EFFECTS OF FOREST COVER ON

SNOW COVER DISTRIBUTION IN THE NASHWAAK

EXPERIMENTAL WATERSHED PROJECT

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ABSTRACT

The Nashwaak Experimental Watershed Project, located in central New Brunswick, was designed to assess the impacts of forest management practices on the water resource. Snow cover has been one of the hydrologic components under study and, since 1973, intensive snow surveys have been carried out on two small basins. In this study analysis was restricted to those surveys carried out before the clearcut treatment, which started in the summer of 1978. Using linear regression seven forest cover parameters were tested for their potential as predictors of snow depth and snow water equivalent. Measures of forest density such as number of stems and basal area were not good predictors as the proportion of hardwoods is not taken into account. Measures of the proportion of hardwood were good predictors as was canopy closure. The variable judged to have the best potential for application was covertype, a subjective estimate of the relative proportion of hardwood and softwood which can be determined by photo-interpretation.

INTRODUCTION

The Nashwaak Experimental Watershed Project (NEWP), located in central New Brunswick, was initiated in 1970. The project was designed to assess the impacts of forest management practices on the water resource. Included among major hydrologic components under study has been snow cover; snow surveys were first undertaken in 1973 and are continuing.

The experimental design in the snow cover study has been the "paired watershed" approach with three phases: 1) the calibration phase; 2) the treatment phase; and, 3) the recovery phase. Beginning in the summer of 1978, a commercially designed clearcut took place on Narrows Mountain Brook, one of the experimental basins. This treatment marked the end of the calibration phase. Spatial snow cover patterns are expected to be altered as a result of wind effects during the accumulation period and differential melt during the ablation period (Dickison and Daugharty, 1975).

This study constitutes an investigation into linear associations between forest cover parameters and snow cover distribution. These relationships are based on snow survey data collected during the calibration phase. The objective of this analysis is not only to study the associations between forest cover and snow cover, but to also assess the relative utility of those parameters as predictors.

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PROJECT AREA

The study site is located in the central New Brunswick uplands about 50 km northwest of Fredericton, the capital city (Figure 1). The region is totally forested and significantly cooler and wetter than nearby settled areas (Anon., n.d.).

The experimental basins, Narrows Mountain Brook (391 ha) and Hayden Brook (660 ha), drain into opposing sides of the Nashwaak river. Hayden Brook basin has an average aspect of 170° and Narrows Mountain basin faces 120°. Elevations in the study area range from 195 to 478 m a.s.l.

On most of the higher elevation areas a hardwood type predominates consisting primarily of beech (Fagus grandifolia) Ehrh.), sugar maple (Acer saccharum Marsh.) and yellow birch (Betula allegheniensis Britton). Occasional red spruce (Picea rubens Sarg.) and hemlock (Tsuga canadensis (L.) Carr.) are found in hardwood stands. Mixed-wood stands cover most of the valley sides along streams and some of the south-facing gently sloping areas. Red spruce, balsam fir (Abies balsamea (L.) Mill.), hemlock, red maple (Acer rubrum L.) and yellow birch are found in mixed-wood stands. Almost pure softwoods occur in some stream-side areas and at low elevations (Anon., n.d.).

METHODS

SNOW DATA COLLECTION

Periodic two-day snow surveys were conducted at approximately three-week intervals, usually starting in January and finishing in April. During the period from 1973 to 1978 thirty-six surveys were carried out, twenty-eight of which were more than two-thirds complete and are included in this analysis.

Mount Rose type snow samplers were used to obtain snow depth (SD) and snow water equivalent (SWE) measurements. In each basin four transects were chosen which corresponded to forest growth study transects (Figure 1). A sampling pattern was used in which SD measurements were taken at approximately 100-m intervals while both SD and SWE were determined at 300-m intervals on forest growth plots (Figure 2). Depth and density values used in analyses were taken to be the average of five measurements spaced at intervals of about two metres on each site.

FOREST COVER VARIABLES

Forest cover variables can be divided into two groups: those that have been determined only on forest growth plots (plot data) and those which have been determined for all sampling sites (all-data). All-data forest cover variables could be related to a larger sample size of SD measurements.

Forest composition data were obtained in the summers of 1973, 1974 and 1976. All trees 25 mm or greater in diameter were measured in 0.04 ha circular plots. From these data four forest cover variables were determined: number of stems (NS), percent stems hardwood (%SH), basal area of the plot (BA) and percent basal area hardwood (%BAH).

Over both basins covertypes were identified on the basis of known %BAH on plots located on aerial photographs. Discrimination was not possible beyond a 20 percent range, resulting in five covertype (CT) classes with class one representing 80-100 %BAH and class five 0-20 %BAH. Two other all-data variables were canopy closure and southerly closure. In the winter of 1978 photographs were taken at each sampling site of overhead canopy closure (CC) and southerly closure at a 30° angle (SC). Percent closure was determined by superimposing dot grids on the photographs.

ANALYSIS OF DATA

Relationships between forest cover variables and SD and SWE were determined using simple linear regression with SD and SWE being dependent variables. Seven forest cover variables (NS, %SH, BA, %BAH, CT, CC, SC) were used as independent variables. All

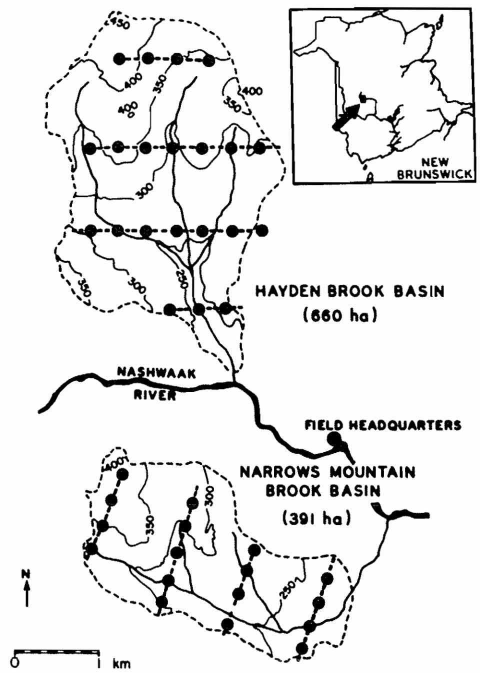

Figure 1. Location of Nashwaak Experimental Watershed Project and snow survey transects across experimental basins.

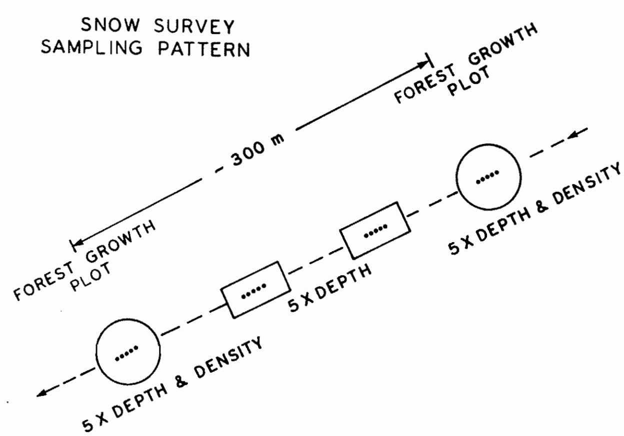

Figure 2. A sketch of the sampling pattern used in snow surveys.

surveys were analysed separately.

In a previous study (Dickison and Daugharty, 1980) several snow survey plot locations were found to be systematically biased and/or to have extreme variability with respect to SD and SWE. Plots for which this bias or variability could be explained were excluded from this analysis.

RESULTS

NUMBER OF STEMS

In 28 surveys SD never correlated significantly with NS. A greater number of stems did appear to be associated with reduced SD, as in 21 surveys SD had a negative correlation with NS. Four of seven surveys in which SD correlated positively with NS were in April. Whereas reduced density leads to less interception loss during the accumulation period, greater solar radiation encourages more rapid snowmelt during the ablation period.

SWE correlated significantly ($P < 0.05$) with NS in two surveys. In 17 surveys SWE correlated negatively with NS. Excluding 1973 and 1974, 16 of 21 surveys showed a negative correlation between SWE and NS. Years in which poor correlations were found will be discussed later.

Linear regression statistics from surveys at time of maximum SD are presented in Table 1. At time of maximum SD, the change in SD per increment of ten stems ranged from -7 to 2 mm. Excluding 1973 and 1974, the other years showed a rather consistent reduction of 5 to 7 mm of SD per increment of ten stems.

Table 1. Statistics from linear regression of snowdepth and snow water equivalent against number of stems for surveys at time of maximum snow depth.

Date of beginning of survey			Snowdepth						Snow Water Equivalent					
		n	a	$\overline{S.D.}$ (mm)	S.E. (mm)	b (mm/10 stems)	b/ SD_{84}	r^2	a	$\overline{SWE}$ (mm)	S.E. (mm)	b (mm/10 stems)	b/ SD_{84}	r^2
6 Mar 73	**Plot data**	23	1067	1084	64	2	0.002	0.017	223	244	30	3	0.011	0.105
25 Mar 74	**Plot data**	33	530	549	106	2	0.004	0.006	136	144	27	1	0.006	0.012
12 Mar 75	**Plot data**	33	1028	969	92	-7	-0.007	0.069	223	231	46	1	0.004	0.006
24 Mar 76	**Plot data**	33	1160	1103	93	-7	-0.006	0.064	277	267	22	-1	-0.005	0.036
1 Mar 77	**Plot data**	33	1080	1029	88	-6	-0.006	0.055	287	279	44	-1	-0.003	0.005
28 Mar 78	**Plot data**	33	912	874	74	-5	-0.005	0.045	232	226	27	-1	-0.003	0.008

PERCENT STEMS HARDWOOD

SD correlated significantly with %SH in 15 surveys. In six of those surveys the correlation was highly significant ($P < 0.01$). A greater SD was generally associated with a greater proportion of hardwoods and only in five surveys was there a negative correlation between SD and %SH. Four of those five surveys were in April, during the ablation period.

SWE correlated significantly with %SH in nine surveys and in six the correlation was highly significant. In 24 surveys a greater SWE was associated with a greater proportion of hardwood stems. Three of four surveys with negative correlations between SWE and %SH were in April.

At time of maximum SD the change in SD per 10 %SH ranged from 2 to 17 mm (Table 2). Non-significant correlations were observed in 1973 and 1974 which were years which showed, by far, the lowest gradients of SD with %SH at time of maximum SD. With SWE

Table 2. Statistics from linear regression of snowdepth and snow water equivalent against percent stems hardwood for surveys at time of maximum snow depth.

Date of beginning of survey		n	Snowdepth a	$\overline{S.D.}$ (mm)	S.E. (mm)	b (mm/10 %SH)	b/ SD_{62}	r^2	Snow Water Equivalent a	$\overline{SWE}$ (mm)	S.E. (mm)	b (mm/10 %SH)	b/ SD_{62}	r^2
6 Mar 73	Plot data	23	1071	1034	64	2	0.002	0.014	229	244	30	3	0.011	0.071
25 Mar 74	Plot data	33	531	549	106	3	0.005	0.008	140	144	27	1	0.004	0.004
12 Mar 75	Plot data	33	862	969	76	17	0.018	0.365**	200	231	43	5	0.022	0.131*
24 Mar 76	Plot data	33	1033	1103	89	11	0.010	0.150*	262	267	23	1	0.003	0.013
1 Mar 77	Plot data	33	936	1029	76	15	0.015	0.304**	241	279	39	6	0.022	0.210**
28 Mar 78	Plot data	33	805	874	66	11	0.013	0.236**	203	226	24	4	0.016	0.199**

* $P < 0.05$

** $P < 0.01$

non-significant correlations at time of maximum SD occurred in 1973, 1974 and 1976.

BASAL AREA

SD correlated significantly with BA in two surveys, once highly significantly. Greater SD was usually associated with reduced BA. Five of seven surveys where greater SD was found with greater BA were in April.

SWE correlated significantly with BA in one survey. As with SD, greater SWE was usually found with reduced BA.

The gradient of SD with BA was extremely variable at times of maximum SD. In 1973, SD correlated positively with BA, changing at a rate of 16 mm per 10 m^2. In 1977, SD changed at a rate of -47 mm per 10 m^2 (Table 3). It should be taken into account, however, that the 1973 relationship was non-significant. SWE gradients were also variable at times of peak snowdepth, ranging from 0 to -15 mm per 10 m^2.

Table 3. Statistics from linear regression of snowdepth and snow water equivalent against basal area for snow surveys at time of maximum snowdepth.

Date of beginning of survey		n	Snowdepth a	$\overline{S.D.}$ (mm)	S.E. (mm)	b (mm/10 m^2)	b/ SD_{29}	r^2	Snow Water Equivalent a	$\overline{SWE}$ (mm)	S.E. (mm)	b (mm/10 m^2)	b/ SD_{29}	r^2
6 Mar 73	Plot data	23	1037	1084	63	16	0.015	0.045	244	244	31	0	-0.001	0.000
25 Mar 74	Plot data	33	556	549	106	-2	-0.004	0.000	147	144	27	-1	-0.010	0.002
12 Mar 75	Plot data	33	1067	969	91	-33	-0.035	0.078	251	231	46	-7	-0.029	0.013
24 Mar 76	Plot data	33	1201	1103	93	-33	-0.030	0.075	286	267	22	-6	-0.024	0.050
1 Mar 77	Plot data	33	1167	1029	83	-47	-0.046	0.167*	322	279	43	-15	-0.053	0.070
28 Mar 78	Plot data	33	895	874	76	-7	-0.009	0.006	227	226	27	0	-0.001	0.000

* $P < 0.05$

** $P < 0.01$

PERCENT BASAL AREA HARDWOOD

SD correlated significantly with %BAH in 20 of 28 surveys; in 16 the relationship was highly significant. Excluding 1973 and 1974, significant correlations were found in 19 of 21 surveys. Only in four surveys, all in April, were negative correlations found between SD and %BAH.

SWE correlated significantly with %BAH in 14 surveys and on 10 occasions the relationship was highly significant. No significant correlations were found in 1973, 1974 and 1976 surveys. Greater SWE was usually associated with greater %BAH. Three of five negative relationships were in April surveys.

At time of maximum SD, SD changed at rates ranging from 6 to 23 mm per 10 %BAH. SWE gradients varied from 0 to 8 mm per 10 %BAH (Table 4).

Table 4. Statistics from linear regression of snowdepth and snow water equivalent against percent basal area hardwood at times of maximum snowdepth.

Date of beginning of survey		Snowdepth							Snow Water Equivalent					
		n	a	$\overline{S.D.}$ (mm)	S.E. (mm)	b (mm/10 %BAH)	b/ SD_{62}	r^2	a	$\overline{SWE}$ (mm)	S.E. (mm)	b (mm/10 %BAH)	b/ SD_{62}	r^2
6 Mar 73	Plot data	23	1051	1084	61	6	0.005	0.095	230	244	30	3	0.010	0.074
25 Mar 74	Plot data	33	499	549	103	8	0.015	0.062	132	144	26	2	0.012	0.046
12 Mar 75	Plot data	33	824	969	56	23	0.024	0.647**	190	231	41	7	0.029	0.222**
24 Mar 76	Plot data	33	1013	1103	84	14	0.013	0.242**	269	267	23	0	-0.001	0.001
1 Mar 77	Plot data	33	906	1029	64	20	0.019	0.512**	229	279	35	8	0.028	0.355**
28 Mar 78	Plot data	33	784	874	59	14	0.017	0.389**	200	226	23	4	0.019	0.256**

* $P < 0.05$

** $P < 0.01$

COVERTYPE

SD correlated significantly with CT in 24 of 28 surveys (all data). In 22 surveys the relationship was highly significant. In 25 surveys a higher CT class, meaning a lower proportion of hardwood, was associated with reduced SD. In three April surveys SD and CT were positively correlated. Those surveys represented three of four surveys where the relationship between SD and CT was non-significant. The time variation of the standardized gradient of SD with CT illustrates the tendency for relationships to deteriorate and reverse themselves in late season (Figure 3).

SWE was significantly correlated with CT in 14 surveys. The relationship was highly significant ten times. No significant correlations were found in 1973, 1974 and 1976. SWE and CT were negatively correlated in 24 surveys. Three of four positive correlations were in April surveys.

At time of maximum SD, SD correlated significantly with CT in all years. Rates of change of SD ranged from -20 to -46 mm per CT class. In the three seasons where SWE correlated significantly with CT at time of maximum SD, rate of change of SWE ranged from -8 to -16 mm per class (Table 5).

CANOPY CLOSURE

SD was correlated significantly with CC in 22 surveys (all data). In 21 the relationship was highly significant. Increased SD was associated with reduced CC in all surveys. Late season deterioration of relationships is shown in Figure 4. Four of six

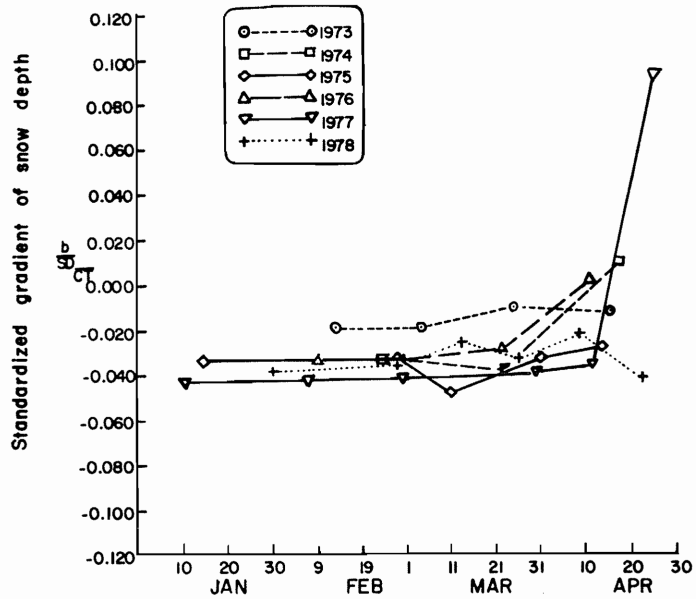

Figure 3. Time variation of the standarized gradient of snow depth (SD) with covertype (CT).

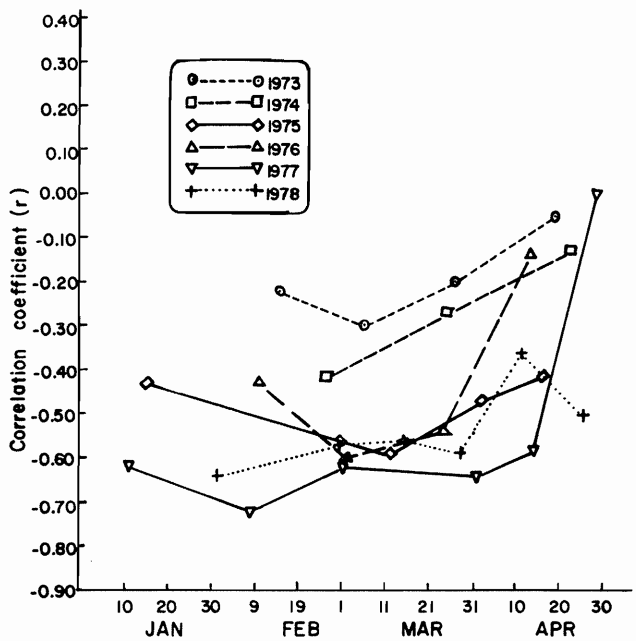

Figure 4. Time variation of correlation coefficients between snow depth (SD) and canopy closure (CC).

Table 5. Statistics from linear regression of snowdepth and snow water equivalent against cover type for times of maximum snowdepth.

Date of beginning of survey		Snowdepth							Snow Water Equivalent					
		n	a	$\overline{S.D.}$ (mm)	S.E. (mm)	b (mm/class)	b/ SD_3	r^2	a	$\overline{SWE}$ (mm)	S.E. (mm)	b (mm/class)	b/ SD_3	r^2
6 Mar 73	Plot data	23	1113	1084	62	-10	-0.010	0.066	256	244	31	-4	-0.017	0.045
	All data	70	1124	1064	71	-20	-0.019	0.171*						
25 Mar 74	Plot data	33	593	549	103	-17	-0.032	0.064	151	144	26	-3	-0.023	0.035
	All data	98	594	537	102	-20	-0.038	0.096**						
12 Mar 75	Plot data	33	1092	969	58	-48	-0.051	0.622**	266	231	41	-14	-0.061	0.211**
	All data	99	1075	949	93	-46	-0.048	0.389**						
24 Mar 76	Plot data	33	1184	1103	83	-32	-0.030	0.267**	268	267	23	0	-0.001	0.000
	All data	98	1175	1091	111	-30	-0.028	0.164**						
1 Mar 77	Plot data	33	1139	1029	62	-43	-0.043	0.541**	321	279	36	-16	-0.060	0.329**
	All data	99	1137	1023	79	-41	-0.041	0.421**						
28 Mar 78	Plot data	33	952	874	59	-31	-0.036	0.389**	246	226	24	-8	-0.035	0.201**
	All data	99	944	865	73	-28	-0.033	0.283**						

* $P < 0.05$

** $P < 0.01$

surveys having non-significant correlations were in April.

SWE correlated significantly with CC in six surveys and in three of those the correlation was highly significant. In 21 surveys SWE was correlated negatively with CC.

At time of maximum SD, SD correlated significantly with CC in all years. SD gradients ranged from -19 to -30 mm per 10 percent increase in CC. SWE and CC did not correlate significantly at time of maximum SD in any year (Table 6).

SOUTHERLY CLOSURE

In 20 surveys SD correlated significantly with SC. Eighteen of the correlations were highly significant. Greater SD was associated with reduced SC in 25 surveys. Positive correlations were found in three April surveys.

SWE correlated significantly with SC in only two surveys. SWE and SC were negatively correlated in 22 surveys.

At time of maximum SD, the SD gradient ranged from -9 to -36 mm per 10 percent increase in southerly closure. SWE did not correlate significantly with SC at time of maximum SD (Table 7).

DISCUSSION

In general, relationships between forest cover variables and snow cover deteriorated and tended to reverse during the ablation period. Reduced density or less canopy closure leads to less interception loss during the accumulation period but, in late season, encourages more rapid snowmelt due to greater solar radiation. The greater melt in open stands erases differences between dense and open situations, first leading to deterioration of the relationships, then to a reversal of the correlations.

Poor correlations between SD and forest cover variables were found in 1973 and 1974. In 1973, the upper two transects of Hayden Brook were not surveyed. Those lines represent areas of higher elevation characterized by a hardwood covertype. Plots on those lines would be expected to have greater snow depth, leading to improved correlations

Table 6. Statistics from linear regression of snowdepth and snow water equivalent against canopy closure for times of maximum snowdepth.

Date of beginning of survey		Snowdepth n	a	$\overline{S.D.}$ (mm)	S.E. (mm)	b (mm/ 10%CC)	b/ SD_{35}	r^2	Snow Water Equivalent a	$\overline{SWE}$ (mm)	S.E. (mm)	b (mm/ 10%CC)	b/ SD_{35}	r^2
6 Mar 73	Plot data	23	1088	1084	64	-1	-0.001	0.003	251	244	31	-2	-0.010	0.037
	All data	70	1096	1064	74	-9	-0.009	0.091*						
25 Mar 74	Plot data	33	568	549	105	-6	-0.011	0.017	144	143	27	0	-0.003	0.001
	All data	98	580	537	103	-12	-0.023	0.071*						
12 Mar 75	Plot data	33	1052	969	74	-26	-0.027	0.392**	241	231	46	-3	-0.013	0.024
	All data	99	1052	949	96	-30	-0.031	0.345**						
24 Mar 76	Plot data	33	1177	1103	80	-23	-0.021	0.306**	267	267	23	0	0.001	0.000
	All data	98	1188	1091	102	-27	-0.025	0.287**						
01 Mar 77	Plot data	33	1101	1029	75	-23	-0.022	0.323**	299	279	42	-6	-0.023	0.111
	All data	99	1119	1023	81	-27	-0.026	0.383**						
28 Mar 78	Plot data	33	927	874	62	-17	-0.019	0.258**	232	226	22	-2	-0.009	0.027
	All data	99	941	865	70	-21	-0.025	0.345**						

* $P < 0.05$

** $P < 0.01$

Table 7. Statistics from linear regression of snowdepth and snow water equivalent against southerly closure for times of maximum snow depth.

Date of beginning of survey		Snowdepth n	a	$\overline{S.D.}$ (mm)	S.E. (mm)	b (mm/ 10%SC)	b/ SD_{67}	r^2	Snow Water Equivalent a	$\overline{SWE}$ (mm)	S.E. (mm)	b (mm/ 10%SC)	b/ SD_{67}	r^2
6 Mar 73	Plot data	23	1076	1084	64	1	0.001	0.001	265	244	31	-3	-0.014	0.037
	All data	70	1128	1064	76	-9	-0.009	0.043						
25 Mar 74	Plot data	33	546	549	106	0	0.001	0.000	140	144	27	0	0.003	0.001
	All data	98	619	537	105	-12	-0.023	0.037						
12 Mar 75	Plot data	33	1114	969	86	-22	-0.023	0.170*	268	231	45	-6	-0.024	0.045
	All data	99	1192	949	101	-36	-0.038	0.276**						
24 Mar 76	Plot data	33	1191	1103	93	-14	-0.012	0.061	270	267	23	0	-0.002	0.001
	All data	98	1267	1091	112	-26	-0.024	0.140**						
1 Mar 77	Plot data	33	1160	1029	84	-20	-0.020	0.150*	329	279	42	-8	-0.028	0.095
	All data	99	1232	1023	88	-31	-0.030	0.270**						
28 Mar 78	Plot data	33	946	874	74	-11	-0.013	0.066	232	226	27	-1	-0.004	0.004
	All data	99	997	865	80	-20	-0.023	0.153**						

* $P < 0.05$

** $P < 0.01$

between SD and measures of openness of the forest. 1974 was a year which had uncharacteristically low snowfall.

SWE also correlated poorly with forest cover variables in 1973 and 1974 and poor relationships were observed again in 1976. 1976 was an abnormal winter with two major rainstorms occurring within a week in late January and early February. In both storms the spatial distribution of rainfall favoured low elevations (Dickison and Daugharty, 1977), and thus areas with greater softwood content. It was probably the effect of those rainfall events which led to poor SWE versus forest cover relationships.

In many surveys high correlations were found between SD and a forest variable while much lower non-significant correlations were found between SWE and that same variable. This may have been somewhat due to problems in sampling SWE. Small brush beneath the snowpack may occasionally interfere with the collection of a solid core in the sampling tube. This would distort SWE measurements but not those of SD. Although this factor probably would not lead to bias on any particular survey, it would lead to consistently poorer SWE versus forest cover correlations. Snowpack quality factors, such as the existence of ice layers, may also interfere with the collection of a representative SWE sample.

One possible explanation, aside from sampling problems, is that snowpack characteristics differ between dense and open stands. If higher density snow were found in denser stands, better relationships would be found between SD and forest density. Differences in SWE in dense versus open stands would not be apparent. Satterlund and Haupt (1970) calculated that one-third of the snowfall in storms was intercepted by conifer crowns of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and western white pine (Pinus monticola Dougl.) saplings. Eventually, 86 percent of this intercepted snow reached the ground by being washed off by rain, falling in large mass release from branches, or falling in minor mass release such as drip from melting snow. Those data were collected during warm winters and under those conditions it would seem that high density snow would indeed be found where a high proportion of snow was first intercepted and then eventually reached the ground.

Conditions of high density snow under denser canopies were observed in 1976. In two surveys immediately following the rainstorms described previously highly significant correlations were found between density and CC. Greater snow density was associated with increased canopy closure.

Other researchers have found good relationships between snow cover and basal area or stem density (Packer, 1962; Ffolliott and Thorud, 1972; Golding and Harlan, 1972). However, those studies were carried out in pure softwood stands. In regions of mixed forest some measure of the proportion of hardwoods is needed for good relationships (Dickison and Daugharty, 1977).

Snow cover did not correlate well with NS and BA. %SH and %BAH showed much better relationships, with %BAH generally explaining more variance in SD and SWE measurements.

Excluding 1976, which was an abnormal year, the gradient of SD versus %BAH was 4.8 mm per 10 %BAH at time of maximum pack. This is equivalent to a difference of 48 mm between pure stands of hardwood and softwood and represents a reduction of 21 percent within softwoods. Lull and Pierce (1960), in a one season study in central New York, found differences of 53 mm and 23 percent between SWE in hardwood and softwood "sawtimber" at time of maximum accumulation.

SD correlated significantly with CT in 24 surveys. Considering measurements at forest growth plots only, significant correlations were found in 20 surveys, the same number as %BAH. CT and %BAH are roughly equivalent with CT classes representing 20 percent intervals of %BAH. The advantage of CT as a variable is that few ground measurements of basal area are required as classes can be determined by photo-interpretation.

CC was not a good a variable as CT, significantly explaining variance of SD and SWE in fewer surveys. However, significant relationships were found in most surveys. At time of maximum SD, gradients of SWE with CC ranged from 0 to -6 mm per 10 percent increase in CC. Packer (1962) found an 11 mm decrease per 10 percent increase in canopy closure in western white pine forest in Idaho. Lull and Rushmore (1960) reported an 8 mm decrease per 10 percent increase in canopy closure in the Adirondacks. Kittredge (1953) presented values from the central Sierra Nevada ranging from 13 to 56 mm decrease in SWE per 10 percent increase in canopy closure. In this study, correlations between SWE and CC were not significant at time of maximum SD.

SC was another variable which did not relate well with SWE. SC was used as a variable in order to see if good correlations would be found during the ablation period. Only in one season (1977) was greater SC significantly correlated with increased SD in late season.

In this region of mixed forest there is an association between forest cover and elevation. This relationship complicates analyses of forest/snow cover relations. Highly significant correlations exist between elevation and %SH (r=0.647) and elevation and %BAH (r=0.609). Studies of snow cover relationships with topography at NEWP (Dickison and Daugharty, 1975, 1977, 1980) show elevation to be positively correlated with SD and SWE. Ideally, in a study of the effects of forest cover on snow cover variability, all other factors would be constant and any snow cover changes would be affected by changes in forest cover. In this study the relationships between forest cover and SD and SWE are improved by the positive relationship between forest cover and elevation.

Anderson and Pagenhart (1957) pioneered multiple regression studies of snow accumulation. In order of importance in explaining variability they found forest variables to be third, behind elevation and solar energy respectively. Meiman (1968), in his extensive review of the effects of elevation, aspect and forest canopy on snow, concluded that differences resulting from canopy influences tend to be smaller than those associated with elevational changes. Anderson (1969) concluded that storm characteristics explain the largest part of variation in snow accumulation. This is not to say that less consideration should be given to forest cover. Indeed, it is of primary importance as it can be and is altered by man, affecting spatial snowpack patterns and ultimately water yield and regime.

As far as relative utility of the forest parameters considered in this study is concerned, CT may have the widest application. Few ground measurements are required for its determination and it was the best predictor. Variables which did not account for the hardwood proportion of the forest were the worst predictors. CC was also a good predictor and CC classes could also be determined by photo-interpretation, although this was not done in this study.

New Brunswick is approximately 86 percent forested and an understanding of the relationships between forest cover and snow cover is vital to water resource management and coping with the annual spring flood threat (Dickison and Daugharty, 1980). Relationships between forest cover, topography and snow cover have been incorporated into statistical models of the spatial distribution of snow cover at NEWP (Dickison and Daugharty, 1978). Wider applications of similar models would serve in predictions of water yield and potential flood hazard. Models of snow cover distribution would also be useful for wildlife management and recreation considerations.

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