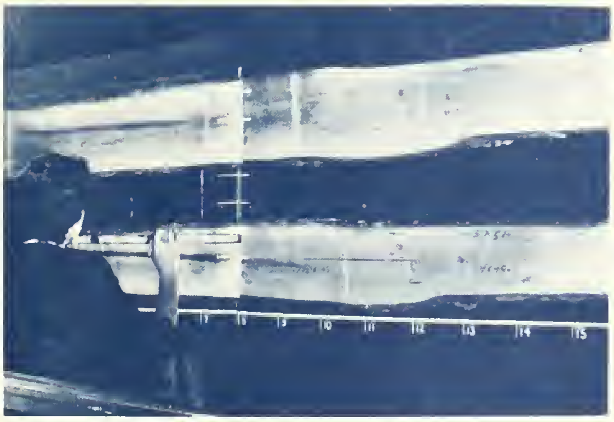
Figure 2. — Unsound cull areas were marked on each flitch and all flitches photographed.

Cull volume by the Zillgitt and Gevorkiantz Method. — The log exterior and end photographs were used to paper-diagram each tree, showing the type, size, and location of all defects. We used these diagrams and table 2 from Zillgitt and Gevorkiantz (1946) to determine defect classes for each tree. The defect classes and the number of 16-foot logs per tree were then used to calculate cull percentage for each tree.

Log-scaled cull volume. — In addition, the tree paper-diagrams and log grades (Vaughan *et al.* 1966) were used to simulate bucking each tree into logs, which were log-scaled using Grosenbaugh's (1952) formulas.[4] Log cull volumes were then summed to determine cull volume per tree.

Cull volume measured from flitch photographs. — Unsound cull volume was measured for each tree by summing the squared-out cull areas on each flitch photograph (fig. 3). To get total cull volume per tree, these unsound cull volumes were added to the sound cull volumes obtained by log scaling as described above.



F-502805
Figure 3. — Flitch photographs were projected onto a screen and unsound cull areas measured.

The average cull percentages calculated for the 90 trees by the three different methods, the Zillgitt and Gevorkiantz, log scaling, and flitch measuring, were then compared.

[4] *These formulas are the same as those given in the National Forest Log Scaling Handbook except they are expressed as a percentage of log volume.*

RESULTS AND DISCUSSION

The cull volume percentage from the Zillgitt and Gevorkiantz method was about four times as large as that obtained from either log scaling or measuring from flitch photographs (table 1). This is in contrast to data published earlier (Zillgitt and Gevorkiantz 1946) showing the Zillgitt and Gevorkiantz method to underestimate cull by 5.3 percent of gross merchantable volume for sugar maple trees. However, Zillgitt and Gevorkiantz measured cull volume by log scaling in the field, whereas we log-scaled in the laboratory using photographs of log exteriors and ends.

Our results indicate that overestimated cull could partially account for the difference between appraised value and bid offers for northern hardwood timber.

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Table 1. — *Comparison between estimated and measured cull*

Method used to determine total cull	Total cull for all 90 trees	Mean cull per tree	Standard deviation	Gross merchantable volume 1/
	Cu. ft.	Cu. ft.	Cu. ft.	Percent
Zillgitt and Gevorkiantz	1,133	12.7	11.8	26.2
Log scaling using photographs of log faces and ends	244	2.7	3.1	5.6
Measuring from flitch photographs2/	266	3.0	4.1	6.2

1/ Total stem volume (Smalian) excluding tops and stumps.
2/ Sound cull was obtained by log scaling using Grosenbaugh's (1952) formulas for estimating crook and sweep. These values were then added to the flitch-measured unsound cull to get total cull.

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1970

U. S. FOREST SERVICE

RESEARCH NOTE NC-98

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Red Oak Lumber Makes Good Shade-Shelter for Hogs

ABSTRACT. — Describes the construction and testing of portable hog shade-shelters made from low-grade red oak lumber.
OXFORD: 833.4:176.1 *Quercus rubra*

Tests show that shade-shelters for hogs made from low-grade red oak lumber are both durable and practical. Usually, small portable farm structures are made from softwood lumber or metal; but we have found that many of them can be made from hardwood lumber if they are designed and treated for outdoor use. The cheaper grades of hardwood lumber are suitable and usually available at hardwood sawmills within the farm belt.

Our shade-shelter for hogs provides about 100 square feet of shade or about 64 square feet of shelter when the three hinged sides are down. We estimate it can be built commercially with about 400 board feet of lumber for about $100.

WHAT WE DID

To find out if shade-shelters for hogs could be built satisfactorily from low-grade hardwood lumber, we made six units out of parts cut from No. 2 Common red oak lumber and tested them at the Southern Illinois University Swine Farms. Each shade-shelter was placed in a pen with one boar ranging in weight from 200 to 800 pounds.

Sides of the shelters were kept down from September through April. During the rest of each year the sides were raised to provide shade (fig. 1). The hogs were rotated among pens and it was judged that all shelters received equal use.

WHAT WE LEARNED

We used slotted, built-in floors instead of removable floors with boards laid edge to edge for several reasons. The slots permit the floorboards to shrink and swell with changing moisture conditions without loosening the fasteners. Slotted floors improve drainage and ventilation in the shelters and keep the floors drier and cleaner than tight floors. When debris under the slotted floors accumulates to undesirable depths, the shelters can be towed to a new spot and the debris left behind. Because the slotted floor is a permanent part of the shelter, it braces the framing and prevents the corners from getting out of alignment. And finally, slotted floors require less lumber to build than solid floors.

Test shelters with board-and-batten siding performed better than shelters with tongue-and-groove siding. Gaps between the boards under the battens allowed the siding boards to swell and shrink freely (fig. 2). This type of siding also weathered better than surfaced tongue-and-groove siding. The weather side of the boards was not planed, and this rough

F-516500

Figure 1. — The combination shade-shelter in summer has the sides raised to provide over 100 square feet of shade.

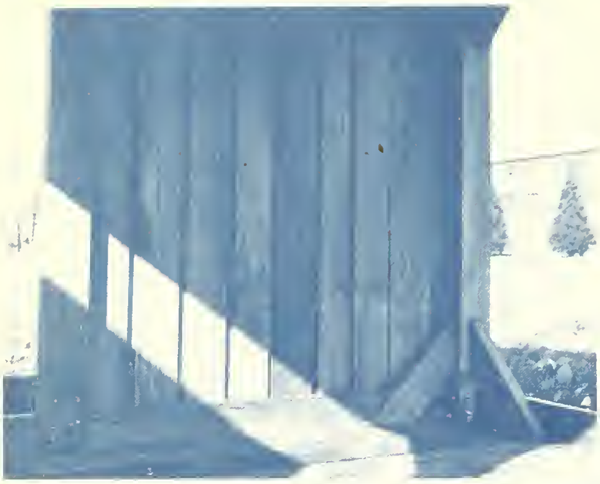

Figure 2. — Interior view of a shelter with board-and-batten siding. Boards are spaced ¾ inch for expansion and shrinkage.

surface held a stain finish better than planed surfaces on tongue-and-groove siding. Also, the board-and-batten siding required less labor to install and less lumber to make than tongue-and-groove siding because boards of random widths could be fully utilized. Tongue-and-groove siding had to be ripped to a few fixed widths before the edges could be matched on a high-speed molder. Both the ripping and the edge molding caused waste.

To avoid seasoning problems inherent with making posts from 4-inch-thick lumber, we made 3⅝-inch-square laminated posts with 2 by 4's. Because they have not checked or split, we believe they are superior to nonlaminated posts used in other tests. Costs of making laminated posts were partially offset by using 2-inch-thick lumber which is easier to obtain and dry than 4-inch-thick stock of the same quality.

By using thicker and wider framing than is usual for this type of structure, we prevented bowing of the side panels. The improved frame members were 15/16 inch thick and 5⅝ inches wide. A midpanel horizontal cleat in the side panels provided strong bracing and permitted us to end-butt short pieces for siding, thus increasing the utilization of our No. 2 Common grade lumber.

Treating farm structures with preservatives can be hazardous to hogs if not done properly. Freshly treated woods exude both salts of the preservative and the oil carrier. Eating these materials or even rubbing against them can cause ulcers, internal poisoning, or possibly death of the animals. However, if the exuded salts have been washed or brushed off and the carrier has evaporated from the wood, this danger is practically eliminated.

We treated the parts of our shade-shelters with a 5-percent solution of pentachlorophenol in mineral spirits. Skids were pressure treated and all other parts were cold-soaked. The pressure-treated flooring parts weathered outdoors for 8 weeks before being installed in the shelters. The other treated parts were left outdoors for several days until they were thoroughly dry. After 5 years of use there have been no toxic reactions of hogs using our treated test shelters and no wood decay has occurred.

Red oak framing, flooring, and siding have proved to be durable. The wood has withstood rubbing, scratching, and bumping by the hogs with little wear or breakage. Also, the hogs have not damaged the wood parts by chewing as they often do in wood structures.

COSTS

The yields of usable parts obtained from No. 2 Common oak lumber kept our material costs low. The 8/4-inch lumber yielded 67 percent, and the ¾-inch lumber 79 percent usable parts. Lumber costs were $35.56 and roofing, stain, hardware, and preservative costs were $16.61, making the total material cost $52.17 for each shade-shelter.

Labor time per shelter for a 2-man crew was 8.1 man-hours. Labor and material costs together were $72.42 per shelter.

Six shelters are an inadequate basis for predicting the cost of building shade-shelters under production conditions. However, we estimate that the labor, shop operation, and processing equipment depreciation costs per shade-shelter would be about $30. On this basis durable shade-shelters for hogs probably can be built commercially from No. 2 Common red oak lumber at a total cost of about $100 per unit, and sold at competitive prices.

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1970

U. S. FOREST SERVICE

RESEARCH NOTE NC-99

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

Relation of Crown Width to Tree Diameter In Some Upland Hardwood Stands of Southern Illinois

ABSTRACT.—Crown width-d.b.h. relationships in well stocked, uneven-aged stands of oak and hickory were similar to those for open-grown trees and were independent of site, crown class, and species. The irregular crowns of forest grown trees interlace and overlap, however, and measuring crown extensions to the branch tips tended to overestimate effective crown area.
OXFORD: 531:521.2:176.1(773)

Tree diameter at breast height (d.b.h.) is related to the amount of crown growing space the tree occupies. For a given stand, the sum of these growing spaces often is useful for interpreting and predicting stand development and growth. Tree crown mass would be preferable for these purposes, but it is difficult to measure. How well, then, does d.b.h. of forest trees express crown width, a factor related to total crown area? And how does this diameter-crown width relationship vary by stand density, species, crown class, and site?

Previous studies have attempted to answer some of these questions. Bonnor (1964) found that the relationship between stem diameter and crown width x height of lodgepole pine (*Pinus contorta* Dougl.) was unaffected by stand density. On the other hand, open-grown lodgepole pine and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) had wider crowns than forest-grown trees of the same diameter, Smith and Bailey (1964). Smith (1964) concluded from a study of conifers and red alder (*Alnus rubra* Bong.) that d.b.h. gives a valid estimate of the crown-root complex. Our study of oaks and hickories in Illinois indicates that the d.b.h.-crown width relationships for forest-grown trees in uneven-aged stands are similar to those reported for open-grown trees (Krajicek *et al.* 1961).

SOURCE OF DATA

The crown widths and diameters of 675 oak and hickory trees were measured on 60 one-half acre plots located in upland hardwood stands in southern Illinois. The plots were marked to leave residual stands of three structural classes — large, medium, and small trees — and three density classes — 40, 60, and 80 square feet of basal area per acre — on good and average sites. Uncut plots were included. The uneven-aged stands were well stocked but had been partially cut about 40 years earlier. The trees ranged from 40 to 150 years old. Basal area for trees 4.6 trees d.b.h. and larger ranged from about 85 to 110 square feet per acre. The average sites — oak S.I. 61 — supported mixed oaks (*Quercus*) and hickory (*Carya*); on the good sites —S.I. 72, yellow-poplar (*Liriodendron tulipifera* L.) also was present.

On each plot, the residual trees were stratified by species and size class and 50 percent of the trees were randomly selected for intensive study. Sample trees ranged from 5 to 26 inches d.b.h. and included all crown classes except overtopped trees. Cull trees were excluded. Measurements were made at the time of the thinning so treatment had not affected d.b.h. or crown width.

Diameter was measured to 1/20-inch. Crown width was determined by measuring the horizontal distance to the nearest foot on north-south and east-west axes to the tips of the branches as estimated by their vertical projection on the ground. Crown width was assumed to be the average of the two measurements. Individual crowns had varying degrees of irregularity; they were not as uniform or full as open-grown trees.

ANALYSES AND RESULTS

Regression analyses of the relation between average crown width and d.b.h. for individual trees were computed by species, crown class, and site. There was generally a linear relationship between crown width and d.b.h. for all species and crown classes on mixed hardwood and oak-hickory sites (table 1). However, there was considerable variation among these forest-grown trees. Within the limits of the data,[1] the regression lines for the three crown classes had essentially the same slope and when taken together formed a single line from 5 to 26 inches d.b.h. This was true for all species, and species equations were similar. Thus, the three short regressions by crown classes formed essentially one continuous line, and the relationship may be curvilinear. The species-site-crown class regressions were variable, but when intercepts were low the slope coefficients were high (table 1). Ratios of crown width over tree d.b.h. were similar for all species, crown classes and sites. Crown width in feet was two times the d.b.h. in inches.

The crown width-d.b.h. relationships differed little between sites and among the upland oaks and hickory species (table 1). Because yellow-poplar had a lower crown width-d.b.h. ratio than the upland oaks and hickory, it was not included in these data.

The combined crown width-d.b.h. regressions for these forest-grown trees were essentially the same as for open-grown upland oaks (Krajicek *et al.*, 1961) (fig. 1). However, the crown variations in forest-grown trees were much greater than among open-grown trees. Because of crown margin irregularities in the forest-grown trees, measuring crown extensions to the branch tips tended to overestimate effective crown width.

The total crown area of all trees in the stands can be computed by use of the general regression equation for the 675 sample forest-grown trees ($Y = 3.70 + 1.709 X$). This was done assuming that crowns were circular in horizontal cross section and using average crown width (north-south and east-west) as the diameter of the circle. As total computed crown area was consistently greater than one acre of ground surface (table 2), the crowns either must be interlaced and/or overlapping or the method used to compute crown area must overestimate it.

A comparison was made of the general regression for these forest-grown trees and that

[1] *The general range of diameters by crown classes was as follows: Intermediate: 5-12 inches d.b.h., codominant: 8-20 inches d.b.h., and dominant: 14-26 inches d.b.h.*

Table 1.—*Significant[1] regressions of average crown width in feet (Y) and tree d.b.h. in inches (X) for trees in well stocked stands*

Species	Site	Crown class	Ratio Y/X	Species coefficients A	Species coefficients B	Number of trees
White oak	Good	Dominant	1.96	7.2	1.6	45
(Quercus alba L.)		Codominant	1.98	3.5	1.7	44
		Intermediate	2.11	3.1	1.8	33
	Average	Dominant	2.02	-0.6	2.1	39
		Codominant	1.97	-1.2	2.1	51
		Intermediate	2.09	7.9	1.1	40
Black oak	Good	Dominant	1.93	8.0	1.5	26
(Q. velutina Lam.)		Codominant	1.86	-5.6	2.3	28
		Intermediate	1.90	1.7	1.7	14
	Average	Dominant	1.97	6.7	1.5	42
		Codominant	1.89	1.6	1.7	50
		Intermediate	1.96	7.9	0.9	18
Northern red oak	Good	Dominant	1.87	9.2	1.3	16
(Q. borealis Michx.F.)		Codominant	2.05	5.3	1.6	19
		Intermediate	1.87	-0.6	2.0	13
Scarlet oak	Average	Dominant	2.06	10.0	1.4	47
(Q. coccinea Muenchh.)		Codominant	2.06	3.3	1.8	35
		Intermediate	2.36	4.0	2.9	16
Hickory	Good	Dominant	1.81	7.7	1.3	11
(Carya)		Codominant	1.99	0.5	2.0	17
		Intermediate	2.07	2.2	1.8	27
	Average	Codominant	2.23	5.3	1.7	20
		Intermediate	2.28	3.3	1.8	24

1/ Nineteen regressions were statistically significant at the one percent level and 4 at the 5 percent level.

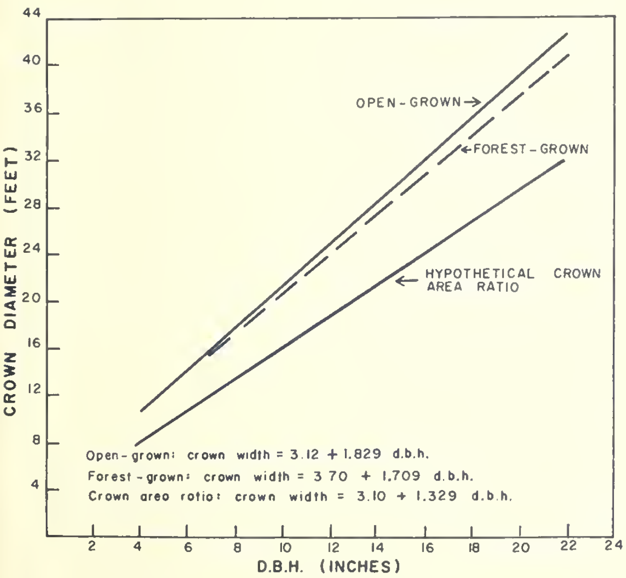

Figure 1.—Comparison of crown width-d.b.h. regressions for open-grown, forest-grown, and trees in hypothetical stands.

Table 2.—*Total crown area[1] per acre for upland hardwood unthinned stands*

Stand	Total crown area per acre	Ratio to one acre
	Sq. ft.	
Mixed hardwoods		
1	50,786	1.17
2	48,661	1.12
3	55,292	1.27
Oak-hickory		
4	60,935	1.40
5	51,835	1.19
6	50,118	1.15

1/ Trees 4.6 inches d.b.h. and larger.

for trees in a hypothetical stand where area is allocated to each tree with an assumption of no interlacing or overlapping crowns (fig. 1). The latter equation represents 100 percent stocking (Gingrich 1967). The ratio of average crown area for forest-grown over the hypothetical trees was 1.5 or more for all tree sizes.

CONCLUSIONS

These findings indicate that in the oak-hickory forests studied, bole d.b.h. can be used to estimate crown area occupancy. This implies that, after thinning, both diameter growth and crown area increase in response to increased growing space and the crown area-d.b.h. ratio is generally maintained.

It is suggested that open-grown trees and the forest-grown trees in this study had approximately the same crown width-d.b.h. relationship because the crowns of forest-grown trees interlaced and overlapped. The crown area ratio based on the average crown widths was greater than ground surface unity. Crown shape and fullness for open-grown and forest-grown trees are, of course, not the same. For the oak-hickory trees studied, the ratio of average crown width to bole d.b.h. appeared to be independent of site, crown class, and species.

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1970

U. S. FOREST SERVICE

RESEARCH NOTE NC-100

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

Lake States Pulpwood Production Rises 11 Percent In 1969

ABSTRACT. — This 24th annual report shows that 1969 Lake States pulpwood output rose to about 3.9 million cords from about 3.5 million cords in 1968. Pulpwood harvesting increased 150,000 cords in Wisconsin, 113,000 cords in Minnesota, and 102,000 cords in Michigan. For the first time, pulpwood imports from western States exceeded those from Canada.
OXFORD: 861.0(77):792

After Wisconsin mills cut back pulpwood inventories one-quarter million cords in 1968 by curtailing purchases, Lake States pulpwood procurement returned to a more "normal" level in 1969. Regional pulpwood production was 3,944,000 cords, nearly 400 thousand cords above 1968, but more than 300 thousand cords below the record output in 1966 (table 1).

PRODUCTION

All Lake States shared the larger pulpwood output. Production rose, 10, 11, and 12 percent, in Minnesota, Michigan, and Wisconsin, respectively.

Roundwood harvesting rose 364,000 cords in the Lake States. This harvest (including chips from roundwood) constituted 93 percent of the 1969 Lake States pulpwood output; mill residue such as chips, slabs, and veneer cores, made up the remaining 7 percent. More than half this harvest increase was aspen. The cut of miscellaneous hardwoods was up 86,000 cords from 1968 and the harvest of pine increased 53,000 cords.

Some softwood species did not share in the larger cut. Balsam fir output fell 21,000 cords, and tamarack 8,000 cords. Spruce cutting showed little change.

Eleven percent more Lake States mill residue was sold to pulpmills in 1969 than in 1968. Most of the additional residue was from Michigan sawmills and veneer mills.

MILL RECEIPTS

In 1969 Lake States pulpmills received 4,366,000 cords of pulpwood, 9 percent more than in 1968. Three-fourths of the additional

Table 1.—*Production and imports of pulpwood, Lake States, 1969*

Species and destination	Production by States[1]				Imports			Total receipts
	Minnesota	Wisconsin	Michigan	Regional total	Other U.S.[2]	Canada	Total imports	
Aspen								
Minnesota	617,343	6,240	--	623,583	--	9,744	9,744	633,327
Wisconsin	39,480	688,298	249,735	977,513	--	285	285	977,798
Michigan	--	2,380	355,894	358,274	--	--	--	358,274
Exported[3]	3,594	356	547	4,497	--	--	--	--
Total	660,417	697,274	606,176	1,963,867	--	10,029	10,029	1,969,399
Balsam fir								
Minnesota	32,712	--	--	32,712	--	--	--	32,712
Wisconsin	6,916	50,398	23,978	81,292	--	--	--	81,292
Michigan	--	--	19,198	19,198	--	--	--	19,198
Exported[3]	--	--	945	945	--	--	--	--
Total	39,628	50,398	44,121	134,147	--	--	--	133,202
Birch								
Minnesota	2,900	--	--	2,900	--	--	--	2,900
Wisconsin	91	61,859	730	62,680	--	--	--	62,680
Michigan	--	--	21,521	21,521	--	--	--	21,521
Exported[3]	72	598	852	1,522	--	--	--	--
Total	3,063	62,457	23,103	88,623	--	--	--	87,101
Hemlock								
Wisconsin	--	50,559	61,328	111,887	--	--	--	111,887
Michigan	--	--	1,937	1,937	--	--	--	1,937
Total	--	50,559	63,265	113,824	--	--	--	113,824
Pine								
Minnesota	172,455	--	--	172,455	--	58,094	58,094	230,549
Wisconsin	63,090	216,326	91,083	370,499	85,711	58	85,769	456,268
Michigan	--	--	115,571	115,571	--	--	--	115,571
Exported[3]	1,290	20	--	1,310	--	--	--	--
Total	236,835	216,346	206,654	659,835	85,711	58,152	143,863	802,388
Spruce								
Minnesota	81,252	--	--	81,252	599	1,971	2,570	83,822
Wisconsin	53,520	13,367	22,821	89,708	--	118,723	118,723	208,431
Michigan	--	--	14,948	14,948	--	1,413	1,413	16,361
Exported[3]	19,791	--	1,117	20,908	--	--	--	--
Total	154,563	13,367	38,886	206,816	599	122,107	122,706	308,614
Tamarack								
Minnesota	293	--	--	293	--	--	--	293
Wisconsin	20,756	1,728	2,195	24,679	--	--	--	24,679
Total	21,049	1,728	2,195	24,972	--	--	--	24,972
Misc. hardwoods								
Minnesota	29,905	--	--	29,905	--	10,345	10,345	40,250
Wisconsin	913	233,064	44,015	277,992	--	--	--	277,992
Michigan	--	--	151,210	151,210	--	417	417	151,627
Exported[3]	1,080	4,678	400	6,158	--	--	--	--
Total	31,898	237,742	195,625	465,265	--	10,762	10,762	469,869
Total roundwood								
Minnesota	936,860	6,240	--	943,100	599	80,154	80,753	1,023,853
Wisconsin	184,766	1,315,599	495,885	1,996,250	85,711	119,066	204,777	2,201,027
Michigan	--	2,380	680,279	682,659	--	1,830	1,830	684,489
Exported[3]	25,827	5,652	3,861	35,340	--	--	--	--
Total	1,147,453	1,329,871	1,180,025	3,657,349	86,310	201,050	287,360	3,909,369
Residues softwood								
Minnesota	1,000	--	--	1,000	--	6,223	6,223	7,223
Wisconsin	2,282	13,388	5,018	20,688	171,335	--	171,335	192,023
Exported[3]	1,500	1,431	2,757	5,688	--	--	--	--
Total	4,782	14,819	7,775	27,376	171,335	6,223	177,558	199,246
Residues hardwood								
Minnesota	38,811	10,905	--	49,716	954	--	954	50,670
Wisconsin	1,308	83,204	36,372	120,884	--	--	--	120,884
Michigan	--	6,268	71,298	77,566	8,898	--	8,898	86,464
Exported[3]	--	5,089	6,433	11,522	--	--	--	--
Total	40,119	105,466	114,103	259,688	9,852	--	9,852	258,018
All wood material								
Minnesota	976,671	17,145	--	993,816	1,553	86,377	87,930	1,081,746
Wisconsin	188,356	1,412,191	537,275	2,137,822	257,046	119,066	376,112	2,513,934
Michigan	--	8,648	751,577	760,225	8,898	1,830	10,728	770,953
Exported[3]	27,327	12,172	13,051	52,550	--	--	--	--
Total	1,192,354	1,450,156	1,301,903	3,944,413	267,497	207,273	474,770	4,366,633

1/ Vertical columns of figures under box heading "Production by States" present the amount of pulpwood cut in each State.

2/ Mostly western States.

3/ Pulpwood shipped to mills outside of region.

Table 2. — *Geographic origin and destination of pulpwood received by Lake States mills, 1969*

Species	Percent of pulpwood originating from:					Percent of pulpwood received by mills in:		
	Minn.	Wis.	Mich.	Canada	Other U.S.	Minn.	Wis.	Mich.
Aspen	33	35	31	1	--	32	50	18
Balsam fir	29	38	33	--	--	25	61	14
Birch	3	71	26	--	--	3	72	25
Hemlock	--	44	56	--	--	--	98	2
Pine	29	27	26	7	11	29	57	14
Spruce	44	4	12	40	*	27	68	5
Tamarack	84	7	9	--	--	1	99	--
Misc. hardwoods	6	50	42	2	--	9	59	32
Residues	9	25	25	1	40	13	68	19
All wood material	27	33	30	4	6	25	57	18
Previous year (1968)	27	32	29	6	6	25	56	19

*Less than 1/2 of 1 percent.

purchases went to Wisconsin. Lake States loggers supplied 90 percent of the volume, western states 6 percent, and Canada 4 percent (table 2).

Receipts were up 13 percent in Wisconsin where 57 percent of all wood purchases in the Lake States were shipped. Pulpwood procurement in Michigan declined because one pulpmill closed. Procurement of spruce, balsam fir, and pine declined in Michigan, but was nearly offset by larger purchases of aspen, birch, and hardwood residues. Receipts rose 9 percent in Minnesota with most of the additional volume in aspen, pine, and mixed hardwoods.

For the first time, pulpwood imports from western States exceeded those from Canada. About one-third of the fiber from western States is roundwood (or chips from roundwood) — most of the rest is softwood chips from mill residues. Softwood residue imports from western States reached a record high and were nearly double the volume received in 1966. By contrast, nearly all of the Canadian imports are spruce and pine roundwood.

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Market Analyst

1970

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