INTERCEPTION OF WET SNOW AND RESULTANT DAMAGE TO WHITE PINE

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ABSTRACT

A heavy fall of wet snow afforded a rare opportunity to examine tree damage due to the loading of snow on branches. The damage, confined to Pinus strobus, was attributed to both the magnitude of the fall (210 mm), and the large proportion intercepted by the canopy (53% of gross precipitation). The visible signs of damage were impressive, as some branches exceeded a diameter of 70 mm at the point of breakage, but they represented losses of only 1% to the above ground biomass, 3% to the leaf area. Therefore the effects of such damage upon tree growth, hence limits to the aesthetic or economic value of individual trees, would appear to be slight.

INTRODUCTION

The interception of snow by the canopies of trees, particularly evergreens, is considered to be a significant term in the local water balance, though the establishment of general quantitative statements about snowfall and interception remains elusive because of large variations in site conditions, measurement methods, and results (Jeffrey, 1970). It is also appreciated that trees can be damaged when interception leads to unusually heavy loading of snow on branches, but there does not appear to be any precise information on the amount of injury which might occur.

The lack of such information is due to the probability that it would be obtained fortuitously. Few researchers would pursue the goal of assessing tree injury during a given winter because many years could elapse before a damaging snowfall might occur. Data are more likely to be obtained within the context of a snow cover or snowfall study.

Such is the case in this instance, where the objective was to compare snowfall amounts and changes in the snowpack under a stand of white pine (Pinus strobus), to those of a small field on the Erindale Campus of the University of Toronto, during the winter of 1982-83. Unusually mild winter conditions prevented the attainment of the original goal, as only a few snowfalls occurred, the results of which quickly disappeared during spells of warm weather. However, one storm left an unusually large amount of wet snow in the crowns, causing a number of branches to break from the tree trunks.

This paper describes an attempt to quantify the damage in terms of the weight and leaf area of individual branches. The results seem conservative by comparison with the impression which one might have gained from the amount of litter which was observed on the ground.

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SNOWFALL MEASUREMENTS

The stand of pines consisted of two rows of trees, approximately 20 m in height, which occupied a strip of land between small fields to the north and south. Snowfall measurements were made at three locations between the rows of trees, and at a similar number of locations in the field to the south. Thus gross snowfall was defined to be the amount which fell in the field, while interception was taken to be the difference between gross snowfall and the amount measured under the trees.

The danger inherent in defining gross snowfall and interception in this way is well known (Jeffrey, 1968). The horizontal redistribution of snow during a storm may transfer snow from tree crowns to adjacent open spaces, thus leading to an overestimate of the amount of interception. Furthermore, such an error could have been enhanced by the small size of the field (McKay, 1968), which covered an area of approximately one hectare. Alternatively, the location of snowfall measurement sites between trees might have led to erroneously large throughfall measurements for reasons similar to those noted for snowpacks (Granberg, 1980), a situation which would reduce the estimate of interception.

Snowfall measurements were made through the use of snow boards at each location. The boards were squares of clear plexiglass, 0.3 m on a side, which were cut free of the snow after a storm, and weighed on a laboratory balance. Average weights and thicknesses of snow on the boards in the field and under the trees were taken to be measures of gross snowfall and throughfall, respectively. Thus the uncertainties associated with gauge catch efficiencies were avoided (Goodison, 1968), though extraction of the boards sometimes proved to be a difficult task.

The winter provided only five storms which yielded substantial amounts of snow (Table 1). The quantities of snow intercepted by the vegetation varied considerably, both in terms of weight and in proportion to the gross snowfall. Temperature appeared to influence the proportion of interception, as the first three storms were associated with air temperatures close to the freezing point, the last two with colder conditions.

Table 1

Snowfall Measurements for White Pine
Winter 1982-83

Date of Storm	Gross Precipitation Depth [mm]	Gross Precipitation Mass [kg m^{-2}]	Intercepted Mass [kg m^{-2}]	Intercepted Proportion of Gross [%]
Dec. 16/82	10	1.57	0.776	49
Dec. 20/82	210	29.2	15.6	53
Jan. 15/83	80	11.3	5.96	53
Feb. 7/83	60	6.69	2.26	34
Mar. 21/83	160	25.1	4.79	19

Damage to the pines came as a result of the storm of December 20, when the mass of snow held in the branches exceeded 15 kg m^{-2}. The visible signs of injury were impressive, as approximately half the ground area under the trees appeared to be littered with twigs and branches, some so large as to impede an observer's movements on the ground. Thus it seemed appropriate to quantify the damage to determine the relative loss to the standing biomass of the trees.

VEGETATION DAMAGE ASSESSMENT

The stand was not purely pine as it included one large oak, a small spruce and a number of maple saplings. Nevertheless, the presence of other species had little effect upon the overall character of the stand. Although the local tree density of 133 stems ha^{-1} is small by comparison with many pure conifer stands (Jarvis et al., 1976), the large size of the trees ensures that their effects upon precipitation are dominant.

Quantification of the standing biomass and tree injury was achieved by first establishing a sampling area 10 m in width, 45 m in length, aligned parallel to the rows of trees. The diameters at breast height, dbh, of six pines found within the sampling area were measured. Injury was recorded by measuring the diameter at branch base, dbb (the point of breakage), of branches which had fallen to the ground under the weight of the snow. Care was taken to identify all the pieces of a broken branch, to avoid multiple measurements of the same injury. Confusion due to the crossing of the areal boundary by fallen boughs was avoided by including a branch only if its base lay within the sampling area.

Measurements of dbh may be used to estimate the dry weight and leaf area of the standing biomass if the relationships are known. Extensive work on such relationships for selected tree species was done by Whittaker and Woodwell (1968), but Pinus strobus was not among those studied. Therefore, regression relationships which they established for a different coniferous species, Pinus rigida, were adopted for use here:

$$\log_{10}(W_d) = 3.6917 + 2.3373 \log_{10}(\text{dbh}) \quad (1)$$

$$\log_{10}(A_1) = 3.2984 + 1.8745 \log_{10}(\text{dbh}) \quad (2)$$

where W_d is the above ground dry weight [kg], A_1 the total leaf area [m^2], and dbh is measured in metres.

Application of eqs. (1) and (2) to the standing vegetation indicated a dry weight per unit area of 15.4 kg m^{-2}, and a leaf area per unit area of 8.15 (Table 2.A). Assuming a spherical orientation of needles, the value of A_1 approaches three on a projected area basis, a value which lies within the range found for pure stands of conifers (Jarvis et al., 1976). The value of W_d per unit area is particularly noteworthy because it is approximately equal to the mass of snow which had been intercepted by the canopy during the storm of December 20 (Table 1). Given the uneven loading of snow on branches, due to differences in exposure, it is likely that the mass per unit area was much greater on the broken branches. In fact the interception figure is in some sense an underestimate because the collapse of boughs contributes to throughfall.

Regression relationships for individual branches of Pinus strobus were established by collecting six broken boughs of various sizes, and subjecting them to further analysis. The analysis consisted of separating the leaves from each branch, and drying the leaf and wood portions at 105 C until weight loss had ceased. Thus it was possible to determine leaf dry weight in each branch, a value which can be used to estimate leaf area if the ratio of leaf area to dry weight is known (Evans, 1972).

Area to weight ratios were obtained by weighing five sub-samples, of 10 needles each, and estimating the total surface area of the leaves in the sample. Area estimates were made by assuming an elliptical cylinder shape for pine needles, thus allowing calculations to be made from measurements of needle length, thickness and width. Application of an average area to weight ratio to the leaf weight of the branch provided an estimate of total leaf area.

Table 2

Vegetation Damage Survey for White Pine
December 20, 1982
(450 m^2 area)

A. Standing Vegetation

Breast Height Diameter [m]	Dry Weight [kg]	Leaf Area [m^2]
0.68	2000	965
0.62	1610	811
0.59	1430	739
0.46	801	464
0.43	684	409
0.35	423	278
TOTALS	6948	3666
(per unit area)	(15.4 kg m^{-2})	(8.15)

B. Vegetation on Ground

Branch Base Diameter [mm]	Dry Weight [kg]	Leaf Area [m^2]
78	8.83	28.8
71	6.61	21.2
69	6.05	19.3
62	4.35	13.6
52	2.53	7.62
50	2.25	6.69
47	1.86	5.47
42	1.31	3.78
40	1.13	3.22
39	1.05	2.96
39	1.05	2.96
37	0.889	2.49
37	0.889	2.49
31	0.516	1.40
23	0.206	0.524
TOTALS	39.5	122
(per unit area)	(87.8×10^{-3} kg m^{-2})	(0.271)

Branch weights, w_d [kg], and leaf areas, a_l [m^2], were regressed against measurements of dbb [mm] to define the following relationships:

$$\log_{10}(w_d) = -4.878 + 3.078 \log_{10}(dbb) \quad (3)$$

$$\log_{10}(a_l) = -4.750 + 3.282 \log_{10}(dbb) \quad (4)$$

Eqs. (3) and (4) were used to calculate w_d and a_l for each branch (Table 2.B), and thus estimate the total damage for the sampling area.

The need to establish separate relationships for branches can be appreciated by comparing them with the predictions of eqs. (1) and (2), which yield different results, particularly for dry weight (Fig. 1). This raises the question of whether the differences are species related, but the contrasts are more likely due to the inclusion of the bole of the tree in eqs. (1) and (2). Other relationships established for Pinus rigida by Whittaker and Woodwell (1968) allow the determination of branch dry weight from dbb measurements. Their predictions agree quite closely with the measurements made in this study (Fig. 1a), thus supporting the application of Pinus rigida results to the task of estimating the dry weight and leaf area of Pinus strobus.

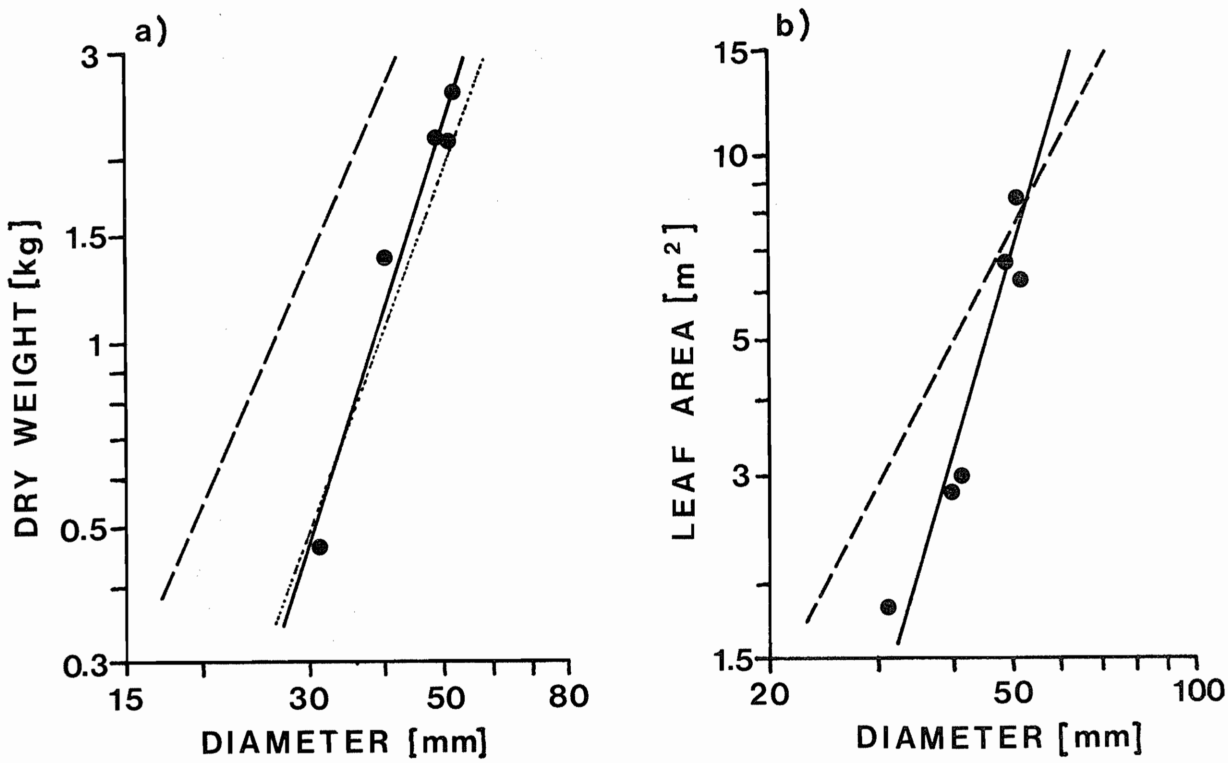

Fig. 1. Plots of a) dry weight, and b) leaf area relationships established for Pinus strobus (solid lines), and Pinus rigida (dashed lines), compared with experimental data (solid circles). An alternative prediction of branch dry weight, based upon the use of dbb measurements in other Pinus rigida relationships, is also shown (broken line).

CONCLUDING REMARKS

The large size of some of the broken boughs, and their widespread distribution on the ground, left an impression of extensive damage to the trees. However, quantitative analysis showed the damage to be relatively small. The total weight of branches found on the ground represented a loss of 0.57% to the biomass, 3.33% to the leaf area of the stand.

The loss of leaves is a potential limitation to photosynthetic production, but such a small loss is likely to have little effect upon growth, particularly since other leaves may gain better exposure to sunlight as a consequence. Broken branches would not diminish the economic value of the trees in the event of harvesting. The main effects are probably aesthetic, though even these will diminish as the broken material decays.

It is certainly not possible to make any quantitative generalization about snowfall interception damage to trees from the results of this analysis. The event was the consequence of a rare instance of heavy snowfall acting in combination with favourable conditions for interception. Nevertheless, one might venture the qualitative generalization that when such events occur, the resultant damage is likely to be relatively slight.

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