REGENERATION FOLLOWING SHELTERWOOD CUTTING IN A NEW BRUNSWICK SOFTWOOD STAND

by

V. C. Baldwin Jr.

Maritimes Forest Research Centre

Fredericton, New Brunswick

Information Report M-X-76

Canadian Forestry Service

Department of Fisheries and the Environment

1977

TABLE OF CONTENTS

ABSTRACT

A shelterwood cutting study in a 50-year-old mixed-species, predominantly spruce-fir, stand in northwestern New Brunswick was established in 1959 by the Canadian Forestry Service. At the time of the initial felling 100, 80, and 60% of the basal area in spruce and fir with breast height diameters 5 inches or greater were to be left standing. Overstory conditions were assessed from repeated measurements in 0.2-acre plots before and after the seed cut in 1959 and 1964, and in all treatments before the softwood overstory was harvested in 1969. Regeneration was monitored through a system of milacre quadrats surrounding the overstory plots; stocking and growth measurements were made every 5 years from 1959 to 1974.

Results of this experiment indicate: (1) removal of up to 40% of the basal area in well established spruce-fir stands on broad valley bottoms need not result in high windfall losses; (2) the shelterwood system keeps out competing shrubs, encourages spruce and fir regeneration, and reduces hardwood seedling density in the regenerating stand; (3) the harvest felling can be accomplished without excessive seedling mortality as soon as the softwood seedlings average 1 ft or more in height; and (4) compared with natural regeneration resulting from clear cutting which is represented by the control treatment wherein 100% of the overstory was left until the final harvest, the shelterwood system can increase the proportion of spruce to fir seedlings, improve height development in both spruce and fir regeneration, and noticeably lower overall softwood densities. These results were pronounced where 60% of the softwood basal area was left after the seed cut.

RESUME

En 1959, le Service canadien des forêts a entrepris la coupe progressive dans un peuplement à bois mélangés du nord-ouest du Nouveau-Brunswick, âgé de 50 ans, où prédominaient l'Epinette et la Sapin. A l'époque de la coupe initiale, 100, 80 et 60 p. cent de la surface terrière en Epinettes et Sapins dont le diamètre à hauteur de poitrine mesurait 5 pouces ou plus, ont été laissés sur pied. On a évalué les conditions de l'étage dominant à partir de mesurages effectués dans des placettes de 0.2 acre, avant et après la première coupe progressive de régénération en 1959 et 1964, et à tous les traitements avant la récolte des résineux de l'étage dominant. On a suivi de près la régénération via une méthode de quadrats d'une milliacre entourant les placettes de l'étage dominant. Les mesurages du matériel sur pied et de croissance ont été faits tous les 5 ans, de 1959 à 1974.

Les résultats de cette expérience indiquent que: (1) la suppression de jusqu'à 40% de la surface terrière des peuplements d'Epinette-Sapin bien établis au fond des larges vallées n'a pas nécessairement comme résultat de lourdes pertes dues au chablis par le vent; (2) la méthode de coupes progressives enraye la concurrence des arbrisseaux, favorise la régénération de l'Epinette et du Sapin et réduit la densité des semis de feuillus dans le peuplement en voie de régenération; (3) la coupe principale peut se faire sans causer une mortalité excessive des semis dés que la hauteur moyenne des semis de feuillus est d'un pied ou plus; (4) comparée à la régénération naturelle après coupe à blanc, la méthode progressive peut augmenter la proportion des semis d'Epinette et Sapin, améliorer la croissance en hauteur des semis de Sapin et d'Epinette, puis réduire notablement la densité d'ensemble des résineux. De tels résultats étaient marqués dans les endroits où 60% de la surface terrière des résineux fut laissé sur pied après la première coupe progressive de régénération.

INTRODUCTION

Stands predominantly balsam fir (Abies balsamea (L.) Mill.) mixed with red (Picea rubens Sarg.), black (P. mariana (Mill.) B.S.P.), or white (P. glauca (Moench) Voss) spruce, and various hardwoods are common throughout the Maritime Provinces of Canada and the extreme northeast United States. Because of the tolerance of these species, advanced reproduction in old growth stands is usually more than adequate to establish new softwood stands following clear-cut harvest (Fowells 1965). However, second growth stands, particularly those started after the extensive 1913-19 budworm outbreak, are now being harvested before the advanced reproduction is prevalent or well established. Hence, alternative silvicultural systems must be considered if natural regeneration is desired. One such regeneration method thought to have some potential in these stands is the shelterwood system (Hawley and Smith 1954).

A shelterwood cutting experiment was established in the Green River Watershed of northwestern New Brunswick in 1959. The purpose of the study was to determine whether initially removing 20 or 40% of the average basal area in softwoods 5 inches[1] or more in diameter at breast height (dbh) would allow adequate spruce and fir regeneration and at the same time discourage the invasion of competing shrubs on the area. It was hypothesized that if the fir and spruce regeneration could reach a mean height of 2 ft before the final felling, the competition from shrubs or hardwoods thereafter would not significantly hinder stand

[1] Establishment of the study area and all measurements were taken in English units. Because of the difficulty in converting the measurements and size classes to metric units, they are reported as taken.

establishment. Furthermore, it was reasoned that summer logging would create sufficient disturbance in the duff and bare enough mineral soil to provide adequate seedbeds for spruce if a seed supply was available. Through this, and a favoring of spruce in the first felling, it was hoped that the percentage stocking to spruce in the existing stand could be maintained in the regeneration.

THE STUDY AREA

The experimental area is located about 30 miles north of Edmundston, New Brunswick, in the Lake Branch Valley, about one mile below and east of the main road to Summit Depot. It is on a uniform lower slope with grades not exceeding 15%. The aspect is westerly and the site is relatively sheltered.

The soil is mostly a silt loam over a fine sand (Malacite series)[2] although some silty tills (Violette series) and gravel (Victoria series), occur along the west boundary and towards the south end of the area. Productive capacity is about average for softwood sites on the Green River Watershed.

The stand developed after a fire which was thought to have occurred in 1899. Seeding took place over at least 24 years, as borings in the pre-treatment stand gave a range of ages from 34 to 58 years. Most trees were in the 40- to 50-year-old range.

The forest was predominantly softwood, 91% by number of stems and 84% by basal area (Table 1). At the precut measurement, the stand had a merchantable softwood volume of 1988 cu ft/acre (23.5 cords). The volume was 29% balsam fir and 71% spruce and was composed of mostly

[2] Soils information provided by K. Langmaid, Soil Survey Division, Canada Department of Agriculture.

6-, 7-, and 8-inch trees. The hardwood species in the stand were trembling aspen (*Populus tremuloides* Michx.), birch (*Betula alleghaniensis* Britton, *B. lutea* Michx. f., and *B. papyrifera* Marsh.), pin cherry (*Prunus pensylvanica* L.), and red maple (*Acer rubrum* L.). The canopy with crown closure approaching 100% (Fig. 1), precluded the development of shrubs and herbs, but there was a luxuriant layer of mosses on most of the area (Figs. 2-5).

Reproduction tallies indicated about 100% stocking to fir and 4% to spruce. The 1800 milacre quadrats examined averaged about 20 fir seedlings each but only 4% had stems over 6 inches in height. On 1% of the quadrats, the largest fir seedling was taller than 1.5 ft. Examination of data from another plot located in the same burn indicated that there had been a continuous turnover of these small seedlings during the preceeding five years with few becoming well enough established to survive more than three years.

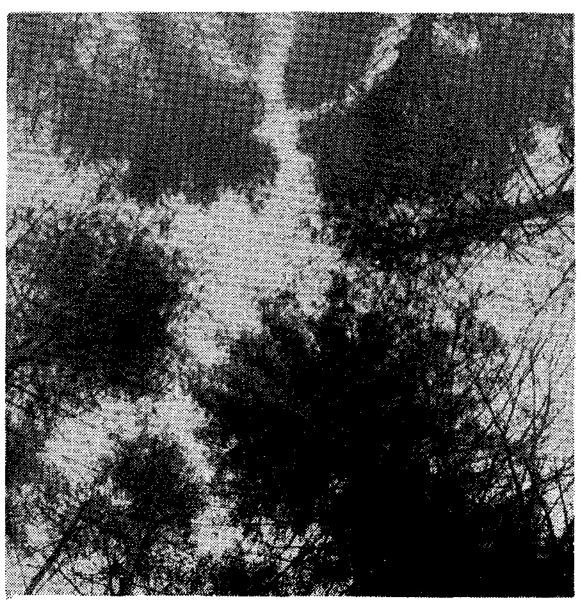

Fig. 1. Vertical view in the stand before treatment. The dense canopy is common to the area.

Table 1. Stand data before the seed cuttings

	Fir	Spruce	Total Softwoods	Birch	Aspen	Cherry	Red Maple	Total Hardwoods	Total
Stems/acre	604	680	1284	60	55	6	2	123	1407
Basal area (sq ft)	55	98	153	12	17	0.4	0.3	30	183
Average diameter (inches)	4.1	5.2	4.7	6.2	7.3	3.4	5.2	6.6	4.9

Fig. 2. Plot before 20% felling. The stand had 95 sq ft of softwood basal area and a merchnatable volume of 1560 cu ft (18.2 cords) per acre.

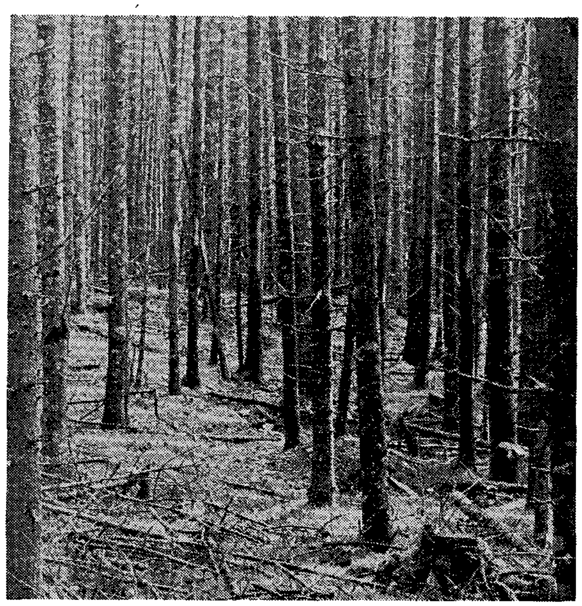

Fig. 3. Plot after 20% felling. The stand was reduced to 86 sq ft of softwood basal area and a merchantable volume of 1420 cu ft (16.7 cords) per acre.

Fig. 4. Plot before 40% felling. The stand had 161 sq ft of softwood basal area and a merchantable volume of 2920 cu ft (34.4 cords) per acre.

Fig. 5. Plot after 40% felling. The stand was reduced to 80 sq ft of softwood basal area and a merchantable volume of 1396 cu ft (16.4 cords) per acre.

METHODS

The two intensities of initial cutting and an untreated control were tested in a randomized block design with three replications. A 106-acre block was subdivided into nine compartments ranging from 8 to 20 acres. A schematic diagram of the compartments and plots is given in Figure 6.

Difficulty was encountered in making up the three blocks from the nine compartments. There were variations in stand density, in the amount of hardwoods, and particularly, in the percentage of total basal area that was in trees 5 inches and larger in diameter. Every effort was made to group in the same block, those compartments having similar (a) hardwood basal area, (b) softwood basal area, (c) softwood basal area in trees over 4.6 inches and (d) merchantable softwood volumes (Table 2).

Table 2. Grouping of compartments within blocks on basis of basal area

	sq ft /acre			cu ft/acre
Block	Hardwood basal area	Softwood basal area	Softwoods >5 inches, basal area	Merchantable softwood volume
A	31.7	161.1	95.6	1566
B	25.5	166.7	140.2	2514
C	31.6	130.8	102.5	1884
Mean	29.6	152.9	112.8	1988

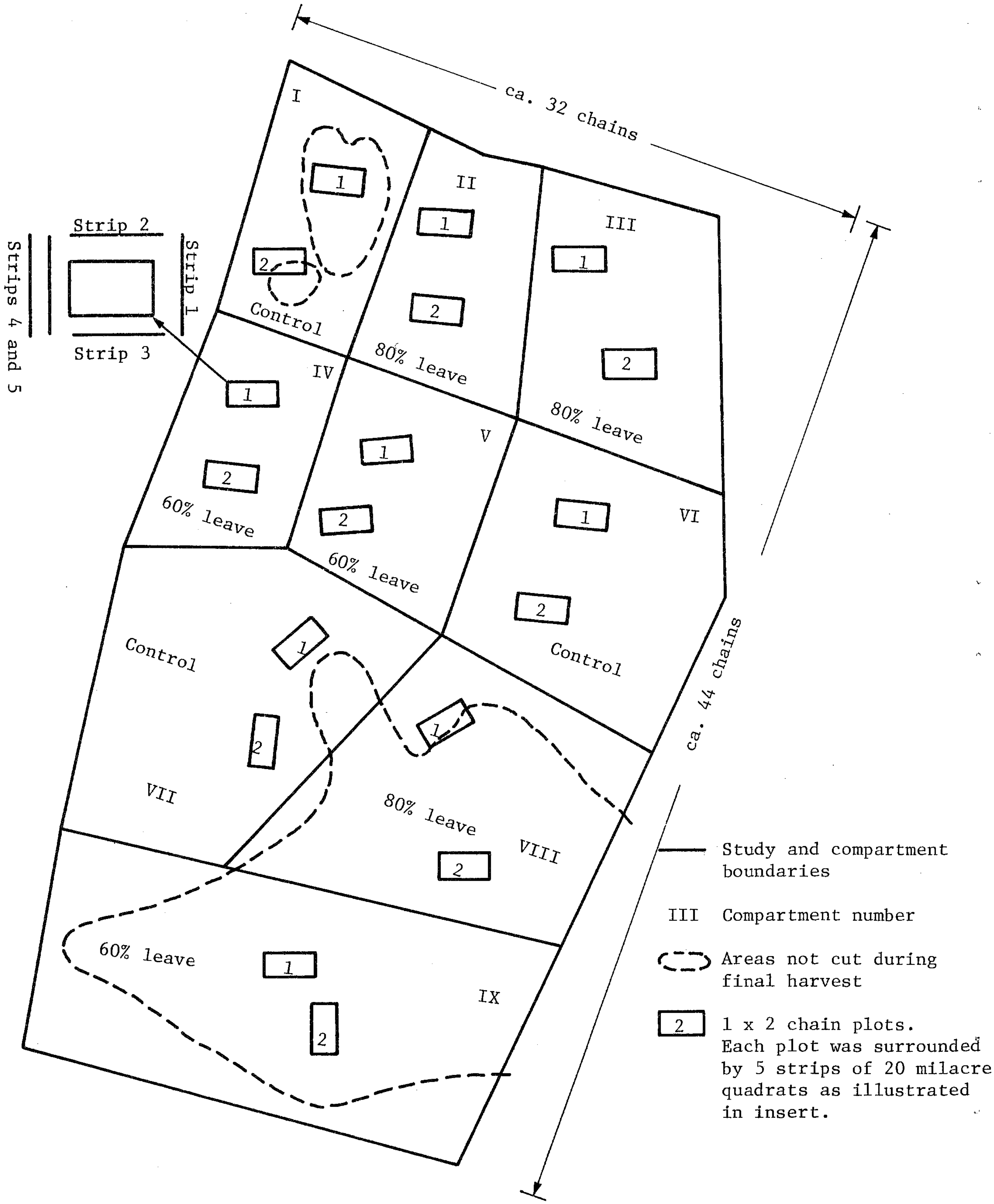

Figure 6. Schematic diagram of the shelterwood study area layout and experimental design.

Treatments were assigned randomly within blocks. The grouping was as follows:

Compartment	Block	Treatment	Area (acres)
I	A	control	11.6
II	A	80%	8.2
III	B	80%	10.2
IV	A	60%	7.2
V	B	60%	8.0
VI	B	control	11.1
VII	C	control	13.4
VIII	C	80%	16.1
IX	C	60%	19.8

Two 0.2-acre (1 x 2 chains) rectangular plots in each compartment were sampled. The plots were located in homogeneous stands and all were situated on the same soil type (Malacite). Around each plot a series of five strips each containing 20 milacre quadrats were laid out (Figure 6).

Data were gathered from the 0.2-acre plots before and after the initial cut in 1959, in 1964, and before and after the final felling in 1969. At each sampling, all live trees over 0.5 inch dbh were tallied by species in one-inch classes and a subsample of at least five trees per softwood species per plot was measured or remeasured for height and diameter to determine growth changes resulting from the treatments.

Within the regeneration quadrats, a stock tally was taken by species and height class (0 to 0.5, 0.6 to 1.5, 1.6 to 2.5 ft, etc.). In this context, stocking percentage is a measure of seedlings distribution throughout the sampling area. High stocking percentages indicate good distribution; low percentages indicate either few seedlings or a clumpy distribution. Results were evaluated for each softwood and hardwood species. A total count of all reproduction including the shrubs was made on the first and twentieth quadrat of each strip. These tallies were done before the seed cut in 1959, in 1963, in 1969 before and after the harvest cut, and finally in 1974.

The average basal area per acre of the softwood trees larger than 4.6 inches dbh in the pretreatment stand was 114.9 sq ft, so the target basal area per acre to leave in the 80% and 60% treatments was 91.9 and 68.9 sq ft, respectively. Basal area in the leave trees for each treatment after the initial felling approximated these figures (88.9 sq ft for the 80% treatment and 67.7 sq ft for the 60% treatment). The remaining relatively uniform overstory in the compartments consisted mostly of codominants and dominants between 5 and 9 inches in diameter. Spruce was retained in favour of fir whenever there was a choice between equivalent trees. The cuttings did little to alter the species distributio in the compartments (Table 3).

Table 3. Average overall distribution of the softwood species within the forest before and after the seed cuts in 1959

	Number of stems (%)	Basal area (%)	Merchantable volume (%)
Spruce before	53	64	70
Spruce after	54	65	73
Fir before	47	36	30
Fir after	46	35	27

During the summer of 1969, the final felling of the merchantable overstory was done by an industrial logging crew. They removed only the largest and best softwood stems and some portions of the area were not cut over at all (as indicated on Figure 6). The unfortunate result was that some uncut patches of overstory were so distributed that the detailed analysis of variance provided for in the experimental design (Mendenhall 1968) could not be applied. Nevertheless, the remaining data are valid and sufficient to point out trends and establish gross treatment differences. Sampling sources for those statistics hereafter presented in the results and discussion section are specifically indicated.

RESULTS AND DISCUSSION

1. *Growth in the Residual Stand*

Mortality of softwoods was light in all treatments over the 10-year period between the seed and harvest cuts. There was no evidence of heavy loss from sudden increased solar radiation or wind exposure. Windfall and minor logging damage along main skid trails near the haulroads were the main causes of the mortality that did occur in the residual stand. The average net decrease in stems per acre was 341 (28%), 274 (25%), and 247 (24%) for the Control, 80% and 60% treatments, respectively (Table 4).

Changes in residual hardwood density and basal area within the treatments were minimal (Tables 4 and 5). Some hardwood trees were felled during the seed cut to improve the softwood composition and spacing, but most were left standing. Most of these trees and the unmerchantable softwoods were also left standing after the harvest cut.

Table 4. Changes in number of stems of mature stand by treatment and block averages

		Density (Stems per acre)									
		1959 Before seed cut		1959 After seed cut		1964		1969 Before harvest cut		1969 After harvest cut	
Treatment	Block	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	A	1602	231	-	-	1302	237	1098	224	not measured[a]	
Control	B	1074	103	-	-	875	96	737	92	19	28
	C	1003	69	-	-	904	71	821	70	28	49
	Mean	1226	134	-	-	1027	135	885	129	24	39
	A	1690	187	1576	173	1279	165	1103	156	130	101
80%	B	1074	15	739	12	587	16	559	29	4	10
overstory	C	1169	128	962	123	849	116	793	106	not measured[a]	
	Mean	1308	110	1092	103	905	99	818	97	67	56
	A	1736	10	1406	6	1112	9	1028	9	16	6
60%	B	1166	160	889	157	707	142	659	146	55	53
overstory	C	1049	206	844	194	719	178	710	161	not measured[a]	
	Mean	1317	125	1046	119	846	110	799	105	36	29

[a] The overstory was not harvested in these blocks.

Table 5. Changes in basal area of mature stand by treatment and block averages

		Basal area per acre									
		1959 Before seed cut		1959 After seed cut		1964		1969 Before harvest cut		1969 After harvest cut	
Treatment	Block	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
Control	A	140.2	47.2	-	-	137.6	53.9	136.7	54.7	not measured[a]	
	B	172.1	36.3	-	-	165.8	44.0	160.9	45.0	1.6	19.0
	C	127.4	22.0	-	-	142.6	26.1	146.6	27.1	2.0	18.4
	Mean	146.6	35.2	-	-	148.7	41.3	148.1	42.3	1.8	18.7
80% overstory	A	164.8	43.7	150.2	44.7	149.9	47.5	146.9	49.6	8.9	36.7
	B	180.7	6.0	110.1	4.9	110.7	6.6	115.8	7.1	0.2	6.0
	C	137.3	28.2	118.7	29.3	130.0	34.4	135.2	32.8	not measured[a]	
	Mean	160.9	26.0	126.3	26.3	139.0	29.5	132.6	29.8	4.6	21.4
60% overstory	A	178.2	4.3	127.2	3.2	128.2	6.1	138.8	7.2	0.9	5.2
	B	147.2	34.2	99.5	34.8	98.0	37.2	104.5	38.2	4.1	16.6
	C	127.8	44.5	90.8	43.6	98.7	50.1	106.5	48.4	not measured[a]	
	Mean	151.1	27.7	105.8	27.2	108.3	31.1	116.6	31.3	2.5	10.9

[a] The overstory was not harvested in these blocks.

Table 6. Changes in merchantable softwood volume of the mature stand by treatment and block averages

		Merchantable softwood volume (cu ft/acre)							
Treatment	Block	1959 Before seed cut	1959 After seed cut	1964	1969 Before harvest cut	Net annual growth (1959-1969)	Annual mortality (1959-1969)	Gross annual growth (1959-1969)	1969 after harvest cut
Control	A	1184.7		1441.8	1720.1	53.5	2.5	56.0	not harvested[a]
	B	2661.7		2886.8	3127.3	46.6	10.6	57.2	3.6
	C	1832.7		2406.0	2685.1	85.2	6.3	91.5	12.6
	Mean	1893.0		2244.9	2510.8	61.8	6.5	68.2	8.1
80% overstory	A	1586.8	1384.8	1775.7	1977.1	59.2	2.4	61.6	21.4
	B	2917.9	1620.1	1932.3	2180.6	56.1	12.0	68.1	0
	C	2017.9	1744.8	2536.2	2287.7	54.3	7.1	61.4	not harvested[a]
	Mean	2174.2	1583.2	2081.4	2148.3	56.5	7.2	63.7	10.7
60% overstory	A	1925.9	1136.6	1519.7	1492.0	35.5	0.1	35.6	0
	B	1962.9	1157.4	1399.2	1644.3	48.7	6.8	55.5	3.6
	C	1800.4	1069.0	1508.2	1801.6	73.3	4.0	77.3	not harvested[a]
	Mean	1896.4	1121.0	1475.7	1646.0	52.5	3.6	56.1	1.8

[a] The overstory was not harvested in these blocks.

Their competitive influence on the regenerating stand may have been significant but their effect, if any, was not considered in this study.

The average losses from 1959 to 1969, in terms of net merchantable volume growth per acre, were only 65 cu ft (3%), 72 cu ft (3%), and 36 cu ft (2%) for control, 80% and 60%, respectively (Table 6). The net annual merchantable volume growth after the seed cuttings ranged from 35.5 to 85.2 cu ft/acre and averaged 61.8, 56.5, and 52.5 cu ft/acre for the control, 80% and 60% treatments, respectively (Table 6). However, if the volumes cut in the 1969 partial harvests are taken into account, then the mean annual growth for the respective treatments become 70.4, 99.6, and 70.9 cu ft/acre for the first 5-year period, and 61.8, 115.6, and 130.0 for the 10-year period before the final harvest. As would be expected in stands of this age (USDA Forest Service 1973) these latter data indicate a significant overall increase in softwood growth as a result of the thinning in the 80% and 60% treatments. The growth response in the 60% treatment was not great until more than 5 years after the seed cut.

Seed production of the residual softwoods was not measured on the site during the interim period; however, measurements during 1959 indicated a moderately good seed year for spruce in the area.

2. *Regeneration*

Quadrat remeasurements in 1963 indicate most softwood regeneration was not of the hypothesized optimum size (between 2 and 6 ft in height) for the final harvest. Tables 7-9 show the changes in seedling density by 1-ft height classes over time for each of the treatments, and

Table 10 gives the percentages of stocked quadrats for different species-treatment-year combinations. Close inspection of these data indicates strong support for some of the study hypotheses and suggests alteration of others.

The density and stocking of the softwood regeneration in all treatments before the harvest cuts were more than adequate. Density ranged from a high of 94,870 seedlings/acre in the control to a low of 40,500 seedlings/acre in the 60% treatment. The 1974 softwood regeneration counts and stocking (Tables 7-10) indicate that the shelterwood system offered little advantage over clear cutting (i.e. a single harvest as in the control) in obtaining adequate numbers of softwood regeneration. Much of the control regeneration was not as tall as that in either the 80% or 60% treatments, but more than 8000 seedlings per acre were over 1.5 ft tall in the control treatment. These data also indicate that the harvest of the forest could have occurred years sooner and adequate numbers of regeneration probably would have been available on the site.

On the other hand, in 1974 the control treatment also contained a much higher number of hardwoods than the shelterwood treatments (11,940 stems/acre with 96% stocking compared to an average of 5,455 stems/acre and 91% stocking in the shelterwood treatments), and a much smaller number of spruce seedlings (180 stems/acre compared to 700 stems/acre average for the shelterwood treatments). In terms of proportions of the softwood regeneration, 1% was in the control and 6% in the shelterwood treatments. Thus, these results demonstrate the advantage of the shelterwood system in controlling competition and altering species composition.

Table 7. Changes in density of the regeneration by species and height classes in the control treatment

Treatment year	Species	Density (stems/acre)[a]								
		Height (ft)								
		<1	1	2	3	4	5	6	>6	Total
1959	fir	30,870	150			20				31,040
	spruce	420								420
	hardwood	5,500	170							5,670
1963	fir	136,530	2,400	20		20				138,970
	spruce	550	30							580
	hardwood	2,900	500	180	20					3,600
1969 Before harvest cut	fir	88,200	5,170		20					93,370
	spruce	1,450	50							1,500
	hardwood	1,970	230							2,200
1969 After harvest cut[b]	fir	21,400	1,410							22,810
	spruce	70								70
	hardwood	4,730	3,670							8,400
1974[b]	fir	1,130	12,920	6,480	2,280	340				23,150
	spruce	80	20	80						180
	hardwood	20	1,350	2,060	2,540	1,830	1,150	710	2,280	11,940

[a] Based on 60 milacres quadrat sample except as otherwise indicated.

[b] Based on 38 milacres quadrat sample.

Table 8. Changes in density of the regeneration by species and height classes for the 80% overstory treatment

Treatment year	Species	Density (stems/acre)[a]								
		Height (ft)								
		<1	1	2	3	4	5	6	>6	Total
1959	fir	44,950	320			20				45,290
	spruce	370								370
	hardwood	250			20					270
1963	fir	57,030	6,420	370	20					63,840
	spruce	1,100	20							1,112
	hardwood	4,130	830	500	50	20	20			5,550
1969 Before harvest cut	fir	39,300	17,520	1,970	150	50				58,990
	spruce	1,330	230							1,560
	hardwood	600	720	250				20	20	1,610
1969 After harvest cut[b]	fir	13,230	12,100	1,050	50	20				26,450
	spruce	270	220							490
	hardwood	1,480	1,130	70	20	20				2,720
1974[b]	fir	300	3,500	4,950	4,700	2,050	680	180	50	16,410
	spruce	120	220	70	20	40	20			490
	hardwood	50	480	720	1,070	970	970	470	1,320	6,050

[a] Based on 60 milacres quadrat sample except as otherwise indicated.

[b] Based on 44 milacres quadrat sample.

Table 9. Changes in density of the regeneration by species and height classes for the 60% overstory treatment

Treatment year	Species	Density (stems/acre)[a]								
		Height (ft)								
		<1	1	2	3	4	5	6	>6	Total
1959	fir	26,030	150		30		20			26,230
	spruce	230								230
	hardwood	380	120							500
1963	fir	27,330	2,800		20					30,150
	spruce	950	70							1,020
	hardwood	1,550	1,120	450	200	130	70	50		3,570
1969 Before harvest cut	fir	26,470	9,870	950	30					37,320
	spruce	2,630	550	50						3,230
	hardwood	1,950	520	80	20	20	20			2,610
1969 After harvest cut[b]	fir	6,450	6,180	800	50					13,480
	spruce	250	200	100						550
	hardwood	1,500	1,300							2,800
1974[b]	fir	625	3,400	2,025	2,230	1,000	550	180	100	10,110
	spruce	350	230	180	50	50	50			910
	hardwood	20	200	700	780	880	480	450	1,350	4,860

[a] Based on 60 milacres quadrat sample except as otherwise indicated.

[b] Based on 40 milacres quadrat sample.

Table 10. Changes in percent stocking of regeneration by species and treatments

		Percent Stocking of Reproduction[a]							
		Softwood and Hardwood Stocking				Softwood Stocking			
Treatment year	Treatment	Softwood only	Hardwood only	Softwood and Hardwood	Vacant	Fir only	Spruce only	Fir and Spruce	No Softwood
1959	Control	80	-	19	1	95	-	4	1
	80%	79	-	20	1	95	-	4	1
	60%	66	-	34	-	97	-	3	-
1963	Control	48	-	52	-	80	-	19	1
	80%	33	1	65	1	76	1	26	2
	60%	35	1	63	1	85	-	13	2
1969 Before harvest cut	Control	51	1	48	-	78	-	21	1
	80%	55	-	43	2	74	-	24	2
	60%	56	-	43	1	67	-	32	1
1969 After harvest cut	Control[b]	21	15	49	15	66	-	4	30
	80%[c]	46	10	36	8	72	-	10	18
	60%[d]	36	4	44	16	71	-	9	20
1974	Control[b]	3	15	81	2	72	-	11	17
	80%[c]	4	13	82	1	75	-	11	14
	60%[d]	10	5	82	3	73	-	19	8

[a] Based on 600 milacre quadrat sample for each treatment except as otherwise indicated.

[b] Based on 380 milacre quadrat samples.

[c] Based on 440 milacre quadrat samples.

[d] Based on 400 milacre quadrat samples.

Because sudden increased exposure to high solar radiation, frost, and wind could be damaging to the softwood regeneration and small seedlings would be easily trampled during logging operations, it was assumed that most of the seedlings would need to be well established before release. The indicator for successful seedling establishment in this experiment was survival of seedlings until they reached an average height of at least 1.6 ft. The results of this study show that the indicator was at least partially valid, but the threshold height could probably be reduced to 0.6 ft. The larger seedlings survived better in all treatments (Tables 7 to 9), but the mean difference between the proportion of 1.5- and 0.6-ft softwood seedlings that died soon after the harvest in the 80% and 60% treatments was only 7% per acre. Most dead seedlings after the harvest cuts were less than 6 inches tall (about 73% in all treatments). Hence, softwood seedlings about 1 ft high are probably well enough established to be released.

Further examination of the 1974 regeneration data for each of the treatments (Tables 7-10) indicates the following:

(1) The highest density of softwoods and hardwoods was in the control and the lowest in the 60% treatment. Thirty-five percent of the control hardwoods were taller than the tallest softwoods.

(2) The proportion of hardwoods to softwoods in the treatments was 51% for the control, 36% for the 80% treatment, and 44% for the 60% treatment.

(3) Stocking of softwoods was essentially the same in the control and 80% treatments (84 and 86%, respectively), but was higher in the 60% treatment (92%).

(4) Stocking and density of spruce was highest in the 60% treatment (19% and 910 stems/acre, compared to 11% and 490 stems/acre in the 80% treatment, and 11% and 180 stems/acre in the control).

(5) The greatest proportion of established softwood seedlings (those taller than 0.5 ft) was in the 80% treatment (98%) and the least in the 60% treatment (91%), but the 60% and 80% treatments each had 18% of their softwoods higher than 3.5 ft, compared to 1% for the control.

In all cases, the softwood density levels were higher than would be desired for short rotation pulpwood production and some degree of later cleaning and spacing would be advisable under intensive management conditions. Although the heavier shelterwood seed cut produced the lowest average softwood density, it cannot be determined from this study whether one heavier seed cut or a series of progressively heavier preparatory cuts could better control regeneration density and stocking in these stands.

CONCLUSIONS

Some conclusions that may be drawn as a result of this study are: (1) Removal of as much as 40% of the basal area in well established spruce-fir stands on broad valley bottoms need not result in high windfall losses. (2) The shelterwood system is effective in keeping out competing shrubs, while encouraging spruce and fir regeneration and reducing hardwood seedling density in the regenerating stand. (3) The harvest felling can be accomplished without excessive seedling mortality as soon as the softwood seedlings average 1 ft or more in height. (4) Compared with the clear-cut/natural regeneration system commonly used in the region, which is represented by the control treatment wherein

100% of the overstory was left until the final harvest, the shelterwood system can increase the proportion of spruce over fir seedlings, improve height development in both spruce and fir regeneration, and noticeably lower overall softwood densities. These results were most pronounced where 40% of the softwood basal area was removed during the seed cut.

REFERENCES

1. Fowells, H.A. 1965. Silvics of forest trees of the United States. Agriculture Handbook No. 271, pp. 10-15, USDA For. Serv., Washington, D.C. 762 p.

2. Hawley, R.C. and D.M. Smith. 1954. The practice of Silviculture. Ch. 5. 6th Ed. John Wiley and Sons, Inc., New York. 523 p.

3. Mendenhall, W. 1968. The design and analysis of experiments. Wadsworth Publishing Company, Inc., Belmont, CA 465 p.

4. U.S. Department of Agriculture, Forest Service. 1973. Silvicultural systems for the major forest types of the United States. U.S. Dept. Agric. Handb. 445, 124 pp.