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REPRODUCTION ON CUT-OVER SWAMPLANDS IN THE UPPER PENINSULA OF MICHIGAN

Z. A. ZASADA

DIVISION OF FOREST MANAGEMENT

LAKE STATES FOREST EXPERIMENT STATION

U. S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

UNIVERSITY FARM, ST. PAUL 1, MINN.

M. B. DICKERMAN, DIRECTOR

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RESULTS IN BRIEF

The 1¼ million acres of coniferous swamp forest in the Upper Peninsula of Michigan are important to industry, game management and water conservation. Because there was little knowledge on handling this type, foresters in 1950 began a program of research in swamp forest management. The first project was a survey of recent swamp cuttings.

The survey shows that new forest stands are becoming established on the cut-over swamps under present logging practices, but these new stands contain a larger proportion of hardwoods on all soil types. The proportion of northern white-cedar has dropped on the muck and wet mineral soils where it grows best. Black spruce reproduction is low on the peat soils where it previously was the main species. The aggressive reproduction of balsam fir is increasing its importance on all soil types. Only on the wet mineral soils is aspen invading the swamps. Generally, coniferous reproduction is more satisfactory on the partial cut than on the clear cut areas.

The increase in hardwood reproduction and the lack of white-cedar and spruce on some soils is viewed as a reduction in stand productivity because of a possible reduction in future yields.

1/ Maintained at University Farm, St. Paul, Minnesota, by the U. S. Department of Agriculture in cooperation with the University of Minnesota.

2/ Acknowledgement is due Paul O. Rudolf and W. M. Zillgitt of the Lake States Forest Experiment Station for planning the project, and to the following cooperators for doing most of the field work for this survey:

Forest Industries
Bonifas Lumber Company, Neenah, Wisconsin
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Public Agencies
Forestry Division, Michigan Department of Conservation, Marquette, Michigan
Ottawa National Forest, Ironwood, Michigan
Upper Michigan National Forest, Escanaba, Michigan

3/ Research Forester, U. S. Forest Service, Lake States Forest Experiment Station, Upper Peninsula Experimental Forest, Marquette, Michigan

The research program continues. Following up the survey of swamp forest cutting, the Upper Peninsula Experimental Forest, with the help of cooperators, is establishing cutting studies to determine reproduction and timber yields resulting from even-aged and uneven-aged management methods. The new study should clarify some of the questions brought to light by the survey of swamp cuttings.

WHY A SURVEY WAS NEEDED

Coniferous swamps are second in commercial value only to the northern hardwoods in the Upper Peninsula of Michigan. These swamps, which occupy $1\frac{1}{4}$ million acres of land, are an important source of pulpwood for the five pulp and paper mills in the Upper Peninsula, and to pulp mills located elsewhere. They furnish the material needed by several other industries, such as producers of posts and poles, mine lagging, lumber, and railroad ties. They provide the range necessary for satisfactory survival of deer herds in most winters. Along with the 270,000 acres of hardwood swamps (chiefly black ash, American elm, and red maple), the coniferous swamps help to maintain water tables and equalize stream flow. But despite their importance, very little research has been done to determine the silvicultural systems best suited to the management of the swamp forests.

At their meetings of 1948 and 1949 the Advisory Council for the Upper Peninsula branch of the Lake States Forest Experiment Station stressed the need for research to aid managers of coniferous swamps. Subsequently the Station developed a plan for initiating such work, and a number of interested companies and public forestry agencies offered to cooperate in the field work. The first project undertaken was a survey of recent swamp cuttings "to determine what kind of stand has resulted from different kinds of cutting on different swamp types and sites." This paper reports results of the survey.

PAST SURVEYS

Several previous reproduction surveys in swamp types were consulted in planning this survey. The more applicable of these studies are reviewed briefly.

Professors Westveld and Bowman of Michigan State College made a study of the growth and occurrence of spruce and fir on upland and swamp pulpwood lands in northern Michigan and found the following: (1) Severity of cutting and site quality largely influence the character of the resulting stand. (2) Stands cut over heavily show a decrease in the proportion of valuable species. (3) Barring fire, almost all productive swamps will reproduce well after cutting. (4) Undisposed coniferous slash remains an obstacle to reproduction for 15 to 20 years.

J. B. Millar of the Kimberly-Clark Corporation studied spruce regeneration in northern Ontario. He found that following fires black spruce, white spruce, aspen, and birch came in on well-drained sites but only black spruce restocked poorly drained swamps and muskegs; on cut-over areas or in young stands no spruce regeneration occurred. He also studied regeneration on areas which had been cut over five years previously and found that 89 percent of the quadrats were stocked with spruce and balsam fir and 68 percent with spruce alone. Slash retarded reproduction. Alder overtopping spruce advance growth dies out in about 25 years, and spruce takes over the site.

H. E. Djerf in northern Minnesota studied more than 20 swamp black spruce cuttings made from one to six years previously. He found that reproduction generally is better on partially cut than on clear cut areas and heavy slash greatly decreases reproduction on both.

H. C. Larsson and G. C. Wilkes have described a regeneration survey of spruce and pine lands made in the Thunder Bay and Western Regions of Ontario. They found in general that these types were reproducing themselves, but with poorer stocking and that much of the reproduction occurred before or during logging.

SURVEY METHOD AND DATA INTERPRETATION

The survey was made in 1950 and 1951 by running strips across selected cuttings and examining groups of four mil-acre quadrats at regular intervals. Recorded for each quadrat (1/1000 acre) was presence or absence, species, and freedom to grow of tree reproduction 4/; species and density of brush; presence of overstory; and slash conditions on the ground. On one group (number 3) of quadrats in each series of ten, the number of tree seedlings by species and size class was counted, and record made of the relative amount of slash, and whether the quadrats were open or overtopped by brush or trees. At this same point along the strip, on a 1/40-acre plot, advance growth (reproduction present before cutting) was counted by species and age; stumps were tallied by species and size; and records were made of soil type or character, approximate depth of water table, slash conditions, evidence of fire or other disturbances, and possible source of seeding after cutting.

Fifty six swamp forest cuttings were examined throughout the Upper Peninsula of Michigan. They represented three general methods of cutting and three broad classes of soil (table 1). So far as was known factors favorable to reproduction, other than cutting treatment, were about the same between methods of cutting.

The data from the field tally sheets were recorded on McBee punch cards and sorted according to: (1) character of soil; (2) years since logging; (3) method of cutting; (4) relative age and species of stocking; (5) growing conditions and competition on the ground.

Cutting Methods Sampled

The cutting methods most commonly represented in the Upper Peninsula swamp areas were clear cutting, diameter or stick limit cutting, and selection cutting. In clear cutting, every tree of a desirable species usually is cut if it has a merchantable pulpwood stick, post, or log. After cutting by this method there remain only small trees, cull trees, and those of undesirable species such as black ash, balsam poplar, paper birch, or red maple. In the cuttings sampled the residual stand varied from less than 50 to as many as 800 trees per acre, depending on the age, mixture, and quality of the original stand.

4/ Trees derived from the overstory parent trees were considered reproduction. They were tallied only if they were considered to have a reasonable chance for survival. In most cases the seedlings were at least six inches tall and, depending on time since cutting, may have been several feet tall.

Table 1.--Distribution of swamp survey sample by cutting methods and soil character

Methods of cutting	Number of swamp cuttings by soil character		
	Peat	Muck	Mineral
Clear cutting	8	20	3
Diameter limit	4	2	5
Selection	2	10	1
Fire	0	1	0
Total	14	33	9

In the diameter or stick limit method, trees are designated for cutting according to the number of pulpwood sticks, posts, or logs they will produce or according to diameter at breast height or stump height. The residual stands examined after cutting in this manner contained about 300 trees per acre partly of desirable species.

In selection cutting, the trees to be cut are marked by paint or blazing with an axe; thus there is close control of which trees are to be cut or left. The areas examined in this survey had residual stands of about 700 trees per acre.

Stocking Standards

To measure the success of the various cutting methods in obtaining reproduction, the following standard of stocking was adopted for the age class of reproduction present: (1) For full stocking, 80 percent or more of the quadrats should contain at least one reasonably well established tree of desirable species. Such stocking has possibilities of developing into a stand of at least 800 trees per acre which can fully utilize the area for timber production. (2) For adequate stocking, 60 to 79 percent of the quadrats should bear tree reproduction. This stocking has reasonable chances of providing a stand of at least 600 trees per acre, which should give an adequate financial return from growing timber. (3) A stocking of less than 60 percent is considered inadequate for forest management and economic timber growing. Comments on the adequacy of stocking are based on this standard throughout this report.

REPRODUCTION SURVEY RESULTS

The swamps examined in this survey represented three broad soil classes: (1) peat, including the Rifle peat and Spalding peat on which composition of original timber stands was similar; (2) Carbondale muck; and (3) the wet and poorly drained mineral soils of Newton sand, Granby sand, Channing fine sandy loam, and Saugatuck sand. Soils were classified in the field and checked against available soil type maps. 5/

Results on Peat Soils

According to timber cutting records and stump counts, black spruce was the main species in the stand before cutting although varying proportions of balsam fir and northern white-cedar occurred in mixture. Only a few hardwoods such as balsam poplar, red maple and paper birch were present.

Five to ten years after logging there was full stocking of reproduction on the partial cut areas and adequate stocking on the clear cut areas (table 2). Because the hardwoods on peats are considered unmerchantable, the results should perhaps be judged on the basis of conifer reproduction alone. There is full stocking of conifer reproduction after partial cutting, but the clear cut areas are understocked. In number of stems per acre reproduction averaged about 2,000 conifers plus 200 hardwoods after clear cutting, and 6,300 conifers plus 1,200 hardwoods after partial cutting. Most of the conifers became established after cutting.

5/ Soil Survey Reports for Alger, Chippewa, Iron, Menominee, and Schoolcraft Counties in the Upper Peninsula of Michigan. Survey by U.S.D.A. in cooperation with Michigan Agricultural Experiment Station and Michigan Department of Conservation.

Table 2.--Stocking of cut-over peat swamplands by cutting methods

Method of cutting	Quadrats with reproduction of one or more trees of - 1/			Basis	
	Any species	Conifers	New conifers 1/	Swamps	Quadrats
	Percent	Percent	Percent	Number	Number
Clear cut	63	57	47	8	320
Partial cut 2/	89	83	78	6	240
Diameter limit	90	87	82	4	160
Selection	86	76	71	2	80

1/ Reproduction includes trees established both before and after cutting. New reproduction includes only those established after cutting.

2/ Partial cut combines the results of diameter limit and selection cuttings.

The effect of the cutting methods on reproduction varied with species (table 3). Black spruce, the main species in the original stand, did not re-establish itself very well under any of the cutting methods. New black spruce reproduction occurred on less than 20 percent of the quadrats. Balsam fir came in vigorously under the partial cutting systems, but poorly with clear cutting. Northern white-cedar, although not vigorous on this site, reproduced best under partial cutting. Partial cutting appears to favor hardwood expansion more than does clear cutting. Tamarack and aspen, minor species in the original stand, maintain a minor position in the new reproduction under all cutting systems.

It is evident that reproduction does come in following all methods of cutting. The clear cut areas are understocked, but there is enough reproduction of desirable pulpwood species to insure a light timber yield. Partial cut areas, on the other hand, have adequate stocked reproduction.

New stands have less black spruce and more hardwoods than the original stands. This can be interpreted as a reduction in stand quality. However, the ability of balsam fir and white-cedar to come in satisfactorily following partial cutting indicates that coniferous timber stands can be maintained on the peats.

Table 3.--Stocking of cut-over peat swamplands by cutting methods and species

Method of cutting	Kind of reproduction 1/	Quadrats with reproduction of one or more trees of -							Basis	
		Spruce	Balsam fir	No. white cedar	Tamarack	Other conifers	Aspen 2/	Other hardwoods 3/	Swamps	Quadrats
		Percent							Number	
Clear cut	Any	35	23	7	8	1	3	16	8	320
	New	18	9	7	6	4/1	3	16		
	Adv.	26	19	0	2	0	0	0		
Partial cut 5/	Any	19	67	41	10	0	2	30	6	240
	New	18	61	38	9	0	2	30		
	Adv.	7	11	15	1	0	0	0		
Diameter limit	Any	18	70	53	5	0	1	23	4	160
	New	17	67	49	5	0	1	23		
	Adv.	5	3	23	0	0	0	0		
Selection	Any	21	61	16	19	0	2	44	2	80
	New	19	51	16	16	0	2	44		
	Adv.	10	27	0	4	0	0	0		

1/ "New" includes trees established since cutting.
"Adv." includes trees established before cutting.
"Any" includes reproduction of both kinds.
2/ Includes some balsam poplar.
3/ Chiefly red maple, black ash, paper birch, and American elm.
4/ White pine.
5/ Partial cut combines the results of diameter limit and selection cuttings.

Results on Carbondale Muck

Areas cut over 5 to 15 years ago were examined on muck soils. These swamps are now fully stocked with reproduction regardless of cutting methods (table 4). Total stocking was highest where partial cuts were made, but conifer stocking was adequate and about the same under both the partial and clear cutting methods. In number of trees per acre reproduction averaged about 5,200 conifers plus 1,900 hardwoods following clear cutting and 8,100 conifers plus 5,000 hardwoods after partial cutting.

Table 4.--Stocking of cut-over muck swamplands by cutting methods

Method of cutting	Quadrats with reproduction of one or more trees of -			Basis	
	Any species	Conifers	New conifers 1/	Swamps	Quadrats
	Percent	Percent	Percent	Number	Number
Clear cut	79	71	69	20	800
Partial cut 2/	90	75	70	12	480
Diameter limit	97	87	77	2	80
Selection	88	72	69	10	400

1/ Reproduction includes trees established both before and after cutting. New reproduction includes only those established after cutting.

2/ Partial cut combines the results of diameter limit and selection cutting.

Cutting methods did affect the reproduction success of some species (table 5). Northern white-cedar came in better following partial cutting, but spruce did better where the cut was heaviest, as in clear cutting and diameter limit cutting. Balsam fir established itself equally well under both. None of the cuttings encouraged a serious invasion of aspen. The hardwoods (red maple, black ash, paper birch, elm) are aggressive reproducers on this soil type, as indicated by 47 percent stocking following partial cutting and 39 percent stocking following clear cutting.

A comparison of the original stand with the reproduction (table 6) shows that (1) the proportion of white-cedar has decreased under all cutting methods; (2) balsam fir has gained slightly but not significantly in the new stand; (3) spruce continues to be a minor species; and (4) hardwoods have increased from 7 percent in the original stand to 31 percent of the stand on the clear-cut areas, 24 percent on the diameter limit cuts, and 34 percent on the selection cut areas.

Table 5.--Stocking of cut-over muck swamplands by cutting methods and species

Method of cutting	Kind of reproduction 1/	Quadrats with reproduction of one or more trees of -							Basis	
		No. white cedar	Balsam fir	Spruce	Tamarack	Other conifers	Aspen 2/	Other hardwoods 3/	Swamps	Quadrats
		Percent							Number	
Clear cut	Any	34	45	14	2	8	3	40	20	800
	New	26	43	13	1	8	3	39		
	Adv.	10	15	2	1	0	0	4		
Partial cut 4/	Any	45	54	8	3	1	4	47	12	480
	New	42	48	7	3	1	4	47		
	Adv.	9	7	1	0	0	0	9		
Diameter limit	Any	77	64	20	0	0	5	46	2	80
	New	62	40	16	0	0	5	46		
	Adv.	36	26	4	0	0	0	31		
Selection	Any	39	52	6	4	1	5	47	10	400
	New	38	50	5	4	1	5	47		
	Adv.	3	3	1	0	0	0	4		

1/ "New" includes trees established since cutting.
"Adv." includes trees established before cutting.
"Any" includes either new or advanced or both kinds of reproduction.
2/ Includes some balsam poplar.
3/ Chiefly red maple, black ash, paper birch, and American elm.
4/ Partial cut combines the results of the diameter limit and selection cuttings.

Table 6.--Comparison of reproduction with original stand on muck soils

Species	Stand composition before cutting	Composition of reproduction stands 1/		
		Clear cut	Diameter limit cut	Selection cut
	Percent	Percent	Percent	Percent
Northern white-cedar	52	24	37	25
Balsam fir	28	32	30	33
Spruce	11	10	9	4
Other conifers	2	3	-	4
Hardwoods	7	31	24	34

1/ Includes advance reproduction and new reproduction.

On Carbondale muck soils trees usually are larger and volumes per acre greater than on peat soils. In the reproduction the increase in hardwoods, which usually outgrow the conifers and overtop them for a long time, can affect the yield of coniferous wood on this site and lengthen the time for the conifers to reach merchantable size. In addition, the presence of more hardwoods, which cannot be fully utilized, lowers stand productivity.

Results on Wet and Poorly Drained Mineral Soils

A hardwood-conifer mixture prevailed on the wet and poorly drained mineral soils before cutting. The main conifers were white-cedar and balsam fir. Black spruce and white spruce trees, although few in numbers, made up a sizable wood volume because of their large size. Tamarack, hemlock, and white pine occurred only as occasional trees. The hardwood species in order of occurrence were paper birch, balsam poplar, aspen, yellow birch, red maple, and black ash.

Clear cuts on these soils usually remove all conifers and some of the usable hardwoods. The residual stand is made up of undesirable hardwoods, often fully stocked. Partial cuts also remove mostly conifers and thus increase the proportion of undesirable hardwoods in the residual stand.

This survey showed that 7 to 10 years after clear cutting and 2 to 7 years after partial cutting there is a fully stocked stand of reproduction on the mineral soil swamps (table 7).

Table 7.--Stocking of cut-over mineral soil swamplands by cutting methods

Method of cutting	Quadrats with reproduction of one or more trees of [1]			Basis	
	Any species	Conifers	New [1] conifers	Swamps	Quadrats
	Percent	Percent	Percent	Number	Number
Clear cut	83	57	45	3	120
Partial cut [2]	84	68	56	6	240
Diameter limit	84	66	52	5	200
Selection	85	75	75	1	40

1/ Reproduction includes trees established both before and after cutting. New reproduction includes only those established after cutting.
2/ Partial cut combines the results of diameter limit and selection cutting.

Unfortunately, 80 percent of the quadrats are stocked either with aspen, balsam poplar, or other hardwoods (table 8). Both aspen and balsam poplar are more aggressive on these soils than on the peat or muck soils. The initial fast growth of hardwoods will keep them above the conifers for many years.

Balsam fir reproduces better than other conifers on this site. It occurs on more than one-third of the quadrats in the clear cut area. New white-cedar reproduction came in well on the one swamp where a selection cut was made, but it is absent in the diameter limit or clear cut areas. Spruce and other conifer species make up a minor part of the new stand. In number of trees per acre reproduction averages 1,100 conifers plus 2,000 hardwoods on the clear cut areas and 11,000 conifers plus 4,600 hardwoods on the partial cut areas.

Compared to the original stand, the reproduction has more hardwoods at the expense of white-cedar (table 9); balsam fir holds its own; and spruce is slightly more abundant. Because of the increase in hardwoods, it can be expected that the yield of conifers will be less from the new stand unless improvement or partial cuttings are made early.

Table 8.--Stocking of cut-over mineral soil swamplands by cutting method and species

Method of cutting	Kind of reproduction 1/	Quadrats with reproduction of one or more trees of -						Basis	
		No. white cedar	Balsam fir	Spruce	Other conifers	Aspen 2/	Other hardwoods	Swamps	Quadrats
		Percent						Number	
Clear cut	Any	1	39	15	3	36	54	3	120
	New	0	37	15	3	35	54		
	Adv.	1	2	0	0	1	2		
Partial cut 3/	Any	29	57	5	3	27	55	6	240
	New	13	49	5	2	27	53		
	Adv.	18	12	0	1	0	6		
Diameter limit	Any	23	55	1	1	26	55	5	200
	New	4	47	1	0	26	53		
	Adv.	21	13	0	1	1	7		
Selection	Any	60	65	22	10	30	55	1	40
	New	60	60	22	10	30	55		
	Adv.	0	8	0	0	0	0		

1/ "New" includes trees established since cutting.
"Adv." includes trees established before cutting.
"Any" includes either new or advanced or both kinds of reproduction.
2/ Includes some balsam poplar.
3/ Partial cut combines the results of the diameter limit and selection cuttings.

Table 9.--Comparison of reproduction with original stand on wet and poorly drained mineral soils

Species	Stand composition before cutting	Composition of reproduction stands 1/		
		Clear cut	Diameter limit cut	Selection cut
	Percent	Percent	Percent	Percent
Northern white-cedar	49	1	14	25
Balsam fir	25	26	34	27
Spruce	3	12	1	9
Other conifers	2	3	1	4
Hardwoods	21	58	50	35

1/ Includes advanced reproduction and new reproduction.

EFFECTS OF BRUSH AND SLASH ON REPRODUCTION

The occurrence of brush and slash was recorded during the survey. Brush occurred so consistently on all soils and under all cutting conditions that there was little basis for comparing its effect on reproduction. Some effects of slash, however, were apparent. For most species, soils, and cutting methods there was a consistent trend toward better stocking of reproduction on areas of light to moderate slash than on those free of slash or covered with heavy slash.

NEED FOR MORE RESEARCH

The results of the survey show that, except for clear cutting on peat soils, a full stand of trees is becoming established on the productive swamp areas under present cutting practices. However, the composition of the reproduction stands is less desirable than that of the original stands both from timber growing and game management aspects. For example, the important species in the peat swamp was black spruce, but after logging reproduction of black spruce is poor. Reproduction on the muck soils contains much less northern white-cedar than the original stand. On the wet mineral soils, the stocking of conifers is decidedly lower than in the original forest. Studies are needed to show how these stands can be harvested without reducing the proportion of spruce and white-cedar.

Hardwood invasion is common on all swamp soils, but these swamp hardwoods usually are not cut at present. Their competition effect on the growth and yield of white-cedar, spruce, and balsam fir should be evaluated through a comprehensive study of release cuttings.

As the second step in a broad program of research in swamp forest management, the Upper Peninsula Experimental Forest, with the cooperation of forest industry and other public agencies, is establishing a study in methods of cutting mixed coniferous swamps. The primary objective of this study is to determine the amounts and kinds of reproduction and timber yields resulting from even-aged and uneven-aged management methods. Results of this study should clarify some of the questions brought to light by the survey of swamp forest cuttings.

LITERATURE CONSULTED

Bowman, A. B.
1944. Growth and occurrence of spruce and fir on pulpwood lands in northern Michigan. Mich. Agr. Expt. Sta. Tech. Bul. 188, 82 pp., illus.

Djerf, H. E.
1947. The effect of slash disposal methods on reproduction and fire hazard in the black spruce swamp type of northern Minnesota. (Unpublished master's thesis, Univ. of Minn., 37 pp., illus.)

Larsson, H. C., and Wilkes, G. C.
1947. Forest regeneration survey on cut-over spruce and pine lands in the Thunder Bay and Western regions. Ontario Dept. of Lands and Forests, Res. Report No. 14, 51 pp. + 10 tables, mult.

Millar, J. B.
1936. The silvicultural characteristics of black spruce on the clay belt of northern Ontario. (Unpublished master's thesis, Univ. of Toronto, 72 pp.)

_____
1939. Spruce regeneration in northern Ontario. For. Chron. 15(2): 93-97.

COMMON AND SCIENTIFIC NAMES OF TREES MENTIONED IN THE TEXT

Common Name	Scientific Name
Ash, black	*Fraxinus nigra*
Aspen	*Populus tremuloides*
Birch, paper	*Betula papyrifera*
Birch, yellow	*B. lutea*
Elm, American	*Ulmus americana*
Fir, balsam	*Abies balsamea*
Hemlock, eastern	*Tsuga canadensis*
Maple, red	*Acer rubrum*
Pine, white	*Pinus strobus*
Spruce, black	*Picea mariana*
Spruce, white	*P. glauca*
Tamarack	*Larix laricina*
White-cedar, northern	*Thuja occidentalis*

STATION PAPERS, 1946-1952

Number

*1 Revised forest statistics for the Lake States, 1945, by the Forest Survey Staff, R. N. Cunningham, Regional Director. Sept. 1946.

*2 Postwar problems of the cross tie industry in the Lake States, by Arthur G. Horn and Harold F. Scholz. Sept. 1946.

3 Estimating cull in northern hardwoods, by W. M. Zillgitt and S. R. Gevorkiantz. Nov. 1946.

4 The reforestation job in the Lake States - a new estimate, by Paul O. Rudolf. Nov. 1946.

5 Lake States forests and the pulp and paper industry, by E. L. Demmon. Dec. 1946.

6 Some forest-wildlife problems in the Lake States, by Shaler E. Aldous. Jan. 1947.

7 Growth and yield of jack pine in the Lake States, by S. R. Gevorkiantz. May 1947.

*8 Spacing of young red pine, by F. H. Eyre and Paul J. Zehngraff. June 1947.

*9 How can research help the Michigan timber owner? by E. L. Demmon. June 1947.

10 Optimum economic stocking for northern hardwoods, by W. M. Zillgitt. March 1948.

11 Balsam fir seed - its characteristics and germination, by Eugene I. Roe. March 1948.

12 An improved increment-core method for predicting growth of forest stands, by S. R. Gevorkiantz and Lucille P. Olsen. July 1948.

13 Forestry situation in the Lake States, by E. L. Demmon. Sept. 1948.

14 Hybrid poplar planting in the Lake States, by Paul O. Rudolf. Dec. 1948.

15 Publications of the Lake States Forest Experiment Station, 1923-1948, by the Lake States Forest Experiment Station. Jan. 1949. Supplement No. 1. Dec. 1951.

---

* Not available for distribution.

STATION PAPERS, 1946-1952
(Continued)

Number

16 Forest fire burning conditions in the Lake States, by John S. Crosby. March 1949.

17 Control of weeds in conifer nurseries by mineral spirits, by J. H. Stoeckeler. May 1949.

18 Winter injury and recovery of conifers in the upper midwest, by J. H. Stoeckeler and Paul O. Rudolf. June 1949.

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20 Commodity drain from forests of the Lake States, 1948, by Arthur G. Horn. April 1950.

21 Size-class distribution in old-growth northern hardwoods twenty years after cutting, by F. H. Eyre and W. M. Zillgitt. July 1950.

22 Growth and yield of upland balsam fir in the Lake States, by S. R. Gevorkiantz and Lucille P. Olsen. July 1950.

23 Reforestation research findings in northern Wisconsin and upper Michigan, by J. H. Stoeckeler and G. A. Limstrom. Dec. 1950.

24 Reducing mortality in old-growth northern hardwoods through partial cutting, by F. H. Eyre and F. R. Longwood. April 1951.

25 Changes in forest conditions 1936-1949 north central Minnesota and Upper Peninsula of Michigan (A preliminary analysis), by R. N. Cunningham. July 1951.

26 Quality of logs and lumber obtained from an improvement cut in second-growth hardwoods in northern Wisconsin, by Carl Arbogast, Jr. Dec. 1951.

27 Reproduction on cut-over swamplands in the Upper Peninsula of Michigan, by Zigmond A. Zasada. Dec. 1952.