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GLAZE DAMAGE IN FOREST STANDS IN SOUTHEASTERN MANITOBA

by

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J. H. Cayford and R. A. Haig[1]

INTRODUCTION

Glaze has been defined as, "A smooth coating of ice on terrestrial objects caused by the freezing of rain or moisture; often popularly called sleet . . . . A deposit of glaze on an extensive scale constitutes an ice storm." (Anon., 1958b).

Ice storms have caused substantial damage to forest stands in North America and numerous studies of their effects have been carried out in the United States. In 1940 heavy glaze accompanied by wind destroyed approximately 30 million board feet of timber, mostly jack pine[2], on the Chippewa National Forest in Minnesota (Eyre and LeBarron, 1944). The same year another storm caused breakage and bending in jack pine plantations in Connecticut (Kienholz, 1941). In 1956 widespread ice damage occurred throughout the forests of the Atlantic Provinces and poplar and tamarack were the species most severely affected (Davidson and Newell, 1956). In 1958 an ice storm caused severe damage to spruce, fir, jack pine, and birch on the Avalon Peninsula of Newfoundland (Anon., 1958a).

In 1930[3], and again in 1958, ice storms damaged forests on the Sandilands Forest Reserve in southeastern Manitoba. The 1958 storm occurred on the night of November 17, beginning with a three-hour fall of rain and winds up to 38 miles an hour. The temperature at the time was just below freezing and the raindrops froze immediately on deposition. The crown portions of trees became coated with a layer of ice up to one inch in thickness. During the night the temperature fell, and the rain changed to snow which added more weight to the already ice-laden tree crowns. The total fall of snow was approximately 12 inches.

One month later most of the ice still remained on the trees, but by January 13 they were virtually free of it, even though above-freezing temperatures had not occurred since the storm.

Following the 1958 storm a study was carried out to determine the area severely affected by the glaze, the amount of damage, some of the factors affecting its severity, and the ability of bent trees to recover. Both natural stands and plantations were examined. This report presents the results of the study in natural stands; a separate report describes its results in plantations (Cayford and Haig, 1961).

DESCRIPTION OF AREA

The Sandilands Forest Reserve is in the Rainy River Section, L.12, of the Great Lakes—St. Lawrence Forest Region (Rowe, 1959). Jack pine characterizes the uplands, and black spruce and tamarack predominate in the

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[2] For a list of botanical names mentioned in text, see Appendix.

[3] Information provided by C. B. Gill, Manitoba Forest Service.

swamps. Trembling aspen is common, while balsam poplar, white birch, bur oak, balsam fir, white spruce, eastern white cedar, and red pine are found only in small quantities. White elm and green ash occur along the river banks.

An upland area between 1,050 and 1,300 feet above sea-level occupies the central and southern portions of the reserve and it was here that the effects of the storm were most pronounced. This area appears to be a recessional moraine formed from glacial deposits which were later modified by wind and water erosion (Anon., 1956).

METHODS

In December 1958, the boundaries of the area within which damage was severe were determined by ground reconnaissance. This involved the traversing of all roads and trails in the general area.

The ability of bent trees to recover was estimated from the reactions of 718 sample trees. Seventy-six of these trees were marked and classified as to the degree of bending they exhibited in December 1958. These trees were re-examined in the spring and autumn of 1959. The remaining 642 sample trees were marked and classified in the spring and re-examined in the autumn of 1959. Two hundred and seventeen of the latter group were again examined in the spring of 1960.

A survey was carried out in April and May, 1959, to secure an estimate of the breakage and bending caused by the storm. Sample strips were examined in the major cover types and age classes occurring within the area severely affected. In the most prevalent cover type (jack pine) sampling was distributed throughout the range of age and density classes. During the survey over 29,000 trees were tallied on 59.2 acres of sample. All trees on each sample strip were recorded by species in one-inch diameter classes, and classified as follows:

Undamaged —stem less than 10 degrees from vertical.

Slightly bent —stem 11 to 20 degrees from vertical.

Moderately bent—stem 21 to 35 degrees from vertical.

Badly bent —stem 36 to 90 degrees from vertical.

Arched —stem more than 90 degrees from vertical.

Top broken —stem broken, less than half of crown length broken off.

Broken —stem broken, more than half of crown length broken off.

CONDITIONS IMMEDIATELY AFTER THE STORM

The area severely affected by glaze was confined mainly to elevations higher than 1,200 feet and damage was most severe in the vicinity of the 1,300-foot contour (Figure 1). Similar elevational effects have been noted in the Appalachian Mountains by Abell (1934), and by Carvell, Tyron, and True (1957). Although some damage occurred outside the area indicated in Figure 1, it was considered too slight to have any significance for forest management.

The most conspicuous forms of damage were the bending and breaking of tree boles. Young stands (less than 20 years) suffered the most bending damage; polewood stands (20 to 40 years) had fewer bent stems but a higher percentage of breakage; older stands were virtually undamaged (Figures 2 to 5).

DAMAGE SURVEY—SPRING 1959

Species

Jack pine was the most severely affected species, followed by cedar and black spruce in that order (Table 1). Although a higher percentage of balsam poplar than black spruce were affected, most of them were only slightly bent. Thirty-five per cent of jack pine, 28 per cent of cedar, and 18 per cent of black spruce were classed as moderately bent or worse. Thirteen per cent or less of the stems of other species were in these conditions. Most of them were slightly bent, although trembling aspen and white spruce were often moderately bent, and small numbers of balsam fir and white birch were broken.

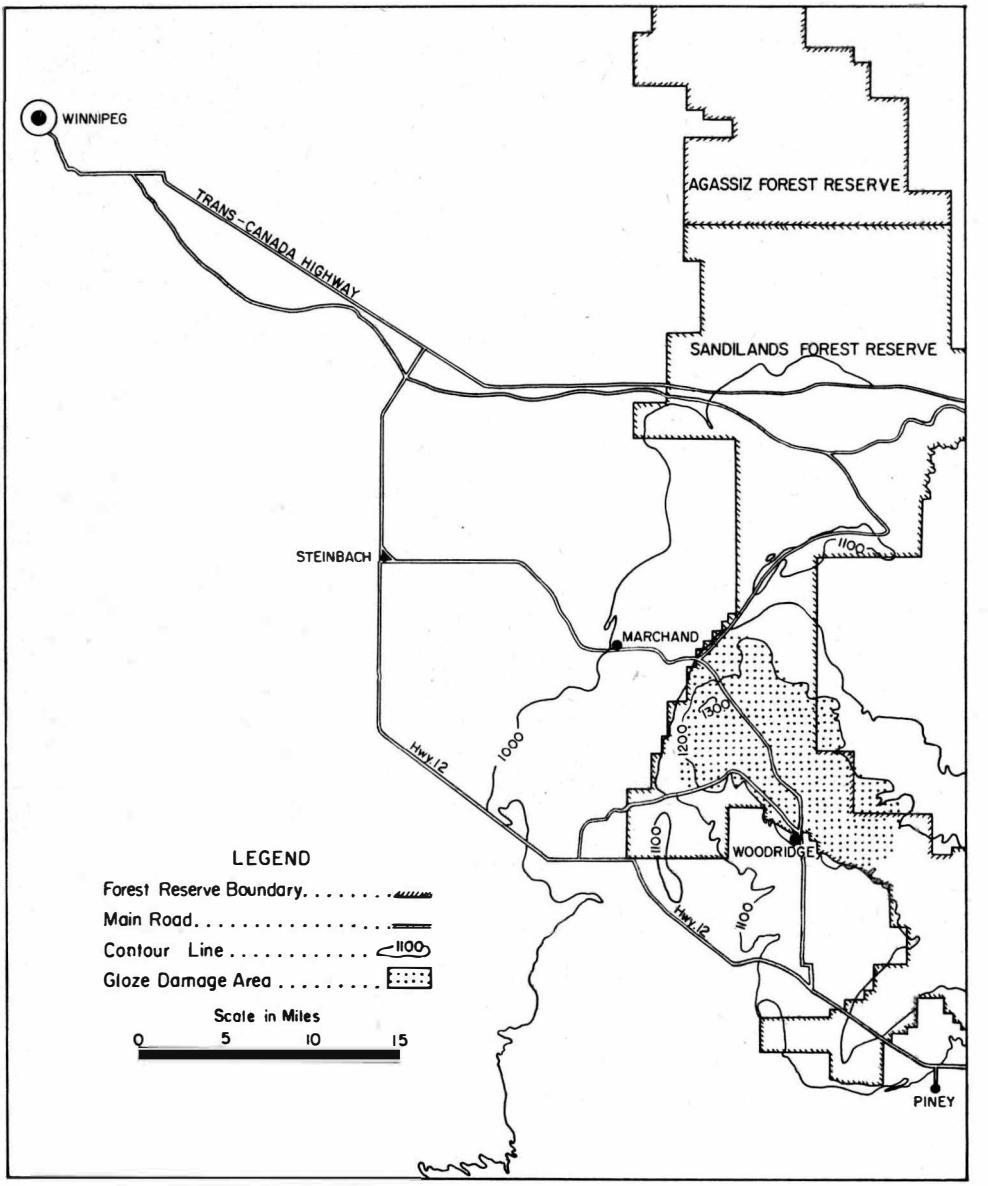

FIGURE 1. Map of southeastern Manitoba, showing the area severely affected by glaze.

FIGURE 2. Bending in a 10- to 15-year-old stand of jack pine. Tops of most trees are touching the ground. Note that scattered larger trees are generally only slightly bent.

FIGURE 3. Bending in a 30-year-old stand of jack pine.

FIGURE 4. Breakage of main stems in a 30- to 40-year-old stand of jack pine.

FIGURE 5. Severe bending of white birch as a result of glaze.

TABLE 1. GLAZE DAMAGE BY SPECIES, SANDILANDS FOREST RESERVE, MANITOBA, SPRING 1959

	Undamaged	Slightly bent	Moderately bent	Badly bent	Arched	Top broken	Broken	Basis	
	Per cent of trees							No. of trees	Diam. range (inches)
Jack pine	51	14	7	8	6	4	10	21,117	1–17
Cedar	64	8	6	13	6	0	3	730	1–16
Black spruce	78	4	3	4	4	1	6	4,131	1–12
Balsam poplar	73	14	3	5	3	1	1	670	1–13
Trembling aspen	79	8	6	4	2	0	1	1,767	1–12
White spruce	87	7	6	0	0	0	0	47	1–12
Balsam fir	89	6	0	2	0	3	0	65	1–10
White birch	89	8	1	0	0	1	1	349	1–13
Larch	97	2	1	0	0	0	0	311	1–11
Green ash	98	1	0	1	0	0	0	194	1–13

Diameter Class

The effects of glaze in relation to diameter for jack pine, cedar, and black spruce are shown in Table 2. Damage decreased with increasing diameter class from 71 per cent of the one-inch trees to less than 10 per cent of trees over 6 inches in diameter. Bending was most severe in the 1- to 3-inch trees, while stem and top breakage predominated in the 3- to 7-inch trees. The small amount of damage to trees over 7 inches was mainly top breakage. These effects are similar to those reported by Kienholz (1941) who reported that breakage in jack pine plantations in Connecticut was concentrated in the 3- to 6-inch classes and that bending was most common in the smallest diameter class examined (3 inches).

TABLE 2. GLAZE DAMAGE BY DIAMETER CLASS, JACK PINE, CEDAR AND BLACK SPRUCE, SANDILANDS FOREST RESERVE, MANITOBA SPRING 1959

D.b.h. (inches)	Undamaged	Slightly bent	Moderately bent	Badly bent	Arched	Top broken	Broken	Basis
	Per cent of trees							No. of trees
1	29	24	17	14	11	1	4	4,300
2	41	16	11	13	9	1	9	5,656
3	52	13	5	7	7	2	14	5,303
4	64	8	2	3	3	5	15	4,101
5	77	4	1	1	1	8	8	2,822
6	88	1	<1	<1	<1	6	4	1,603
7	93	<1	<1			5	1	961
8	96	<1		<1		3	<1	582
9	97	<1				2	<1	290
10	96					4		195
11	99					1		83
12	100							54
13	94					6		16
14	100							6
15	100							2
16	100							3
17	100							1

Basal Area and Average Stand Diameter

For all jack pine stands sampled in the survey, the effects of glaze in relation to basal area and average stand diameter are summarized in Table 3.

TABLE 3. GLAZE DAMAGE IN JACK PINE STANDS BASED ON BASAL AREA AND AVERAGE STAND DIAMETER, SANDILANDS FOREST RESERVE, MANITOBA, SPRING 1959

Basal area class	Average diameter class (inches)							
	2	3	4	5	6	7	8	9
Sq. ft./acre	Per cent of trees damaged							
<20	57	55	36	21	22			
21–40	49	56	41	34	23	7	6	
41–60	60	54	44	37	27	18	11	
61–80		63	51	35	20		7	5
81–100						2		
Average <20–100	58	56	44	35	23	10	7	5

It is apparent that severity of damage decreased with increase in average stand diameter, and was relatively light in stands with average diameters of 7 inches or greater. Also, for stands with average diameters less than 6 inches, damage tended to increase with increase in basal area. Maximum damage occurred to stands with a basal area of from 61 to 80 square feet and an average diameter of 3 inches. These dense stands of small trees proved particularly vulnerable.

RECOVERY OF JACK PINE

As mentioned previously, the trees were nearly free of ice by January 13, 1959, but little improvement in their condition was noted at that time. However, examination of the marked jack pine sample trees indicated that many of them had straightened considerably by the spring of 1959 (Table 4). Twenty-nine per cent of the trees which were arched in the autumn had completely recovered by spring, and another 25 per cent were only slightly bent. Similar recovery was noted among trees originally classed as badly, moderately, or slightly bent.

TABLE 4. RECOVERY OF JACK PINE AFFECTED BY GLAZE, AUTUMN 1958 TO SPRING 1959, SANDILANDS FOREST RESERVE, MANITOBA

Condition in autumn of 1958	Condition in spring of 1959					Basis	
	Per cent of total					Number of trees	Per cent of trees
	Arched	Badly bent	Moderately bent	Slightly bent	Recovered		
Arched	0	32	14	25	29	28	37
Badly bent	0	10	10	76	4	21	27
Moderately bent	0	0	0	67	33	9	12
Slightly bent	0	0	0	11	89	18	24
Total	0	14	8	41	37	76	100

Recovery between the spring and autumn of 1959 is shown in Table 5. Comparison of Tables 4 and 5 indicates that much greater recovery occurred prior to the examination in the spring of 1959 than in the period from the spring to the autumn of 1959. However, during the latter period over one-half of the slightly bent trees recovered completely, and over 80 per cent of the moderately bent trees recovered or improved to the slightly bent class. Only four per cent of the badly bent and one per cent of the arched trees advanced to the slightly bent class and none recovered completely.

TABLE 5. RECOVERY OF JACK PINE AFFECTED BY GLAZE, SPRING 1959 TO AUTUMN 1959, SANDILANDS FOREST RESERVE, MANITOBA

Condition in spring 1959	Condition in autumn of 1959					Basis	
	Per cent of total					Number of trees	Per cent of trees
	Arched	Badly bent	Moderately bent	Slightly bent	Recovered		
Arched	73	25	1	1	0	146	21
Badly bent	3	74	19	4	0	72	11
Moderately bent	0	1	17	65	17	203	29
Slightly bent	0	0	0	46	54	265	39
Total	16	13	7	38	26	686	100

Figures 6 and 7 show two views of the same portion of a 30- to 40-year-old jack pine stand which was badly damaged by the storm. Figure 6 was taken in November 1958 and Figure 7 one year later, and it is evident that many of the bent trees had straightened.

In the autumn of 1959 it was thought that trees then moderately bent, badly bent, or arched had little chance of complete recovery, and indeed many of them were dying at the time. An examination of 217 of these trees in the spring of 1960 substantiated this opinion. Only six had shown any recovery since the autumn, 143 were classified in the same condition, and the condition of 68 had deteriorated. While it is possible that a small percentage of the moderately bent trees may eventually be harvested they will be permanently crooked.

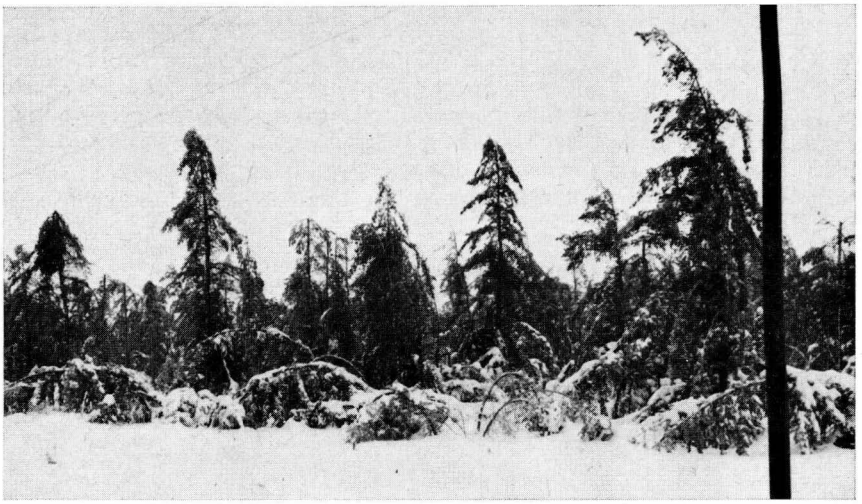

FIGURE 6. A jack pine stand badly damaged by the storm. Photographed in November 1958.

FIGURE 7. The same jack pine stand as shown in Figure 6. Photographed in November 1959.

However, it is likely that badly bent and arched trees will eventually break or uproot. Thus all trees which were moderately bent, badly bent, or arched in the autumn of 1959, plus those which were broken or top broken are considered to have been permanently damaged.

It has been shown that compression failures in living trees can occur without breakage of the stem, provided the bending force is great enough to cause the inner side of the bole to fail in compression but not sufficient to cause tension failure on the outer side (Mergen and Winer, 1952). Thus the following estimate of the amount of permanent damage is probably very conservative, because even trees that appear to have recovered completely may contain compression failures which will make them unfit for some future uses.

ESTIMATE OF PERMANENT DAMAGE

Table 6 is a summary of the permanent damage to jack pine, cedar, and black spruce caused by the ice storm[4]. In this table, the results obtained from the main damage survey (Table 1) have been adjusted in accordance with the degree of recovery indicated in Table 5, assuming that recovery was uniform over the entire damage area for given diameter and damage classes. The table shows that 29, 22, and 16 per cent, respectively, of jack pine, cedar, and black spruce were permanently damaged.

TABLE 6. ESTIMATE OF PERMANENT DAMAGE TO JACK PINE, CEDAR, AND BLACK SPRUCE CAUSED BY GLAZE IN NOVEMBER, 1958, SANDILANDS FOREST RESERVE

Species	Number of trees examined	Per cent permanently damaged
Jack pine	21,117	29
Cedar	730	22
Black spruce	4,131	16

In order to obtain an estimate of the total loss sustained, the areas occupied by jack pine, cedar, and black spruce types[5] within the zone of severe damage were determined, and the total losses in numbers of trees and volume determined for each type. Out of a total forested area of 45,140 acres, 37,670 acres were occupied by jack pine stands and 2,320 acres by black spruce and cedar. Approximately 13,500 cords of merchantable jack pine were permanently damaged, plus about 1,120 cords of black spruce and 50 cords of cedar. However, as the greatest damage occurred in trees below the merchantable size class (4 inches d.b.h.), the loss of potentially valuable material was even greater. It is estimated that over 3,250,000 jack pine, 52,000 black spruce and 33,000 cedar in the 1- to 3-inch diameter classes were so severely damaged that they were unlikely ever to be harvested. The significance of these large losses is more apparent when it is realized that these three species are commercially the most important in southeastern Manitoba (Anon., 1956).

FOREST MANAGEMENT IMPLICATIONS

The merchantable volume per acre represented by permanently damaged trees varied in jack pine stands, from 0.1 cord to 1.3 cords per acre. These relatively small volumes virtually preclude the undertaking of a large-scale salvage logging operation. Thus even those trees which were merchantable in size represent almost a total loss.

As there appeared to be little chance that permanently damaged stems less than 4 inches in diameter would produce merchantable material, the future yields of the affected stands will almost certainly be reduced. In some stands, over one-third of the stems were permanently damaged; consequently the reduction in future yield may be considerable.

Where breakage and severe bending were common, many tops were lying on or touching the ground. Williams (1955) has shown that such an accumulation of inflammable material in this area will increase the fire hazard over that in undisturbed stands. Thus a secondary effect of the storm has been to increase the fire hazard in an area where it was already relatively high.

[4] Recovery data for jack pine were applied to black spruce and cedar, as insufficient data were collected on the recovery on these two species.

[5] The forest types as recognized by the Manitoba Forest Service on their cover-type maps were used in this study. These types are based on species composition, density, and age class.

As dense young jack pine stands suffered the greatest losses, silvicultural measures to reduce the risk of glaze damage should be concentrated in them. However, the costs of treatment coupled with the relatively uncommon occurrence of ice storms in Manitoba would tend to make a program designed solely for reducing potential glaze damage impractical. It appears that a series of judicious thinnings would increase resistance to glaze damage and as this is the treatment advocated for reducing the rotation of jack pine, the increased resistance to damage would be an added benefit.

SUMMARY

In November, 1958, an ice storm caused severe damage to forest stands on a portion of the Sandilands Forest Reserve in southeastern Manitoba. Damage was characterized by the bending and breaking of tree boles. Young stands suffered the most bending damage, polewood stands had fewer bent stems but a higher percentage of breakage, and older stands were practically undamaged. Jack pine was the most severely affected species, followed by cedar and black spruce. Damage to balsam poplar, trembling aspen, white spruce, balsam fir, white birch, green ash, and larch was minor.

A survey of the effects of the storm was undertaken in the spring of 1959 and a study of the recovery of bent trees was continued until the following spring. The results of these studies indicated that on an area of about 40,000 acres, 29 per cent of the jack pine and 22 and 16 per cent respectively of the cedar and black spruce trees were damaged sufficiently that they would not recover completely.

Approximately 13,500 cords of jack pine, 1,120 cords of black spruce, and 50 cords of cedar were destroyed by the storm. In addition, over three million trees in the one- to three-inch diameter classes were permanently damaged. The stocking of many stands has been seriously reduced, and the fire hazard increased.

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APPENDIX

Common and Botanical Names of Species Mentioned in Text

Ash, green	*Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl.) Fern.
Aspen, trembling	*Populus tremuloides* Michx.
Birch, white	*Betula papyrifera* Marsh.
Cedar, eastern white	*Thuja occidentalis* L.
Elm, white	*Ulmus americana* L.
Fir, balsam	*Abies balsamea* (L.) Mill.
Oak, bur	*Quercus macrocarpa* Michx.
Pine, jack	*Pinus banksiana* Lamb.
Pine, red	*Pinus resinosa* Ait.
Poplar, balsam	*Populus balsamifera* L.
Spruce, black	*Picea mariana* (Mill.) BSP.
Spruce, white	*Picea glauca* (Moench) Voss
Tamarack	*Larix laricina* (Du Roi) K. Koch