INFLUENCE OF FOREST COVER ON SNOW AND FROST IN THE ADIRONDACKS

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Snow studies conducted in the Adirondacks during the past two winters by the Northeastern Forest Experiment Station are a part of its watershed management research program. Most of the Station's snow studies are carried on at the Hubbard Brook (N.H.) Experimental Forest, a northern-hardwood area in the White Mountains. The Adirondack studies were started in the winter of 1958-59, to determine the influence of conifers on snow accumulation and melt and to compare conifer and hardwood influences. The general site of the study, Paul Smiths, N.Y., is about 130 miles west-north-west of Hubbard Brook. Elevations of the Paul Smiths study plots ranged from 1,500 to 1,700 feet; those at Hubbard Brook range from 700 to 3,300 feet. To be in a better position to evaluate snow study results from the two areas, past years' records of snow accumulation and melt were compared as well as percents of runoff during the snow-melt months.

Snow accumulation and melt for the two areas are very similar, as shown in the comparison of 1955-59 records in figure 1. Snow-water accumulation begins in late November or early December and tends to rise rather steadily to a peak of 8 to 11 inches of water in March or early April. Melting is rapid; the snow disappears before May 1. An accumulation of 8 to 11 inches of water represents about one-fourth to one-third of the annual precipitation.

The influence of snowmelt on annual runoff is also similar for both areas, as illustrated in figure 2. From 45 to 50 percent of the annual flow of the upper reaches of the Pemigewasset River in the White Mountains and the Hudson River in the Adirondacks comes from melting snow and spring rain during April and May. For drainage areas as large as 1,500 square miles, as represented by the Merrimack and Hudson River comparisons, 35 percent of the annual flow is furnished during these 2 months (Lull and Pierce, 1960).

The contribution of snowmelt runoff to the streamflow regimen lends importance to one of the objectives of watershed research: determining the influence of forest types and conditions on snow-melt runoff

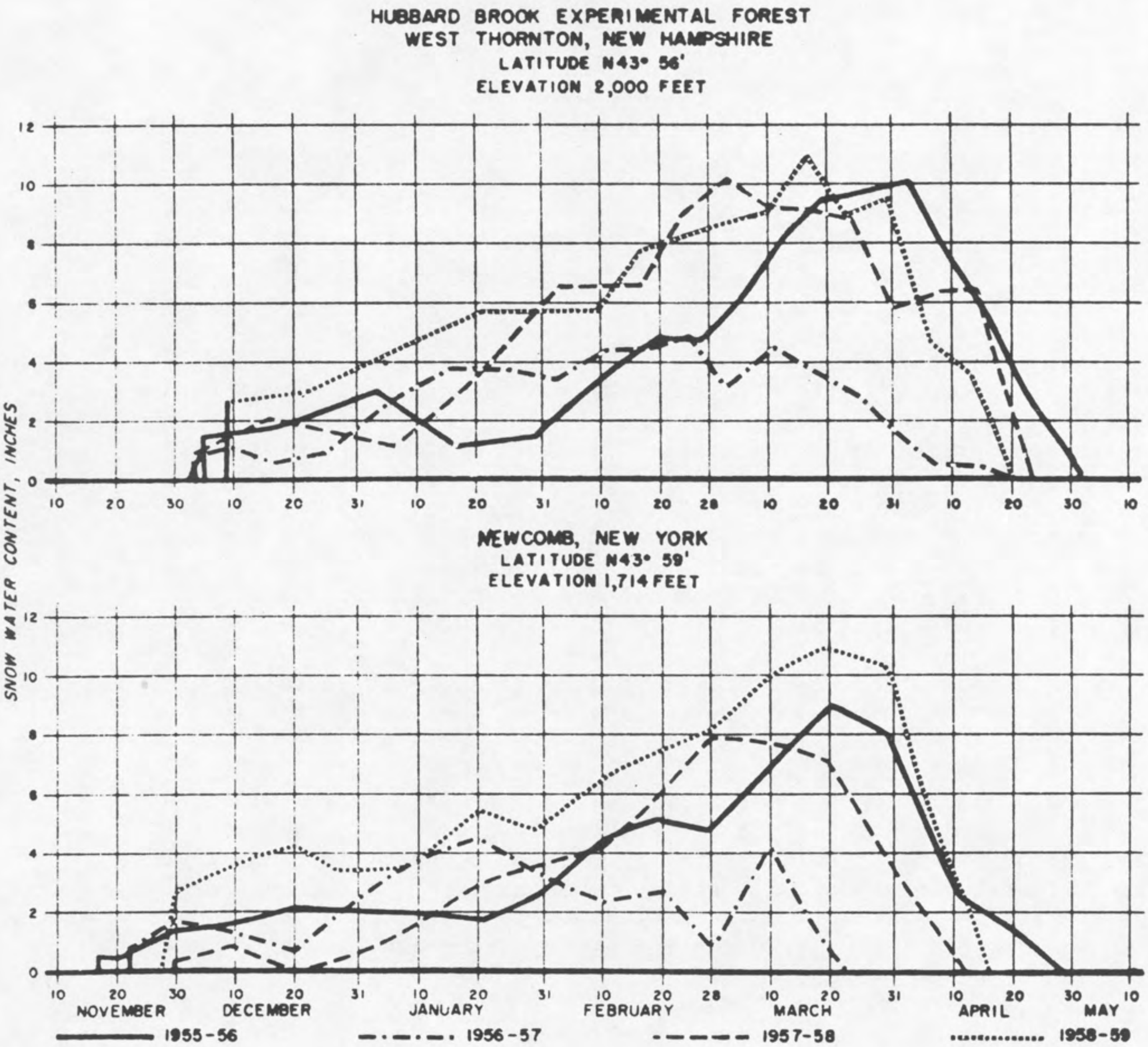

Figure 1.—Snow water accumulation in the White Mountains and in the Adirondacks, 1955-59.

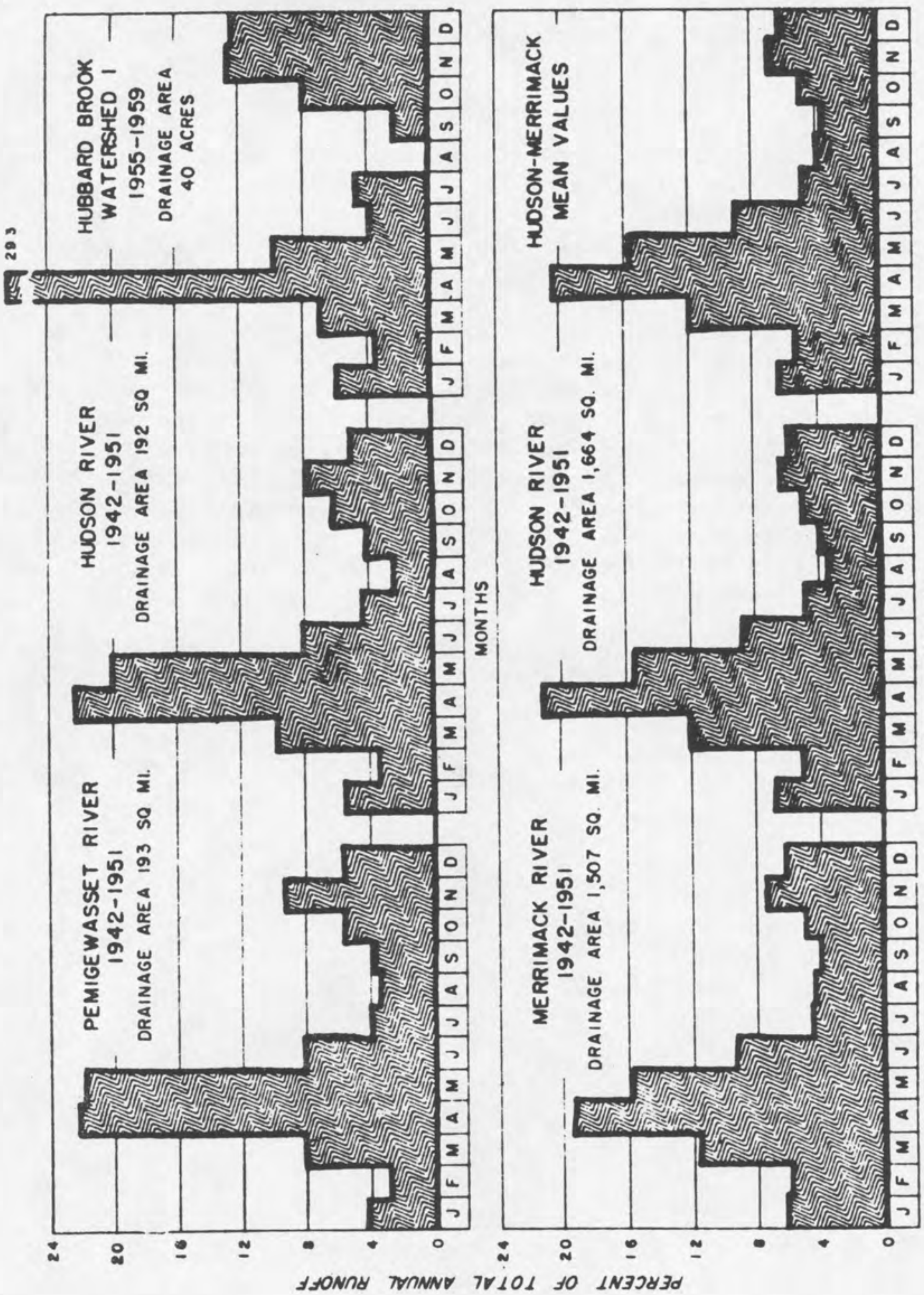

Figure 2.—Percent runoff by months.

through their influences on snow accumulation and melt.

EFFECT OF FOREST COVER ON THE SNOWPACK

The magnitude of the forest influences are suggested from snow-water content measurements, taken in the Adirondacks at 32 snow-survey courses during March and April 1959, in conifer (red spruce, balsam fir), hardwood (beech, maple, birch), and cutover plots in a mature stand of conifers and hardwoods (Lull and Rushmore, 1960).

Greatest accumulation of snow water--in mid-March--was in the hardwoods, averaging 9.01 inches as compared to 6.92 inches in the conifers (table 1). By mid-April the greater melt rate in the hardwoods had more than erased this 2-inch difference, snow-water content then averaging 4.51 and 4.89 inches in hardwoods and conifers, respectively. Thereafter, until snow disappeared in early May, the conifer areas possessed the greater snow-water contents. After peak accumulation, snow melted in the hardwood stands in 34 days and in the conifer stands in 43 days. Degree-day melt rates (above 32°F.) were twice as great for the hardwood plots as for the conifer plots (table 1).

Table 1.--Snow-water content at maximum accumulation, number of days to melt, and melt rate at experimental plots near Paul Smiths, N.Y., 1959.

Condition	Snow-water content	Percent of maximum (by areas)	Days to melt	Mean degree-day melt rate
	Inches			Inches
Hardwood sawtimber	8.92	98	34	0.06
Hardwood sapling	9.10	100	34	.06
Conifer sawtimber	6.85	75	40	.03
Conifer sapling	6.98	76	46	.03
Forest road, demi-open	9.68	96	36	.06
Commercial clearcut	9.25	91	36	.05
Selective cut 25-35 year cycle	10.08	100	36	.06
Selective cut 15-20 year cycle	10.12	100	38	.06
Selective cut 5-10 year cycle	9.30	92	38	.05
Control	8.25	82	41	.03

Different cutting practices had much less effect on accumulation and melt. Maximum accumulation was in the more heavily cut selection plots. Accumulations of 91 and 96 percent of the maximum were found in the clear-cut plot and in the road area (table 1), perhaps because of greater exposure and greater melting during initial snow accumulation. Smaller accumulations of 92 percent in the most lightly cut plot and 82 percent in the uncut plot may have been due to increased interception by their greater conifer component. The differential in days of melt amounted to 5 days at most, and only the control plot had a substantially lower melt rate, very likely because of the shade cast by its greater conifer component.

PREDICTION OF ACCUMULATION AND MELT

In an effort to relate accumulation and melt to some physical measurement of the overhead canopy, at each snow-measuring point the canopy opening was estimated with the spherical densiometer (Lemmon, 1957).

Figure 3 shows the average canopy closure for each snow course against the average accumulation and melt for the course. From the accumulation regression, for each 10-percent increase in canopy closure, snow-water content decreased about one-third of an inch (or in terms of snow depth at 30-percent density, about 1 inch). The correlation coefficient of 0.794 signifies that this relationship accounts for 63 percent of the variation in accumulation.

The snow-melt relationship is such that it decreased at the rate of about 0.005 inches per degree-day for each 10-percent increase in canopy closure. With a correlation coefficient of 0.869, this accounts for 76 percent of the variation in melt-rate.

In March and April 1960, snow measurements were taken to check on the snow accumulation and melt predicition procedures developed the previous year.[1] Eight snow courses were laid out, two each in the four hardwood and conifer cover type conditions previously studied, but in different stands. Snow measurements were taken at the time of maximum accumulation with complete snow cover, April 18. Canopy closure over each sampling point was again measured with the densiometer.

The percentage of canopy closure for each snow course was then used to estimate the snow-water content ratio (depth in forest condition/ depth in hardwood saplings) for the time of maximum snow accumulation, employing the regression developed from the 1959 data, figure 3. The estimated ratio was then multiplied by 8.6 inches, the average snow-water content of the two hardwood-sapling courses, to estimate the snow-water content of the three other forest conditions. Percentage of canopy closure for each snow course was also used to estimate the snow-melt in inches per degree-day above 32°F. Then the actual and predicted melt during the period March 21 to April 18 were calculated. Results, given in table 2, indicate that the 1959 prediction regressions are adequate.

[1] Further observations of snow and frost in the Adirondacks. Unpublished manuscript, Northeastern Forest Experiment Station, 1961.

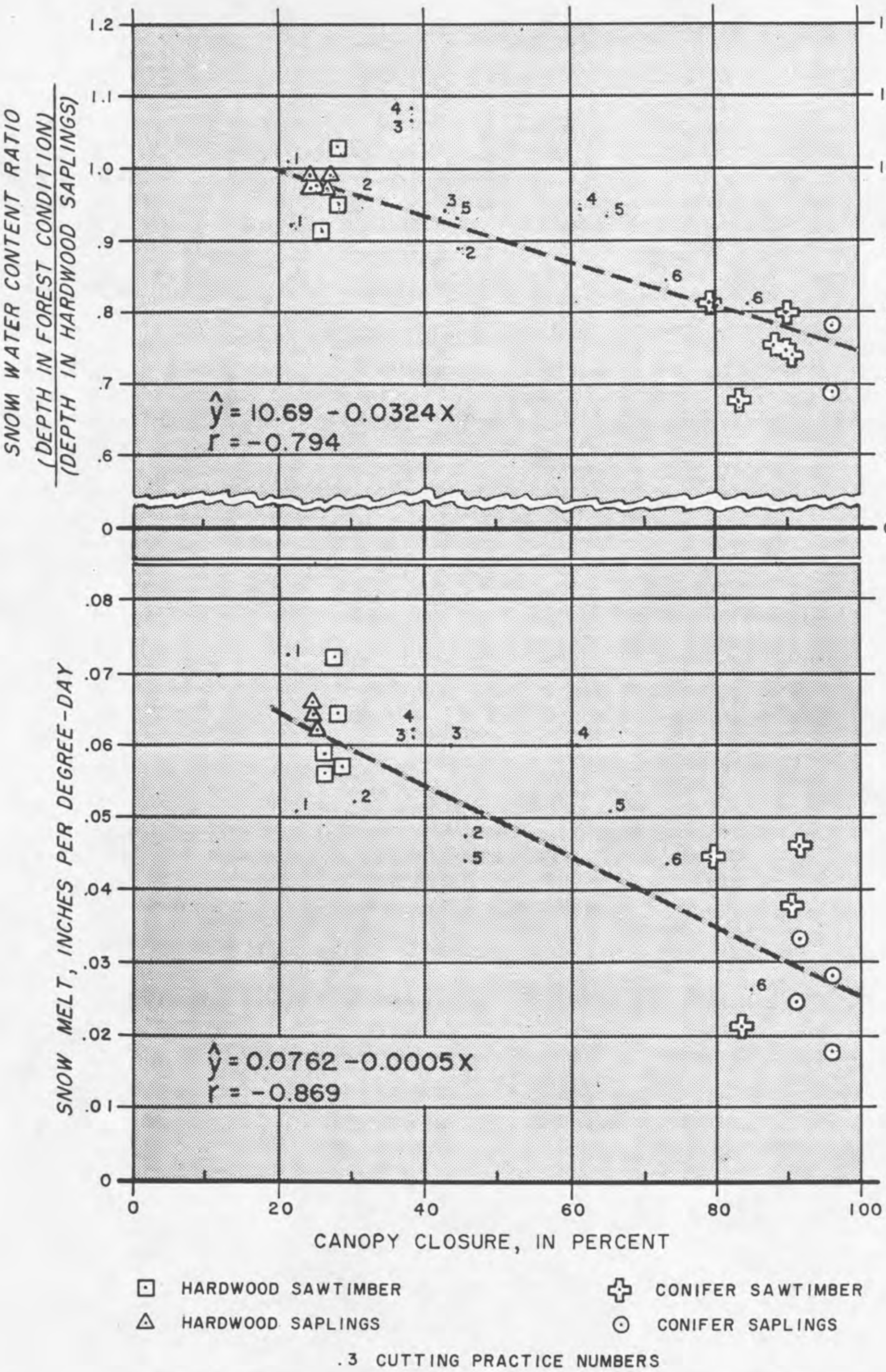

Figure 3. Canopy closure and snow accumulation and melt.

Table 2.--Predicted and actual snow accumulations and melt.

Condition	Canopy closure	Maximum snow-water accumulation		Melt per degree-day above 32°F.	
		Predicted	Actual	Predicted	Actual
	Percent	Inches	Inches	Inches	Inches
Conifer saplings	66	7.5	7.4	.043	.036
	60	7.7	7.8	.046	.035
Conifer sawtimber	60	7.7	7.8	.046	.044
	64	7.6	8.0	.044	.044
Hardwood saplings	28	--	8.0	.062	.053
	24	--	9.2	.064	.054
Hardwood sawtimber	23	8.9	8.6	.065	.061
	20	8.9	8.4	.066	.060

To observe more closely the snow interception process, 4-foot long branches of balsam fir, red spruce, white pine, and hemlock were nailed to two posts, at a height of 5-feet, simulating two stems bearing branches of different species. Week-day observations of snow depth, at three points on each branch, were made during the period December 8, 1959, to March 22, 1960. Snow was present on the branches a total of 69 snow-days--or about two-thirds of the period.

Maximum accumulations were 4.7 inches on balsam fir, 4.3 inches on red spruce, 6.2 inches on white pine, and 4.5 inches on hemlock. Average accumulations for the period were 2.1, 1.8, 1.8, and 1.2 inches for the four species, respectively; only the difference between hemlock and other species was statistically significant.

The branches of hemlock are feathery, flexible, and slope downward to form a poor platform for snow accumulation. Balsam fir had the best platform for snow support, apparently because needles persist along branches and there are many stiff branchlets. Spruce was next, and though its needles are small, like hemlock, the branchlets are much stiffer and would not dump snow as readily. On a white pine branch, snow was caught within the bare whorls at two of the three positions measured, branches cupping the whorls permitting deepest accumulations of snow; the small stems provided good support for patches of snow when wind or thaws occurred.

CONCRETE FROST

Only sporadic occurrence of concrete frost was observed at maximum snow accumulations. Frost incidence and depth determinations at 160 points along the snow survey courses revealed a frequency of occurrence of 15 percent in conifer and hardwood sawtimber, 30 percent in conifer saplings, and 40 percent in hardwood sapling. The average depth of the frost was about 2 inches.

However, concrete frost did tend to concentrate beneath conifer crowns in the snow interception zone. This tendency, first observed during the 1959 field season, was investigated in 1960 by digging trenches beneath the crowns of isolated conifers (3 red spruce, and 7 balsam fir) in a hardwood stand and taking snow depth and frost measurements every 2 or 3 feet along the trench. Three of the snow and frost profiles are shown in figure 4.

No relationship between frost and snow depth may be deduced from these limited observations, the concrete frost observed having developed from antecedent, unobserved weather and snow conditions.

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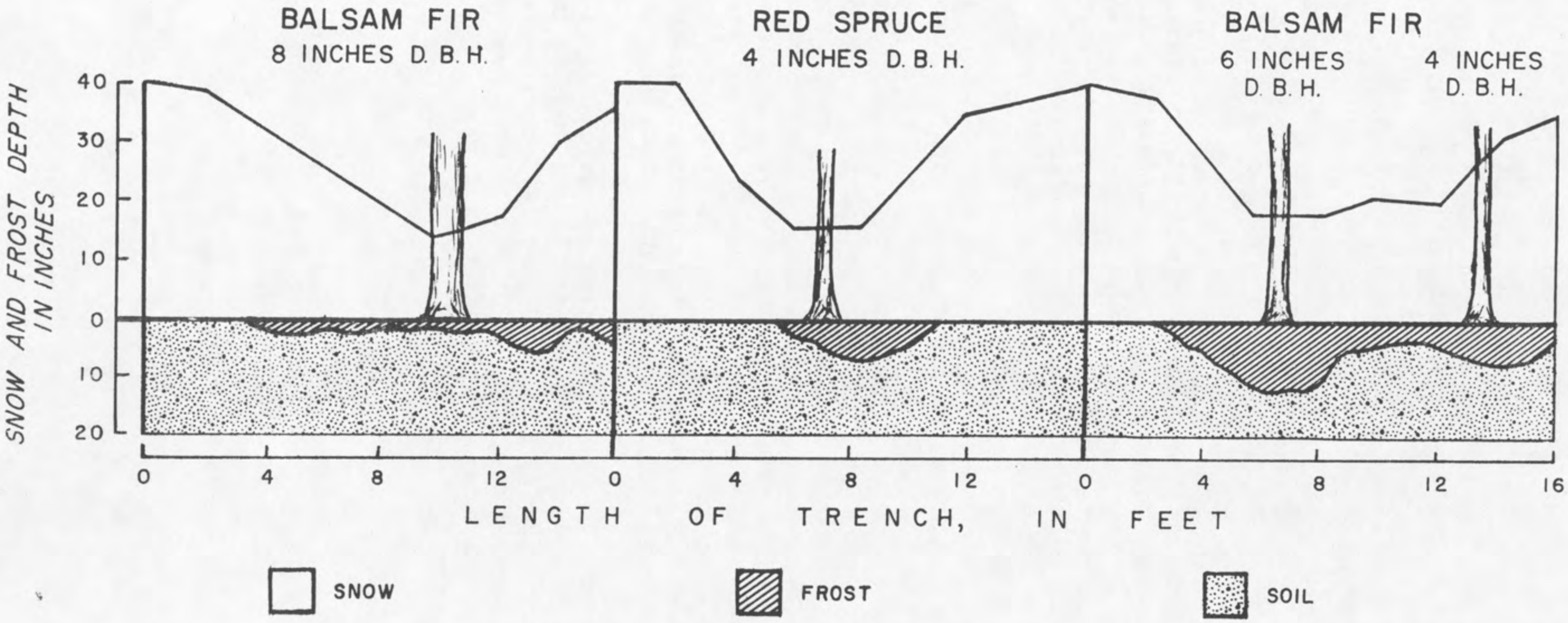

Figure 4. Snow and frost profiles under selected forest cover.